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Petten Establishment
The Netherlands

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Service and Support Activities

High Flux Reactor (HFR) ◀
Informatics
Fissile Material Control
Training and Education
Technical Evaluations in Support of the Commission

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PROGRAMME PROGRESS REPORT

January-June 1977

COMMISSION OF THE EUROPEAN COMMUNITIES
JOINT RESEARCH CENTRE (JRC)
PETTEN ESTABLISHMENT

HFR DIVISION

Abstract

Within JRC's proposed 1977/1980 programme, the materials testing reactor HFR continued its scheduled operation. During the first half of 1977, it reached 85 °/o availability at 45 MW. The occupation by irradiation experiments and radioisotope production devices varied between 60 and 75 °/o.

The report consists of a summary and a detailed main part.

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Summary

1. SCOPE

Operation and utilization of the HFR (High Flux Reactor) Petten fall within the scope of Part 10 (Service and Support Activities) of the 1977/80 JRC Programme. The definition as a service activity has been chosen for this action since the available irradiation capacity is used by the large technological research centres and the industry of the participating countries, as well as by the JRC Establishments of Ispra, Karlsruhe and Petten.

The successful operation and exploitation of the reactor under the 1973/76 programme, confirmed by the relevant Advisory Committee for Programme Management (ACPM) justify the continuation of the entire activity.

The work in and around the HFR Petten is oriented towards

- the testing of materials under reactor conditions, in support of nuclear power plant development and reactor safety research,
- fundamental investigations into material properties under irradiation,
- nuclear and solid state physics research,
- radioisotope production and activation analysis.

2. OBJECTIVES FOR THE REPORTING PERIOD

2.1 Operation

The cycle calendar established by the end of 1976 forecasted, for the reporting period, six reactor cycles and the annual maintenance outage in February/March, 1977. The objective therefore was

a. to reach an accumulated reactor power of
   150 days x 45 MW = 6750 MWd
b. to satisfy the detailed list of routine inspection, repair and overhauling activities which fall under the annual maintenance stop.

2.2 Utilization

Work on about 30 irradiation and 10 general projects has been planned for the irradiation period.

The scheduled reactor occupation by irradiation devices resulted in 74 °/o of the theoretical full load.

3. RESULTS

3.1 Operation

The reactor has been operated according to the predetermined calendar (Table 1).

Table 1 HFR Operation during the first half year 1977

Date	Programme	Accumulated reactor power*)
01.01 - 24.01	Cycle 77-01	1014 MWd
25.01 - 21.02	Cycle 77.02	1183 MWd
22.02 - 07.03	Maintenance stop	—
08.03 - 11.04	Cycle 77.03	1401 MWd
12.04 - 09.05	Cycle 77.04	1169 MWd
10.05 - 06.06	Cycle 77.05	1140 MWd
07.06 - 04.07	Cycle 77.06	990 MWd*)
	Total	6897 MWd

*) during first half year only

The annual maintenance period in February/March has been used for the following main activities:

- inspection and repair of the core clamp-down devices (grid bars),
- modification of the new central reactor top lid,
- inspection, repair or replacement of various components of the reactor primary and secondary circuits, the building ventilation, nuclear instrumentation, radioactivity monitoring, etc.

The routine maintenance of the control rod drive mechanisms had to be postponed due to elevated gamma radiation in the sub-pile room, originated from lost ^{192}Ir pellets.

3.2 Utilization

- General

The occupation of the reactor by irradiation equipment averaged 66 $^{o}/o$ of the theoretical full load.

During the first half of the year the following turn-over of irradiation (including major isotope) facilities took place, (see Table 2):

- 7 experiments continued throughout the reporting period,
- 9 new capsules have been loaded, two of which were also unloaded during the reporting period,
- 5 other experiments have been terminated,
- 15 short-term transient condition irradiations took place.

- Graphite

The large fundamental graphite irradiation programme for KFA Jülich continued with several capsules, and temperatures ranging between 300 °C and 1250 °C. Three new experiments are being prepared for the second half of the year. The results of three terminated graphite creep irradiations have been evaluated, and a new series prepared.

- HTR Fuel

A facility with three carriers containing HTR advanced coated particle fuel has been unloaded, dismantled, and transferred to post-irradiation examens. Project preparations commenced for two new HTR fuel experiments.

- Structural Materials

The irradiation of stainless steel tensile specimens for ECN Petten has been resumed in three TRIO facilities. A new design will increase the number of irradiated specimens for future capsules. For the ECN LWR programme, a natural convection pressurized water facility has been taken in operation for studies on mechanical fuel bundle components.

- LWR Fuel

Within the large series of power variation experiments for pre-irradiated LWR fuel pins, by means of the Boiling Water Fuel Capsule (BWFC), fifteen more transient tests have been carried out. Further additions have been made to the equipment for pre- and post-irradiation inspection and for in-pile operation.

A highly instrumented capsule commenced irradiation in May.

- Fast Reactor Fuel

For ECN Petten, the experiments for research on SNR fuel pin safety continued with the irradiation of three loss-of-cooling devices ("LOC") and one overtemperature capsule ("SHOT"). Design and development work started on oxide fuel pin transient experiments for GfK Karlsruhe.

- Miscellaneous

A joint JRC Karlsruhe/JRC Petten experiment started on in-pile testing of noble metal and ultrasonic high temperature thermometers.

Table 2 HFR Petten. Status of experiments, and major progress achieved during the first six months.

Project nr.	Designation, Kind of Experiment	Work carried out January through June, 1977
ER 005	DRAGON graphite irradiation	PIE of the last irradiations
ER 006,007,008	Standard isotope facilities	Continuous utilization for radioisotope production
R 009,010, 011,013,014 107,130,159	Horizontal beam tubes Various nuclear physics and solid state physics experiments	Continuous utilization throughout the year. Installation of new equipment for several experimental series.
RX 043	CADO. Nuclear Heating Calorimeters	Regular measurements in various in-tank positions
R 054	Fast Reactor fuel overtemperature test (SHOT)	Irradiation of rig 38 started. Three subsequent rigs under assembly.
R 063	Fast reactor fuel loss-of-cooling tests (LOC)	Rigs nr. 15, 17 and 18 irradiated. Two subsequent experiments in preparation.
D 085	Fundamental graphite properties investigation	Rigs nr. 15, 16 and 27 irradiated. Three new experiments under preparation.
ER 090	Reloadable isotope facility (RIF)	Continuous utilization for radioisotope production
RX 092	Neutron damage studies on HFR vessel material	Intermittent irradiation.
E 094	In-pile high temperature sensor tests	Third irradiation started.
R 103	BERO. high pressure water irradiation facility	Continuous irradiation.
E 121	LWR fuel irradiation device development	Irradiations nr. 2 and 5. Three subsequent rigs under assembly.
D 125	Power cycling of pre-irradiated fuel pins	15 pre-irradiated fuel pins submitted to various power ramp programmes.
D 128	In-pile behaviour investigation on LWR fuel pins	First irradiation started.
E 132	Vanadium sample irradiations	Irradiation nr. 6 completed.
R 137	Coated HTR fuel particle irradiation (BATAVIA)	PIE started.
R 139	TRIO steel specimen irradiations (SINAS)	Two capsules irradiated.
E 145	TRIO steel specimen irradiation (AUSTIN)	Continuous irradiation.
R 151	NIRVANA V and Nb irradiations	Design and manufacture completed.
E 154	CARSON, Ultra sonic thermometry	Design and manufacture completed.
D 156	DISCREET Graphite creep rigs	Design and manufacture completed.
R 158	HOBBIE. Zircalloy creep collapse experiment	Design, manufacture and part of assembly completed.
E 160	PLAISIR. Plastic specimen irradiation	Three irradiations carried out.

Design and manufacture for three vanadium and niobium sample irradiation devices (ECN) are well advanced.
The behaviour of different plastic material samples under low neutron dose exposure has been evaluated (JRC Ispra).

- Beam tubes, radioisotopes

The utilisation of the horizontal beam tubes for solid state and nuclear physics experiments (ECN, FOMRE) continued. The major effort in radioisotope facilities still concerned ^{99}Mo, the production of which has been intensified.

3.3 General Activities

These concerned manufacture and purchase of general-purpose irradiation equipment (capsules and out-of-pile control panels), the development of new capsules, and laboratory work on special in-pile instrumentation.

4. CONCLUSIONS

Operation and utilization of JRC's materials testing reactor HFR Petten were resumed on January 1st, 1977, in accordance with the 1977/80 programme proposal.
The plant has been operated within a few percent of the planned schedule. The maintenance activities have been carried out to the detailed programme, with one exception (inspection of the control rod mechanisms).
The reactor occupation lagged behind schedule by 8 ^{o}/o (66 vs. 74^{o}/o), due to the following reasons:

- delays during design and development stages of new projects (3 ^{o}/o),
- delays in fabrication and assembly of irradiation equipment (4 ^{o}/o),
- in-pile failures and programme modifications (1 ^{o}/o).

Severe limitations in authorized staff levels, as already emphasized in past Annual Reports make it hard to exploit the reactor to its full capacity.

Programme
Progress Report

1. INTRODUCTION TO THE HFR PROJECT

As a typical Materials Testing Reactor (MTR), the High Flux Reactor (HFR) Petten uses plate-type fuel elements with fully enriched uranium and burnable poison, light water cooling/moderating, and beryllium moderating/reflecting.

Built for the former Reactor Centrum Nederland (RCN) as an ORR (Oak Ridge Reactor) type, HFR has been transferred to the European Atomic Energy Community in 1962. Since that time, operation and utilization of the reactor have been part of the research programmes of the JRC (Joint Research Centre).

Operation and maintenance of the plant are entrusted to the Dutch research establishment ECN (Energie Onderzoek Centrum Nederland) under contract.

The operating pattern of the HFR follows a 28-days' period, comprising 26 days of actual reactor operation, followed by a 2-days' regular reactor shut-down. This shut-down period is used for installation and reloading of the irradiation rigs, maintenance to the reactor and experiment facilities, and for refuelling. The 26 days cycle duration has been realised by a fuel loading in five zones and a maximum burn-up of 55°/o.

The fresh assemblies containing 390 g ^{235}U and the nearly spent assemblies are loaded in the peripheral zones of the core, while the other assemblies are placed in the central zones of the core. By moving the fuel assemblies stepwise from one zone to another after each reactor cycle, stable irradiation conditions can be maintained for successive cycles.

The HFR is operated at 45 MW for approximately 290 days per year. Two extended shut-down periods, i.e. a 3-weeks period for maintenance and modifications at the beginning of the year, and a 4-weeks period for holidays and maintenance during the summer season, interrupt the reactor operation during each year.

The tight inspection and maintenance schedule, together with a continuous process of replacement and renewal of components, has kept the plant in an excellent condition. Outages due to component failures are practically unknown.

The reactor can be considered as a large testing facility for material specimens and components of operating and future nuclear power plants. Its main use is therefore directed towards the support of R & D programmes of European Research Centres, nuclear industry, and own JRC projects. As a side-line, experiments in solid state and nuclear physics are carried out, and radioisotopes are produced.

In terms of the nature of specimens irradiated, the distribution in 1976 was approximately as follows (in percentages of the used capacity):

Graphite, and HTR fuel	37
Structural materials	16
LWR fuel	8
Fast breeder reactor fuel	8
Neutron physics, and radioisotopes	21
Miscellaneous	10

After the dismantling of the high pressure water loop, only capsule-type experiments are carried out in HFR. Special devices have been developed for various reactor safety related experiments, for in-pile creep measurements, in-pile instrumentation development, fracture mechanics studies, etc. Close collaboration between all organizations and covering all specialities involved in reactor materials research has turned out to be the most efficient approach for irradiation testing.

The HFR Programme Progress Reports contain major contributions from staff of the Dutch establishment ECN, through their functions as contractual reactor operators.

The HFR is part of point 10 (service and support activities) of the 1977/80 JRC Programme. It is endowed with a staff of 94 of which 42 are research personnel.

Sub-Projects

2. SUBPROJECTS

2.1 HFR Operation and Maintenance

2.1.1 Objectives

Reactor operation during the first half year of 1977 aimed at

- high availability, in order to satisfy a consistent irradiation programme,
- thorough inspection and maintenance during spring, in order to assure the technical health of the plant.

2.1.2 Methods

A precise operating calendar has been established by the end of 1976. It included six cycles of four weeks each, and three weeks for the maintenance outage.
Technically, the operation of HFR Petten follows usual MTR practice and has been described in several earlier publications.

2.1.3 Results

2.1.3.1 HFR Operation

Operation Summary

During the first half year of 1977, HFR was in operation on full power of 45 MW for nearly six reactor cycles of 26 days. The planned end of the last cycle was on July 4, 1977.
The yearly maintenance period, normally planned for three weeks, could be reduced to two weeks, as some maintenance work had to be postponed to the summer holidays period because of locally high radiation levels. The start of cycle 77-03 was thus advanced by six days. In Table 2.1 a survey of the reactor operation schedule is given.
A presentation of shutdown and operating periods is given in Fig. 2.1, while Fig. 2.2 presents the relative occupation of the different HFR irradiation positions during this half year.

Table 2.1 Survey of reactor operation

Date	Programme	Accumulated reactor power *)
1.6 - 24.1	Cycle 77-01	1014 MWD
25.1 - 21.2	Cycle 77-02	1183 MWD
22.2 - 7.3	Maintenance stop	—
8.3 - 11.4	Cycle 77-03	1401 MWD
12.4 - 9.5	Cycle 77-04	1169 MWD
10.5 - 6.6	Cycle 77-05	1140 MWD
7.6 - 4.7	Cycle 77-06	990 MWD
	total	6897 MWD

*) during first half year only

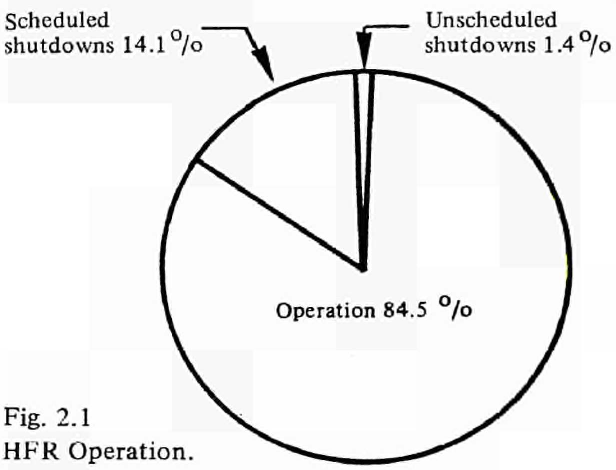


Fig. 2.1
HFR Operation.

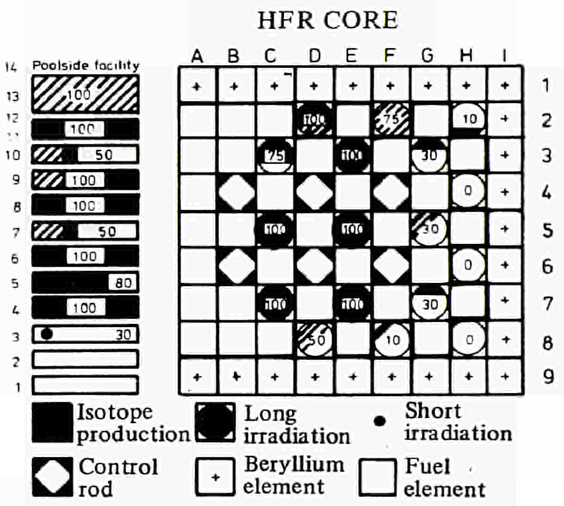


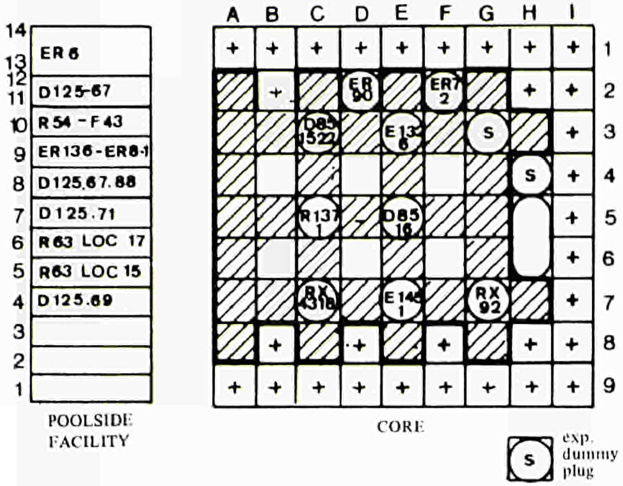
Fig. 2.2 Occupation of HFR irradiation positions.

Further specification of the experimental utilisation of the HFR during cycles 77-01 until 77-06 is given in Figures 2.3 to 2.8.

HFR REACTOR LOADING FOR CYCLE : 77.01

CYCLE NO. : 77.01
START-UP DATE : 1-1-'77

POWER : 45 MW
COOLING FLOW : 4300 m^3/h
INLET TEMP. : 40 °C



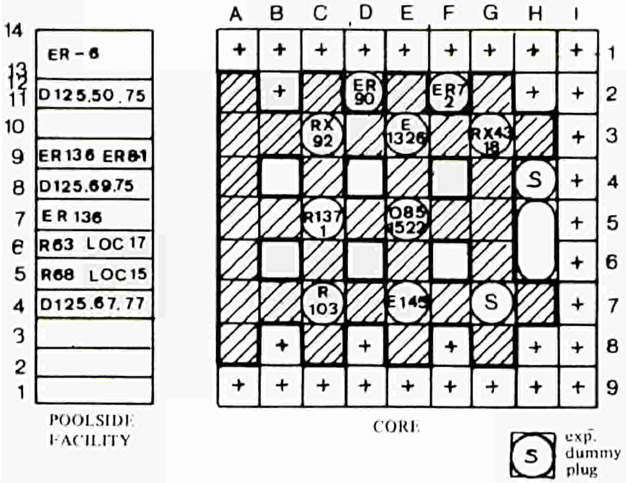
No.	Description	position	vessel entry
RX92	HFR Al irradiation	C3	--
D85-15	High temp. graphite (TRIO 129-8, leg III)	C5	--
D85-22	Low temp. graphite (TRIO 129-8, leg I)	C5	C5
D85-27	Intermediate temp. graphite (TRIO 129-8, leg II)	C5	C5
R103	Grid material irradiation (BERO)	C7	C7
ER90	Reflector isotope facility (RIF)	D2	D2
D85-27	Intermediate temp. graphite (TRIO 129-3, leg I and II)	E3	E3
D85-16	High temp. graphite (TRIO 129-2, leg II and III)	E5	E5
E145-1	Austenitic steel irradiation (TRIO 129-6, 3 legs)	E7	E7
ER7-2	Reflector isotope plug (RIP II)	F2	--
EX43-18	Gamma heating measurements (CADO)	G5	G5
E160-1,2,3	Plastic irradiation (PLAISIR)	psf 3	--
D125-91	Power ramp experiment (BWFC)	psf 4	--
D125-92	Power ramp experiment (BWFC)	psf 4, 8	--
R63LOC15	Loss-of-cooling experiment (UO_2)	psf 5	--
R63LOC17	Loss-of-cooling experiment (UO_2)	psf 6	--
D125-50	Power ramp experiment (BWFC)	psf 8,11	--
D125-77	Power ramp experiment (BWFC)	psf 8	--
ER136	Fissile irradiation target (FIT)	psf 9	--
ER8-1	High flux poolside isotope facility (HFPIF)	psf 10	--
D125-66	Power ramp experiment (BWFC)	psf 11	--
ER6	Poolside isotope facility (PIF)	psf 12,13 and 14	--

Fig. 2.3

HFR REACTOR LOADING FOR CYCLE : 77.02

CYCLE NO. : 77.02
START-UP DATE : 26-1-'77

POWER : 45 MW
COOLING FLOW : 4300 m^3/h
INLET TEMP. : 40 °C



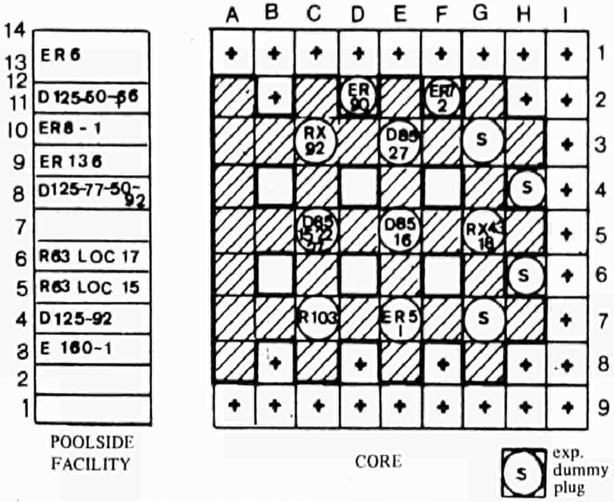
No.	Description	position	vessel entry
RX92	HFR Al. irradiation	C3	
R137-1	Coated particles irradiation (BATAVIA) (TRIO 129-4, 3 legs)	C5	C5
R103	Grid material irradiation (BERO)	C7	C7
ER90	Reflector isotope facility (RIF)	D2	D2
E132 -6	Vanadium irradiation (filler)	E3	E3
D85-15	High temp. graphite (leg III) (TRIO 129-7)	E5	E5
D85-22	High temp. graphite (leg I) (TRIO 129-7)	E5	E5
E145-1	Austenitic steel irradiation (TRIO 129-6, 3 legs)	E7	E7
ER7-2	Reflector Isotope Plug (RIP II)	F2	
RX43-18	Gamma heating measurement (CADO)	G3	G3
D125-67	Power ramp experiment (BWFC)	psf 4, 9	
D125-77	Power ramp experiment (BWFC)	psf 4	
R63LOC15	Loss-of-cooling experiment (UO_2)	psf 5	
R63LOC17	Loss-of-cooling experiment (UO_2)	psf 6	
D125-69	Power ramp experiment (BWFC)	psf 8	
D125-75	Power ramp experiment (BWFC)	psf 8,11	
ER 136	Fissile irradiation target	psf 9, 7	
ER8-1	High flux poolside isotope facility (HF-RIF)	psf 9	
D125-50	Power ramp experiment (BWFC)	psf 11	
ER6	Poolside isotope facility (PIF)	psf 12,13 and 14	

Fig. 2.4

HFR REACTOR LOADING FOR CYCLE : 77.03

CYCLE NO. : 77.03
START-UP DATE : 10-3-'77

POWER : 45 MW
COOLING FLOW : 4300 m^3/h
INLET TEMP. : 40 ^{o}C



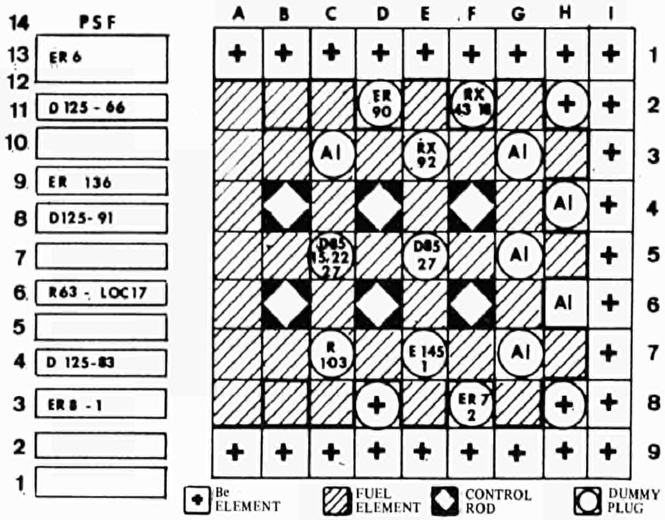
No.	Description	position	vessel entry
RX92	HFR Al. irradiation	C3	--
D85-15	High temp. graphite (TRIO 129-8, leg III)	C5	C5
D85-22	Low temp. graphite (TRIO 129-8, leg I)	C5	C5
D85-27	Intermediate temp. graphite (TRIO 129-8, leg II)	C5	C5
R103	Grid material irradiation (BERO)	C7	C7
ER90	Reflector isotope facility (RIF)	D2	D2
D85-27	Intermediate temp. graphite (TRIO 129-3, leg I and II)	E3	E3
D85-16	High temp. graphite (TRIO 129-2, leg II and III)	E5	E5
E145-1	Austenitic steel irradiation (TRIO 129-6, 3 legs)	E7	E7
ER7-2	Reflector isotope plug (RIP II)	F2	–
EX43-18	Gamma heating measurements (CADO)	G5	G5
E160-1,2,3	Plastic irradiation (PLAISIR)	psf 3	--
D125-91	Power ramp experiment (BWFC)	psf 4	--
D125-92	Power ramp experiment (BWFC)	psf 4, 8	–
R63LOC15	Loss-of-cooling experiment (UO$_2$)	psf 5	--
R63LOC17	Loss-of-cooling experiment (UO$_2$)	psf 6	--
D125-50	Power ramp experiment (BWFC)	psf 8, 11	--
D125-77	Power ramp experiment (BWFC)	psf 8	--
ER136	Fissile irradiation target (FIT)	psf 9	--
ER8-1	High flux poolside isotope facility (HFPIF)	psf 10	–
D125-66	Power ramp experiment (BWFC)	psf 11	--
ER6	Poolside isotope facility (PIF)	psf 12,13 and 14	--

Fig. 2.5

HFR REACTOR LOADING FOR CYCLE : 77.04

START-UP DATE : 13-4-'77
END OF CYCLE : 9-5-'77

REACTOR POWER : 45 MW



No.	Description	position	*
D85-15	High temp. graphite (TRIO 129-8, leg III)	C5	
D85-22	Low temp. graphite (TRIO 129-8, leg I)	C5	
D85-27	Intermediate temp. graphite (TRIO 129-8, leg II)	C5	
R103	Grid material irradiation (BERO)	C7	
ER90	Reflector isotope facility (RIF)	D2	
RX92	HFR Al irradiation	E3	
D85-27	Intermediate temp. graphite (TRIO 129-3, leg I and II)	E5	
E145-1	Austenitic steel irradiation (TRIO 129-6, 3 legs)	E7	
RX43-18	Gamma heating measurements (CADO)	F2	
ER7-2	Reflector isotope plug (RIP II)	F8	
ER8-1	High flux poolside isotope facility (HFPIF)	psf 3	
D125-83	Power ramp experiment (BWFC)	psf 4	
R63LOC17	Loss-of-cooling experiment (UO$_2$)	psf 6	
ER136	Fissile irradiation target (FIT)	psf 6,9,10	
D125-91	Power ramp experiment (BWFC)	psf 8	
D125-66	Power ramp experiment (BWFC)	psf 11	
ER6	Poolside isotope facility (PIF)	psf 12,13 and 14	

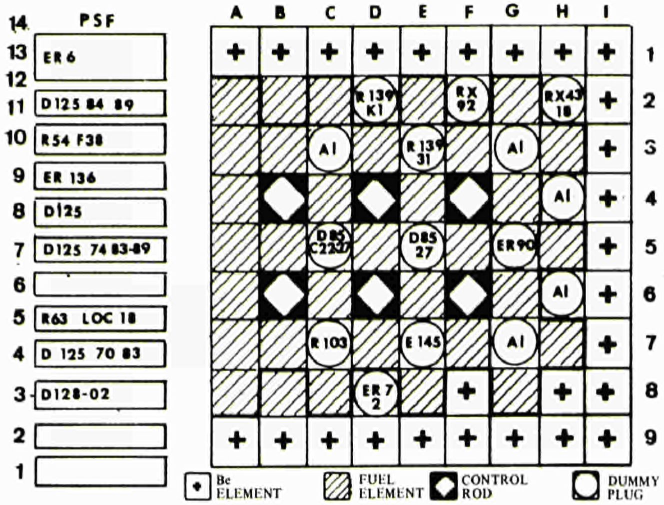
* Remarks	
F :	first loading
P :	plug type exp. no vessel entry
S :	short irradiation

Fig. 2.6

HFR REACTOR LOADING FOR CYCLE : 77.05

START-UP DATE : 11-5-'77
END OF CYCLE : 6-6-'77

REACTOR POWER : 45 MW



No.	Description	position	*
D85-C	Graphite copper test (TRIO 129.08 leg III)	C5	F
D85-27	Intermediate temp. graphite (TRIO 129-08, leg II)	C5	
D85-22	Low temp. graphite (TRIO 129-08, leg I)	C5	
R103	Grid material irradiation (BERO)	C7	
R139-K1	Steel irradiation in Sodium (TRIO 129-5, 3 legs) SINAS	D2	F
ER7-2	Reflector isotope plug (RIP)	D8	
R139-31	Steel irradiation in Sodium (TRIO 129-11, 3 legs) SINAS	E3	F
D85-27	High temp. graphite (TRIO 129-5, leg I and II)	E5	
E145-1	Austenitic steel irradiation (TRIO 129-6, 3 legs) AUSTIN	E7	
RX92	HFR Al irradiation	F2	P
ER90	Reflector isotope facility (RIF)	G5	
RX43-18	Gamma heating measurement (CADO)	H2	
ER8-1	High flux poolside isotope facility (HFPIF)	psf 3	
D128-02	Fuel stack displacement	psf 3	
R63-18	Loss-of-cooling experiment UO_2 (LOC)	psf 5	S
D125-83	Power ramp experiment (BWFC)	psf 7	
D125-89	Power ramp experiment (BWFC)	psf 7, 11	
D125-70	Power ramp experiment (BWFC)	psf 8	
D125-66	Power ramp experiment (BWFC)	psf 8	
ER136	Fissile irradiation target (FIT)	psf 9	
R54-F38	Stationary high temp. fuel irradiation (SHOT)	psf 10	
D125-84	Power ramp experiment (BWFC)	psf 11	
ER6	Poolside isotope facility	psf 12,13,14	
D125-75	Power ramp experiment (BWFC)	psf 8	

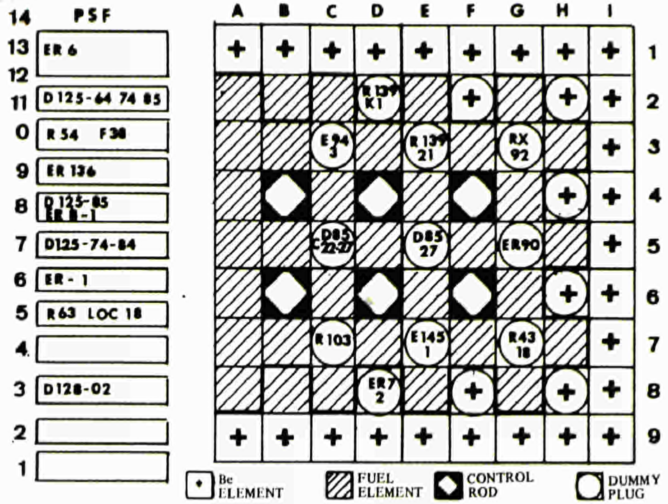
* Remarks F: first loading. P : plug type exp. no vessel entry S: short irradiation

Fig. 2.7

HFR REACTOR LOADING FOR CYCLE : 77.06

START-UP DATE : 8-6-'77
END OF CYCLE : 4-7-'77

REACTOR POWER : 45 MW



No.	Description	position	*
E94-03	Thermocouple irradiation (TRIO 129-9, leg I)	C3	F
D85-C	Graphite copper test (TRIO 129-08, leg III	C5	
D85-27	Intermediate temp. graphite (TRIO 129-08. leg II)	C5	
D85-22	Low temp. graphite (TRIO 129-08, leg II)	C5	
R103	Grid material irradiation (BERO)	C7	
R139-K1	Steel irradiation in Sodium (TRIO 129-3, 3 legs) SINAS		
ER7-2	Reflector isotope lug (RIP)	D8	
R139-21	Steel irradiation in sodium (TRIO 129-10, 3 legs) SINAS	E3	F
D85-27	High temp. graphite (TRIO 129-5, leg I and II)	E5	
E145-1	Austenitic steel irrasiation (TRIO 129-6, 3 legs) AUSTIN)	G3	P
RX92	HFR Al. irradiation	G3	P
ER90	Reflector isotope facility (RIF)	G5	
RX43-18	Gamma heating measurement (CADO)	G7	
D128-02	Fuel stack displacement	psf 3	
R63-18	Loss-of-cooling experiment UO_2 (LOC)	psf 5	
ER8-1	High flux poolside isotope facility (HFPIF)	psf 6	
D125-74	Power ramp experiment (BWFC)	psf 7,11	
D125-84	Power ramp experiment (BWFC)	psf 7	
RE 136	Fissile irradiation target (FIT)	psf 9	
R54-F38	Stationary high temp. fuel irradiation (SHOT)	psf 10	
D125-74	Poolside isotope facility	psf 12, 12	
D125-64	Power rramp experiment (BWFC)	psf 11	
D125-85	Power ramp experiment (BWFC)	psf 11	

* Remarks: F :first loading
P :plug type exp. no vessel entry
S :short irradiation

Fig. 2.8

A survey of some basic operating data during this half year is compared with the previous half year in Table 2.2.

The control rod positions (bankwise) during all reactor-cycles and the reactor power are given in Fig. 2.9 and 2.10.

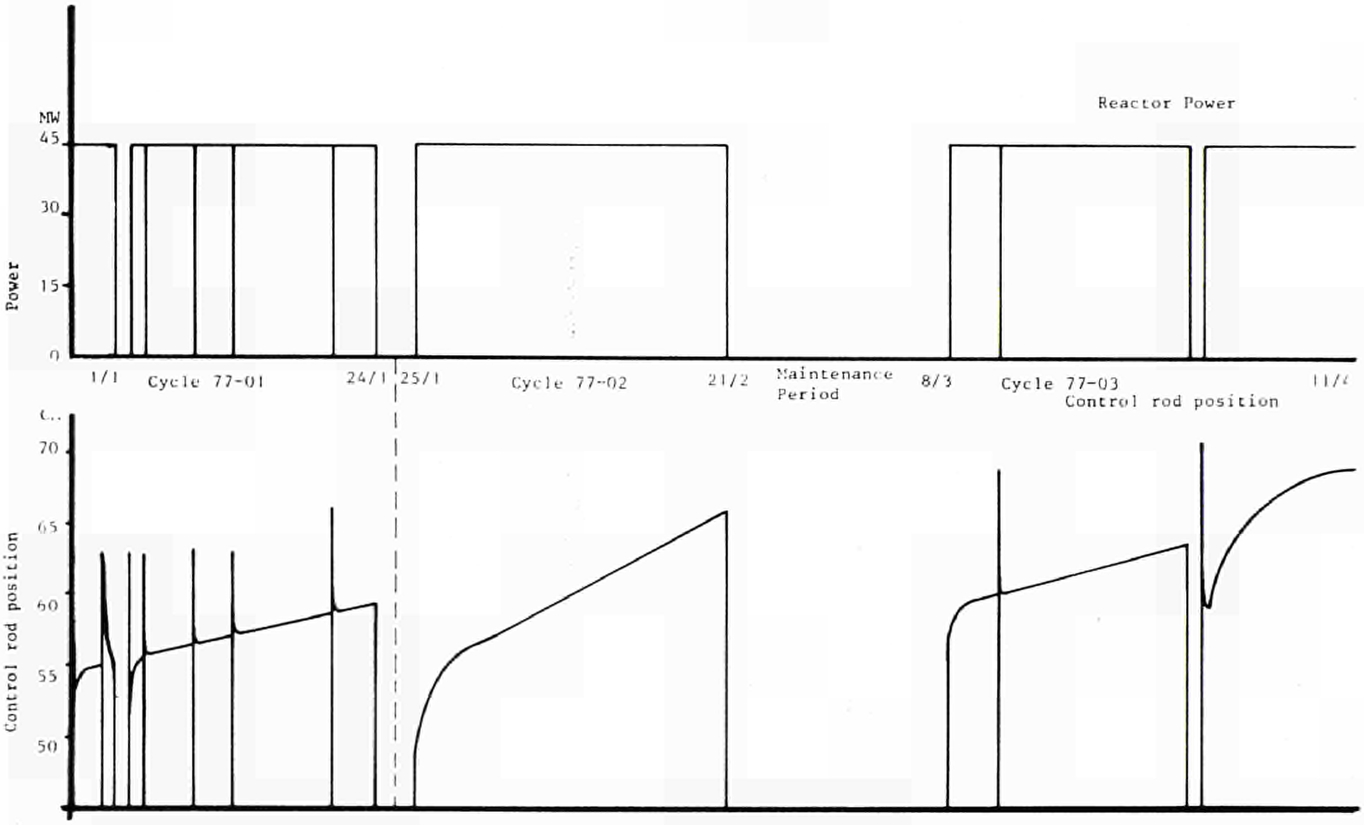


Fig. 2.9 Reactor power and control rod position for cycle 77-01, 02 and 03.

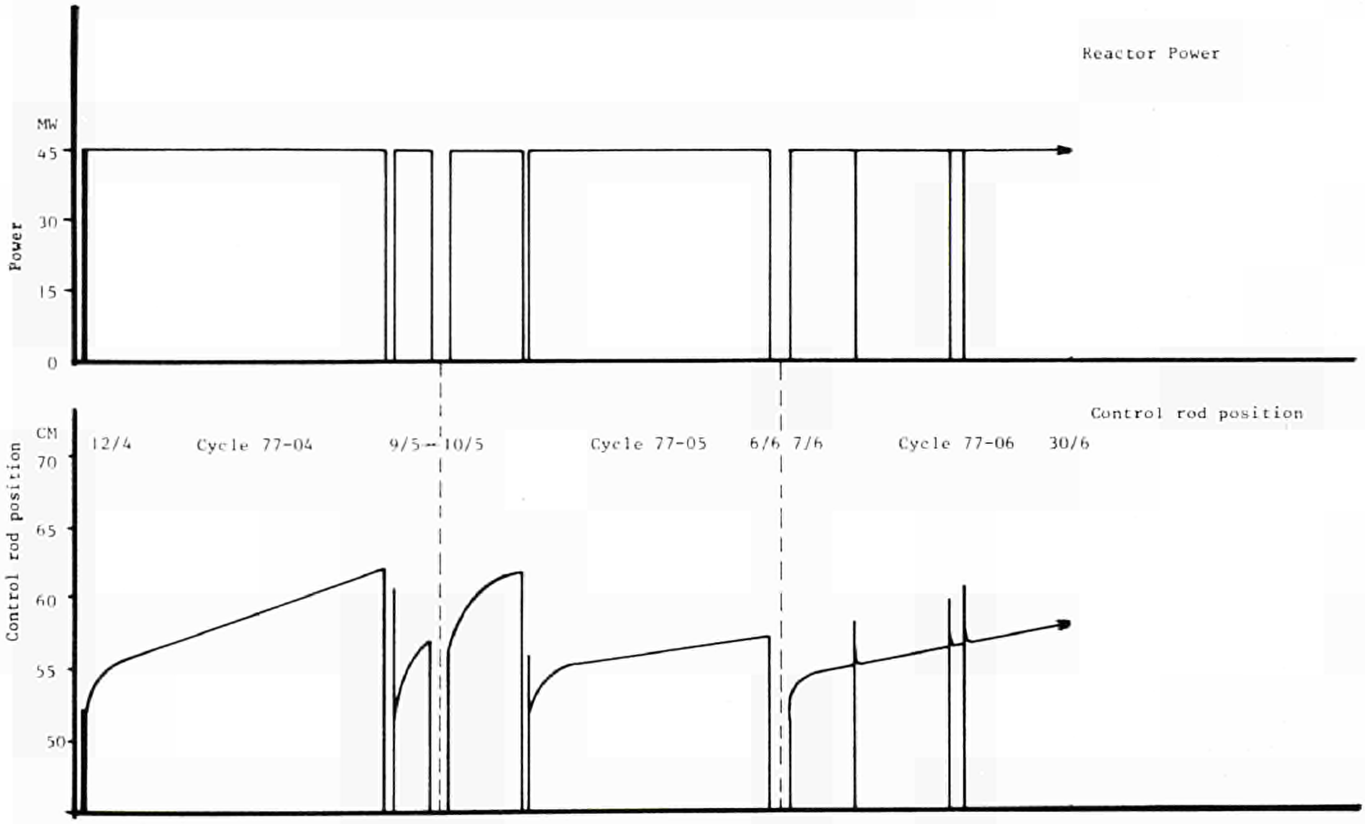


Fig. 2.10 Reactor power and control rod position for cycle 77-04, 05 and 06.

Table 2.2 Basic operating data

Subject		1st half 1977	2nd half 1976
Integrated reactor power	MWD	6897	5968
Average reactor power	MW	45.1	45.4
Operating time	°/o	84.5	71.8
Unscheduled shutdown time	°/o	1.4	0.2
Unscheduled scrams		13	12
Unscheduled power decreases		–	–
Planned scrams		2	2
Planned power decreases		1	1
Fuel consumption	gr^{235}U	8614	7454
Released through stack (^{41}Ar)	Ci	234	269

Table 2.2 reveals that reactor operation was interrupted by 13 unscheduled scrams. Two scrams and one power decrease were scheduled. In four situations, restart of the reactor after scram was not possible because of Xenon poisoning. During cycle 77-01 a power supply failure of several hours necessitated core reloading. In cycle 77-03 and 77-04 the excess reactivity of these cores was too low to restart the reactor after the scrams caused by a temperature overshoot in a LOC (R63-17) experiment and by a human error during pre-operational testing on a SHOT (R54-38) experiment.

In cycle 77-05 a very short increase in radioactivity of the ventilation air caused a scram on gasmonitor I. During restart of the reactor this occurred again and after this second scram restart was not possible and core reloading was necessary. The cause of the short increase of gasactivity was the opening in the release of slightly radioactive air in the cell ventilation to the building ventilation system.

More detailed information such as nature and causes of all operational disturbances is given in Table 2.3.

Table 2.3 Scrams, power decreases and incidents

Date	Hour	Duration hrs./min.	Disturbance type	Reactor system or experiment	Cause	Code	Core no.
4/1	09.43	00.17	AS	BWFC installation	During check of instrumentation a short circuit was made.	OE	77.01.1
4/1	14.09	19.01	AS	Power supply	Power supply failure. Xenon poisoning necessitated core reloading.	PS	77.01.1
6/1	20.51	00.27	AS	Interlock system	Blown fuse in reactor interlock system.	FR	77.01.2
10/1	08.50	00.14	AS	BWFC installation	Loose connection in instrumentation.	IE	77.01.2
13/1	11.27	00.22	AS	Exp. R63-15	Interference spike on MV units while adjusting NaK level indicators	IE	77.01.2
21/1	15.31	00.24	AS	Exp. R63-17	Mechanical interference between (moving) D125 (BWFC) and R63 exp. caused "high temp." scram in latter.	FE	77.01.2
15/3		00.31	AS	Exp. R63-15	Intended fuel failure	ME	77.03.1
30/3	19.32	17.08	AS	Exp. R63-17	As 21/1 (above)	FE	77.03.1
13/4	14.45	00.21	AS	interlock	Blown fuse in reactor interlock system	lE	77.04.1
6/5	11.18	13.36	AS	R54-F38	E-unit reactivated without previous clearance of "low cooling" scram status of SHOT experiment. Xenon poisoning necessitated core reloading	OE	77.04.1
18/5	09.41	00.17	AS	Gasmonitor I	Both scrams caused by active gas release from exp. R63-17 during cutting of exp. in hotcell Second scram caused xenon poisoning of core.	FE	77.05.1
18/5	10.22	10.33	AS	Gasmonitor I			
13/6	20.53	00.32	AS	Control rods	Spontaneous drop of control rod I	FR	77.06.1
21/6	04.24	00.36	AS	Control rods	Same as above		
21/6	23.40	00.29	PD	R63-18	Power 20 MW, testing of R63 PSF-trolley	ME	77.06.1
22/6	16.41	00.22	AS	R63-18	Intended failure of fuel pin	ME	77.06.1

AS : Automatic scram
APD : Automatic power decrease
PD : Manual power decrease
MS : Manual shut down

F : Failure system or operating condition
I : Instrument failure
O : Operating error
PS : Power supply failure

R : Reactor
E : Experiment

Special Measurements

Before the start of cycles 77-02 and 77-03 four flux measurements have been carried out in order to investigate the possibility to measure the neutron fluence of reactor experiments with flux wires in the corners of filler elements rather than inside the experiment itself (see section 2.1.3.3, "external dosimetry"),
In the reactor stop period between cycle 77-04 and 77-05 a series of reactivity measurements on in-core experiments have been carried out in order to investigate the possible causes of the relatively small excess reactivity margin in the cores of cycles 77-03 and 77-04.
During all cycles nuclear heating measurements were performed with the CADO rig in the HFR irradiation positions C7, C3, C5, F2, H2 and G7 (see section 2.1.3.3).

Utilization of isotope and rabbit facilities

A survey of the utilization frequency of the various isotope and rabbit facilities is given in Table 2.4.

Table 2.4 Utilization of standard isotope facilities.

Code	Facility	Number of irradiations 1st half 1977	 2nd half 1976
PR 1	Pneumatic rabbit system	589	787
HR	Hydraulic rabbit system	7	6
PIF(ER6)	Poolside isotope facility	72	90
HFPIF(ER8)	High flux PIF	46	14
PROF	Poolside rotating facility	82	69
RIP (ER7-2)	Reloadable isotope plug	20	8
RIF (ER90)	Reloadable isotope facility	423	273
GIF	Gamma irradiation facility	11	32
FASY	Fast rabbit system	171	603

Fuel management (see section 2.1.3.2 and 2.1.3.3)

During the first half year 55 new fuel elements have been delivered. No depleted fuel elements have been transferred for reprocessing. Preparations are made for the transfer of a large amount of fuel elements for reprocessing to the United States (see also 2.1.3.2).

A new contract has been negociated for the 1977/80 supply of HFR fuel elements. During the reporting period, numerous adjustments have been made to the draft; the final version will be ready by July, 1977.

Table 5 Status of HFR fuel elements.

	1st half 1977	2nd half 1976
Transfer of depleted fuel elements	–	–
Transfer of depleted control rods	–	–
Average burn-up of transferred fuel elements	–	–
Average burn-up of transferred control rods	–	–
Delivery of new fuel elements	55	24
Delivery of new control rods	–	17
New fuel elements available for use at end of half year	52	40
New control rods available for use at end of half year	9	16
New fuel elements charged to the core	43	30
New control rods charged to the core	7	9
Fuel elements depleted	37	32
Average burn-up of depleted fuel elements	48^{o}/o	47^{o}/o
Control rods depleted	8	6
Average burn-up of depleted control rods	50^{o}/o	47^{o}/o

2.1.3.2 Maintenance and modifications

Mechanical installation

General

During this period the yearly maintenance program has been carried out. Because of high irradiation fields near the control rod drive mechanisms in the subpile room, it has been decided to postpone the maintenance of these parts to the summer holiday period. The increased radiation levels are caused by several irradiated iridium pellets which have remained near the reactor bottom cover after failure of an iridium irradiation capsule in September 1976 (see third quarterly report of 1976).
Efforts to remove these pellets by means of a suction tube during the first part of the maintenance stop failed. The radiation levels at several spots on the ceiling of the subpile room vary from 5 to 25 R/hr. Due to ^{192}Ir decay these levels will be reduced by a factor 6 at the time of the summer shutdown period.

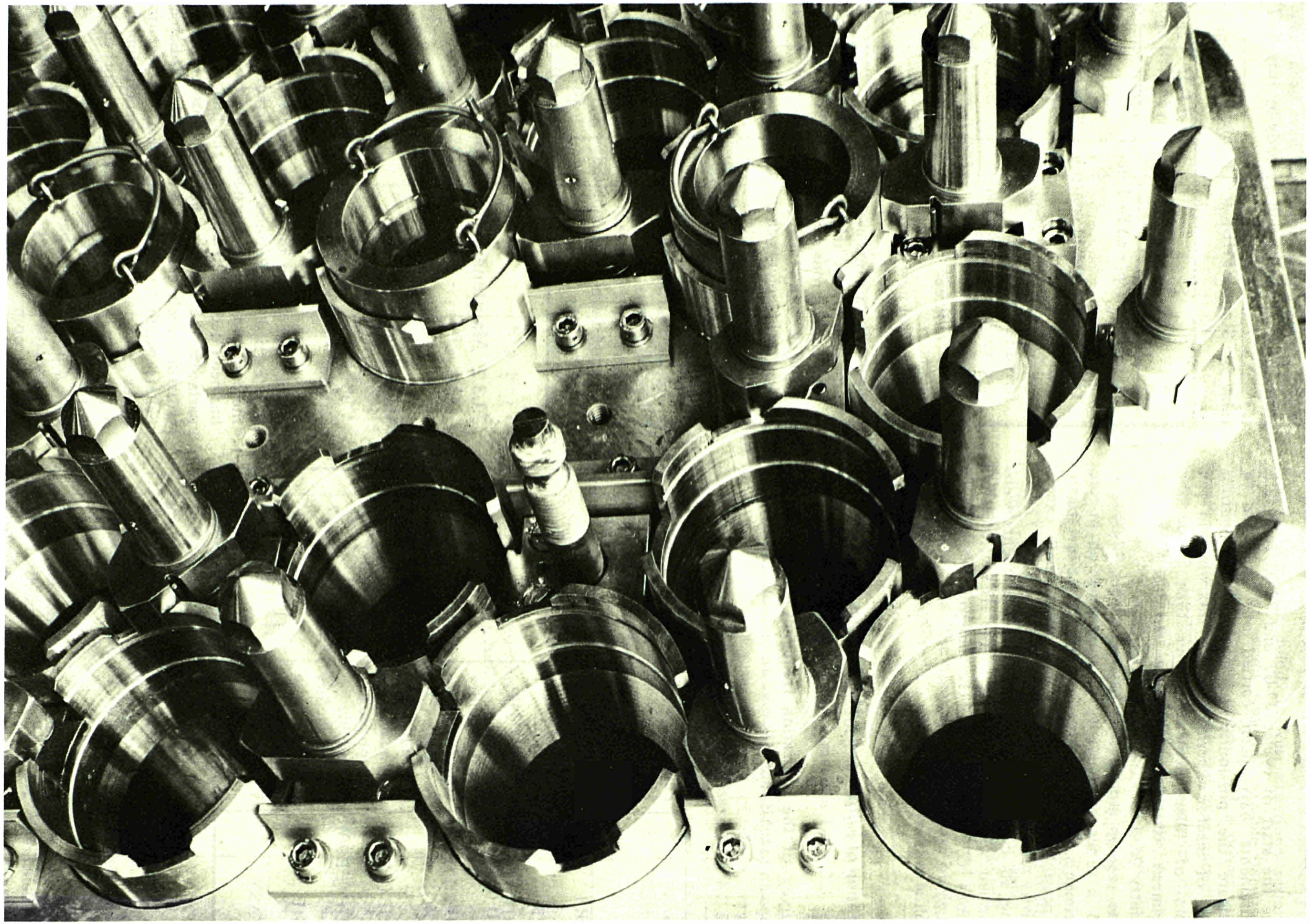


Fig. 2.11 Clamping devices on new central reactor top lid.

Cleaning of the aluminium pipes on the secondary side of the heat exchanger, in which also some iridium pellets are situated, could be performed without important radiation consequences after installation of a temporary shield of concrete blocks.

Grid bars

As in previous years the tolerance of the grid bars in closed position has been measured in three points (a, b, c), near the hinge end and one point (d) near the lock end. The results are given in Table 2.6. Because of the dismantling of the in-core part of the high pressure loop this time also the grid bar in row H could be measured. Since this old grid bar does not correspond with the existing experiment positions it cannot be utilized and a new one has to be fabricated.

Table 2.6 Tolerances of grid bars in closed position, with empty core (mm)

Grid bar position	Measuring position			
	a	b	c	d
B	0.19	0.16	0.25	0.01
D	0.04	0.03	0.02	0.12
F	0.02	0.03	0.03	0.03
H	0.02	0.02	0.02	0

Central reactor top lid

The clamping devices on the new central reactor top lid, which had been taken in use in August last year, have been modified in such a manner that all experiments are now clamped on two sides (Fig. 2.11).

Core box inspection and measurements

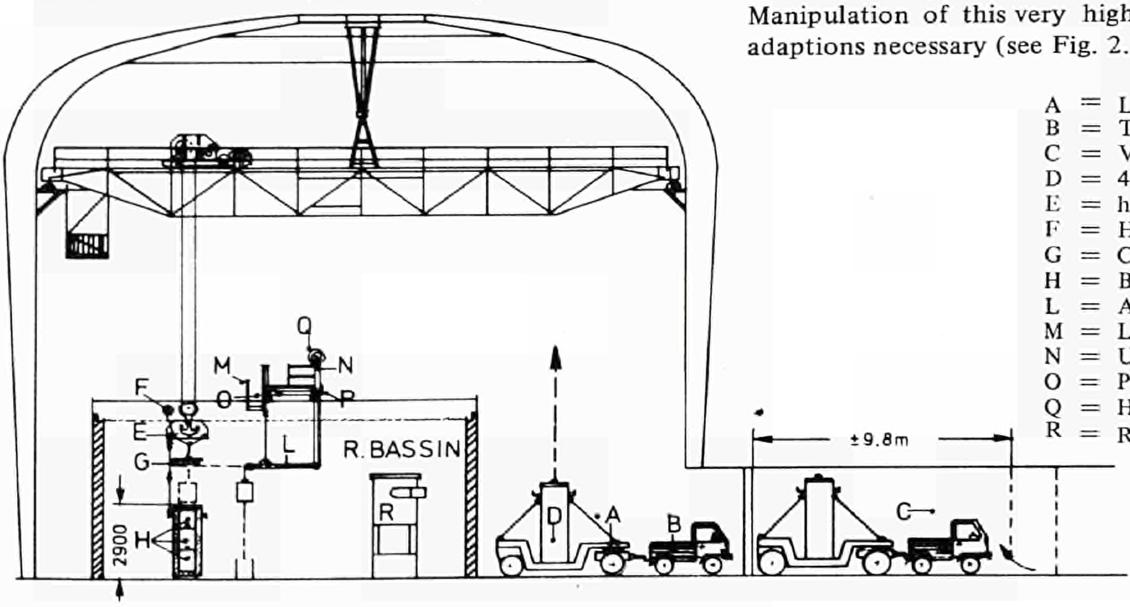
- The measurements of the internal dimensions of the core box, which have been performed last year for the first time in order to check for irradiation-induced deformations, have been repeated. No significant differences with the previous results, as given in Table 6 of the first quarterly report of 1976, could be observed.
- Also as part of the core box surveillance programme, a video recording has been made of the PSF core box wall. No deviations with respect to the observations from the previous year could be detected.
- All diameters and depths of the 81 lower grid hole positions have been measured. Only the insert of position H6 (in which the High Pressure Water Loop has been inserted) has been renewed.

Miscellaneous maintenance jobs

- Both blowers of the off gas system were overhauled, the automatically operating valves of the system inspected and the pneumatic cylinders of these valves were replaced.
- Absolute filters of the ventilation system replaced.
- Bottom plug cooling circuit inspected. The flow under normal operating conditions proved to be 1,6 m^3/hr.
- Check valves of the main primary pumps inspected.
- Supporting points of the main primary system pipelines inspected.
- Basement of the primary pump building cleaned.
- Leak test of the reactor containment building carried out at 0.1 ato. Some minor leakages detected and repaired.
- Outlet filters of heat exchangers on primary side inspected.
- Remote operation drive gears of main valves in primary and secondary cooling system overhauled.

New fuel element transport provisions (see section 2.1.3.3).

As the spent HFR fuel elements will, in the future, be shipped to the USA for reprocessing, some transport and hoisting equipment had to be modified.
A new type of transport container will be utilized, in which 42 elements will be stocked into three baskets, standing on top of each other.
Manipulation of this very high container made several adaptions necessary (see Fig. 2.12).:



A = Low loader
B = Towing motor vehicle Unimog
C = Vehicle airlock
D = 42 element coffin
E = hoisting yoke
F = Hand chain hoist
G = Coffin cover
H = Baskets no. 1, 2 and 3
L = Auxiliary hoisting equipment
M = Lower pool bridge
N = Upper bridge
O = P = DIN grid profiles
Q = Hand chain hoist
R = Reactor

Fig. 2.12 New type transport container. Handling scheme.

a) The length of the 40-tons (ex-ISPRA) low loader has been reduced by about 2 m in order to obtain a suitable length for towing by motor vehicle through the vehicle air lock.
The modified transport cart can also be utilized at other Petten-based facilities for handling of radioactive materials.
b) In order to provide for sufficient height of water shielding during insertion of the loaded fuel baskets into the container, the fuel container hoisting yoke has been provided with an additional support on which a hand-operated hoisting chain for lifting the coffin cover has been mounted. In this way the fuel-coffin can be inserted deeper into the pool than earlier container types.
c) For loading of the three fuel baskets from the pool bottom into the container an auxiliary hoisting facility has been made, guided by means of two DIN profiles mounted on the pool bridge. Hoisting is done by means of the existing hand winch installed on top of the pool bridge.

Instrumentation

Reactor instrumentation

Nuclear channels

- Signal cables and plastic hose of safety-channels 1 and 3 and of period channels renewed.
- Routine check and calibration of the electronic equipment of the nuclear channels.
- Power demand unit of the automatic control channel replaced by a new one with a digital power indicator (see Fig. 2.13).
- Routing maintenance and minor repairs.

Wide range nuclear channel

A prototype of a new flux measuring channel based on the "Campbell" technique has been installed in the control room in order to get experience with this instrument, developed and built by the ECN electronics division.
As the neutron detector , the fission chamber of start-up channel nr. 2, positioned in a vertical tube in the North-West corner of the reactorpool, has been used.
The system has been observed during one cycle and the results look very promising. Further observations will be made during the next quarter (see Fig. 2.14).
A complete "Campbell" channel has been ordered.

Activity monitors

The GM tubes in the area radiation monitor detectors have been replaced by a new type provided with energy correction filters.
At the same time the input circuits of the amplifiers have been adapted to the standards applied to similar monitors used in experimental installations.

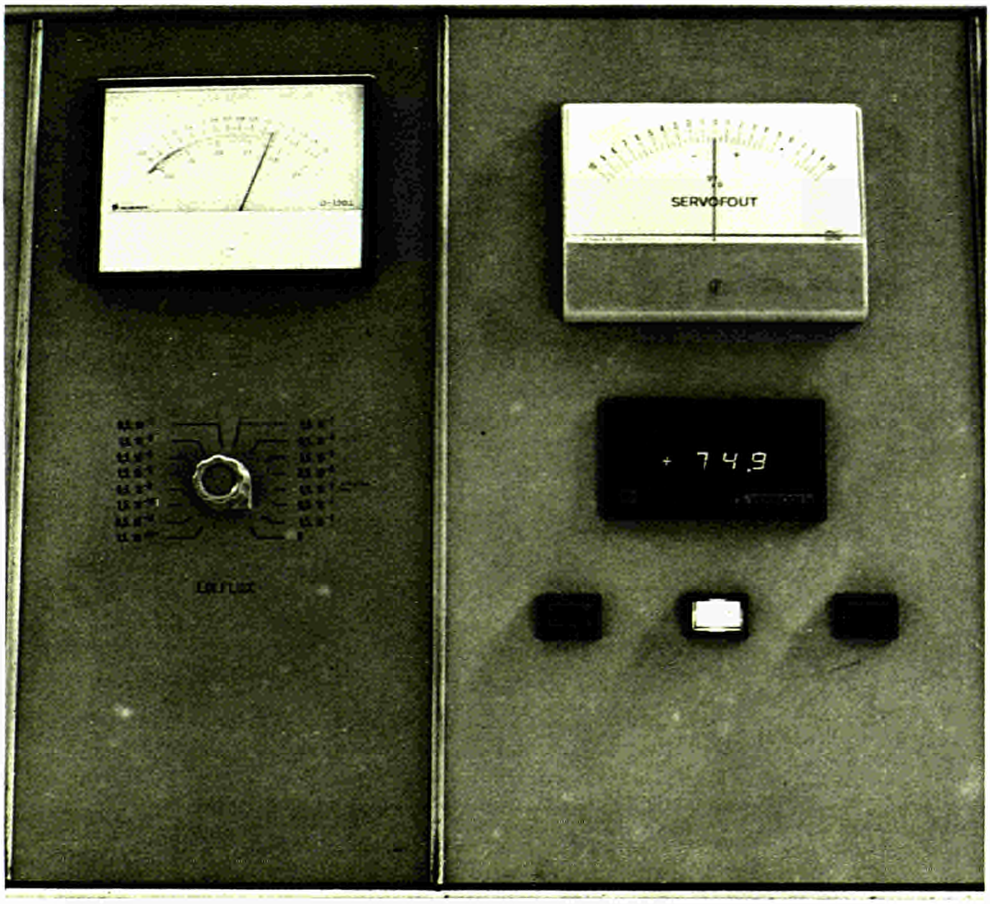


Fig. 2.13 Nuclear channels. New power demand unit.

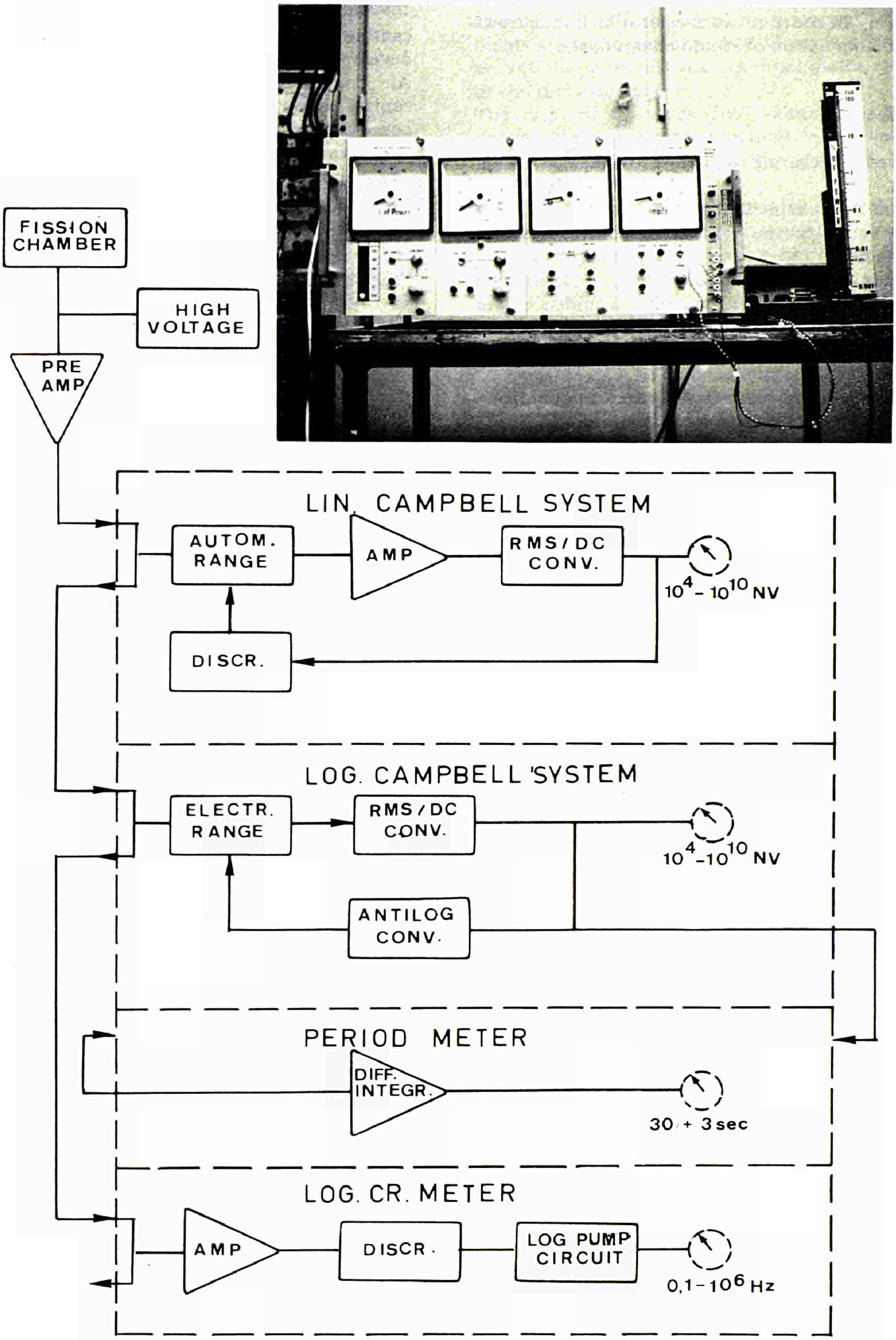


Fig. 2.14 Wide range nuclear channel.

A new γ-radiation monitor has been installed at the poolside balcony in order to warn against high radiation levels during manipulation of stored experiments.

Process instrumentation

- Temperature measuring systems overhauled and calibrated.
- Pressure and flow channels checked.
- Pneumatic valves in the ventilation control system fully overhauled.
- Routine maintenance and minor repairs.

Miscellaneous

The CCTV monitor and control system in the controlroom replaced by two 9" control desk monitors and one 20" panel monitor together with a new camera selection and control system. This work was done in connection with the installation of the physical protection system. (see "Physical protection).

Experiment instrumentation

- Electronic position control of PSF trolleys checked and recalibrated.
- Connection of new experiments to the standard instrumentation and interlock systems.
- Disconnection of the heater control panel of the NAST experiments.
- Dismantling of the HD-loop instrumentation started.

- The COSAC computer has been installed behind the control room and connected to a spare data-logger for testing and for instruction and training of reactor operators.
- Modification of the PSF trolley control panel has started in order to get a higher degree of flexibility in the connection between the BWFC control panel and the trolley drive units.

Electrical installation

Power and light installation

- Block brushes of emergency supply systems VZO 1 and VZO 2 renewed.
- Installation of the new electric supply and control circuit of the helium liquifying system in the primary pump building.
  Adaption of the control of the vehicle corridor to the physical protection system.
- Lighting system in reactor hall extended to new balconies.
- Installation of electric system in the new operators' cantine and in the new neutron radiography film development room.
- Air dust monitors in the reactor hall and in the central measuring panel in the Health Physics room connected to the emergency power supply instead of the normal supply.
- The chimney gas activity monitor in the ventilation building connected to the failure-free emergency power supply.
- Special power connection system (380V) installed for the under-water vacuum cleaner. This system had to be supplied with a current-leakage safety device in accordance with the rules given by the Labour Inspectorate.

Physical protection

During this quarter numerous cables have been installed and connected to the various electronic detectors and switches. In view of capacity problems the gastight connection blocks of the emergency airlock had to be renewed.

Experiment installations

- Dismantling of electrical systems of the high-pressure loop.
- Connection of the central BWFC installation to the emergency power supply system.

Miscellaneous

- Electric motor of off-gas blower overhauled, and bearings renewed.
- Obstacle lighting on chimney of ventilation building replaced.
- Several minor repairs and modifications.

2.1.3.3 Nuclear support and development

Characteristics of HFR cores

Flux calculation method

The HFR-TEDDI computer code package, which is routinely used for providing all HFR users with the nuclear characteristics of the actual HFR cycle cores, has been extended by a summary of the flux and fluence data in experiment positions for publication in the monthly cycle reports.

In this period the users report of the HFR-TEDDI programme package has been edited [1].

Neutron spectrum measurements

Experiment FLUX 76-02

The results of neutron spectrum measurements in the positions C3, D2, E5, G7, and H8 of core 490-2 have been presented in the report ECN-77-001.
With the obtained spectrum results, damage-to-activation ratios and damage flux densities have been calculated for graphite, stainless steel and aluminium.

Experiment FLUX 76-03

The results of the thermal and fast flux density measurements performed in HFR core configurations 493, 494 and 495 within the framework of experiment "FLUX 76-3" (characteristics of the new core type 1976), have been given.

Local Flux distribution in fuel elements

In order to obtain best values for the radial (f_h) and axial (α) flux factors for HFR fuel elements, flux measurements derived from copper wire irradiations have been compared to fission product distribution data obtained by γ-scanning of irradiated fuel plates.

Up till now four scans of fuel plates have been made (position C4 of core 74.02.1, position F7 of core 74.02.2, position G6 of core 489 and position C2 of core 493). Simultaneously with the irradiations of the fuel assembly with dismountable fuel plates a number of copper wires was irradiated.
From both types of measurements values were derived for f_h and for α-300. The parameter f_h denotes the maximum value of the horizontal distribution factor; parameter α-300 denotes the ratio of the thermal flux at the bottom of the fuel layer and the vertically averaged thermal flux density.
Now a comparison has been made which shows that in principle the scan procedure is very attractive for arriving at more accurate values of the parameters f_h and α-300. If in future more copper wire measurements are to be performed, it seems worthwile to try to mount the wires just near the fuel plates at the outside of the fuel assembly.
The ratio of f_h values (four values) as measured with copper wires to those measured by scanning the fuel plates was 1.0 with a relative standard deviation of 6.5 $^o/o$.
For the α-values the average ratio (17 values) was 1.3 with a relative standard deviation of 13 $^o/o$. The large value of the standard deviation can be explained by the facts that:

a. the collimator slit used for the SCANSPEL measurements is not so very small;
b. the copper wires were positioned at some distance from the SCANSPEL measuring positions;
c. the position of the fuel bottom is not well known.

Neutron damage calibration

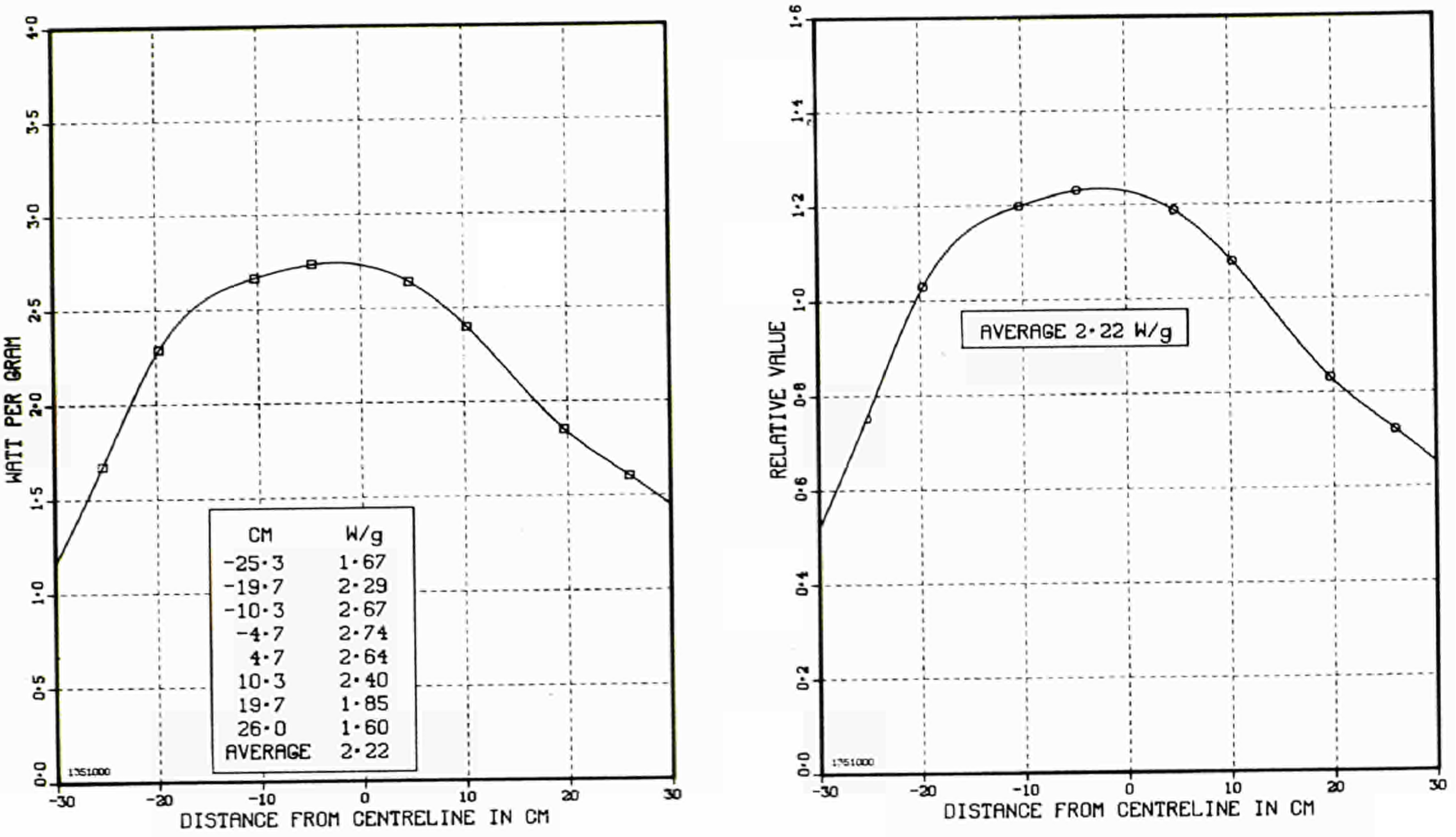
A report, ECN 77-026, has been written which describes the results of exp. GAMIN-1 and GAMIN-2. With aid of the graphite damage dosimeters, GAMIN, an experimental correlation has been established between damage of graphite and the fast neutron fluence involved.
The irradiation of these dosimeters and activation detectors took place in several experiment positions of the HFR.
The experimental correlation data are compared with the number of displacements as calculated with the damage function of Thompson and Wright applied to the neutron spectrum at the irradiation position, which is determined with the SAND-II unfolding technique.

Nuclear heating measurements

The nuclear heating measurements in small graphite samples have been continued in each reactor cycle during this period. In the Figures 2.15 through 2.19 the axial nuclear heating distributions are given for the positions C7, G3, G5, F2 and H2. As shown in Table 2.7, which summarizes nuclear heating data for five different core positions, reasonable agreement is found between measured and calculated data.

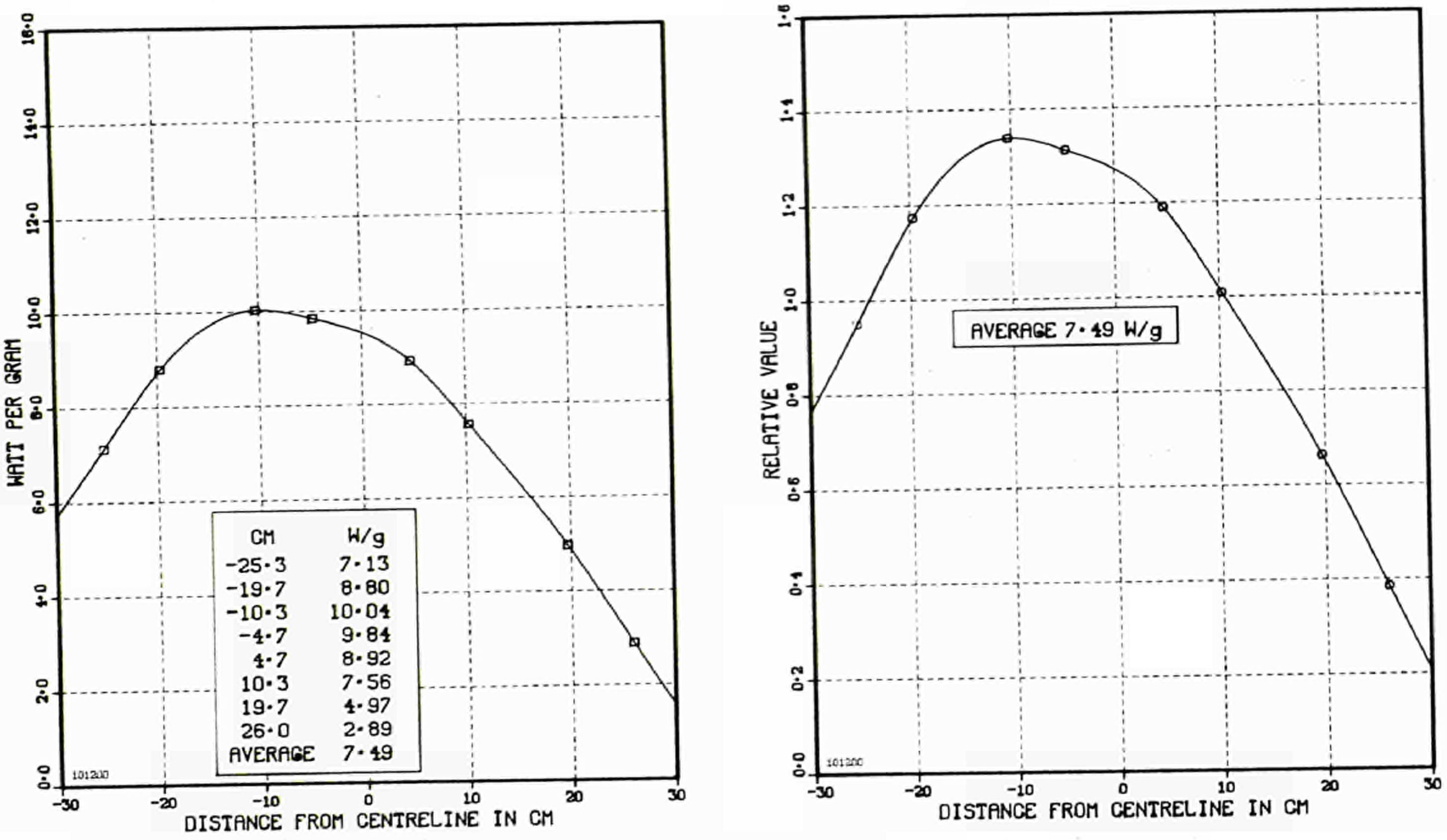
Table 2.7 Nuclear heating in small graphite samples.

Core number	Control rod setting in cm	In-core position	Max. nuclear heating measured in W/g	Axial average nucl. heat		Difference at 45 MW in $^o/o$
				measured in W/g	calculated in W/g	
77.01	55	C7	10.04	7.49	6.62	- 12
77.02	56	G3	6.73	5.33	4.92	- 8
77.03	60	G5	8.09	6.51	5.85	- 10
77.04	56	F2	5.39	4.24	4.12	- 3
77.05	61	H2	2.74	2.22	2.44	+ 5



CM	W/g
-25·3	1·67
-19·7	2·29
-10·3	2·67
-4·7	2·74
4·7	2·64
10·3	2·40
19·7	1·85
26·0	1·60
AVERAGE	2·22

Fig. 2.15 Nuclear heating in graphite. Small samples in position H2.



CM	W/g
-25·3	7·13
-19·7	8·80
-10·3	10·04
-4·7	9·84
4·7	8·92
10·3	7·56
19·7	4·97
26·0	2·89
AVERAGE	7·49

Fig. 2.16 Nuclear heating in graphite. Small samples in position C7.

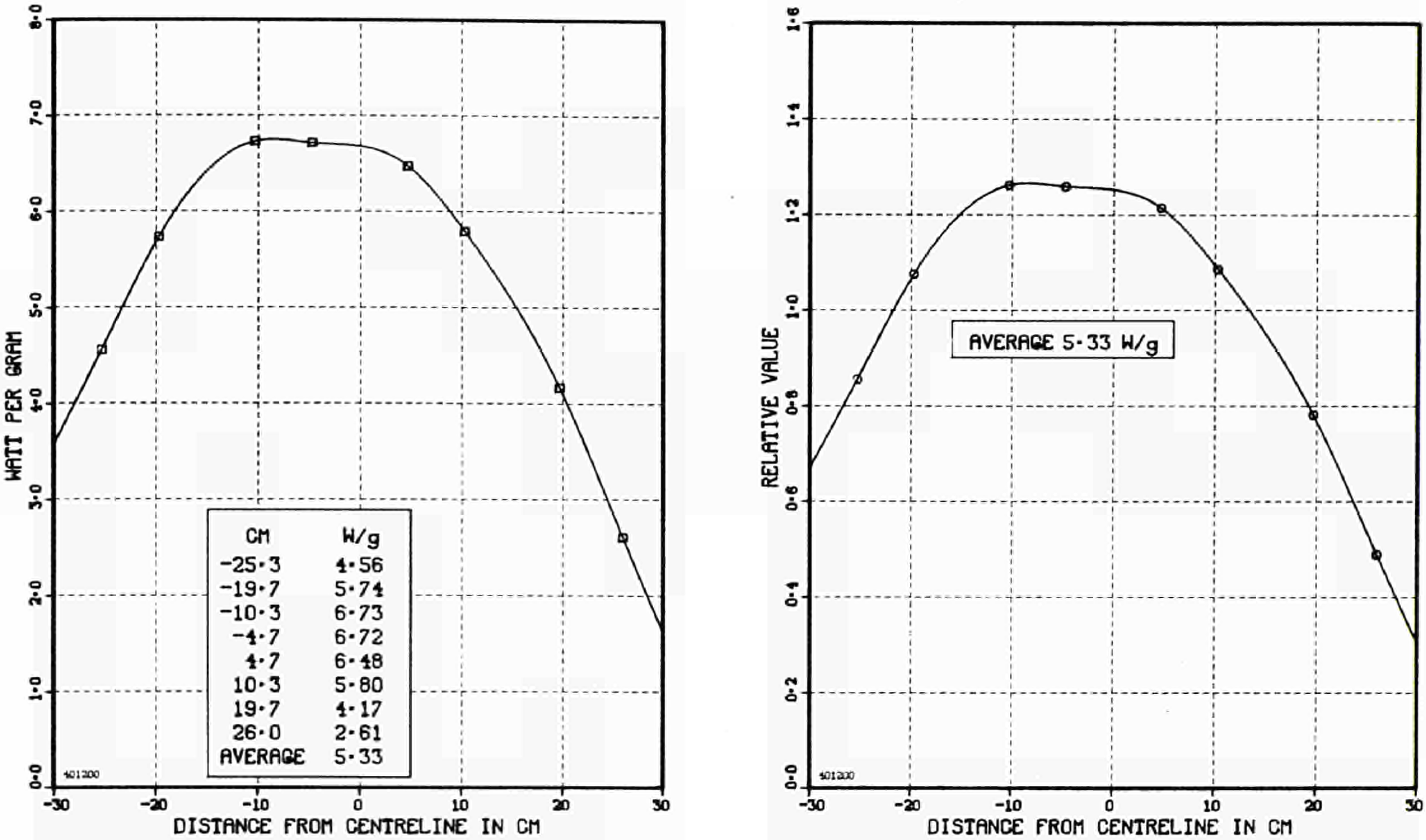


Fig. 2.17 Nuclear heating in graphite. Small samples in position G3.

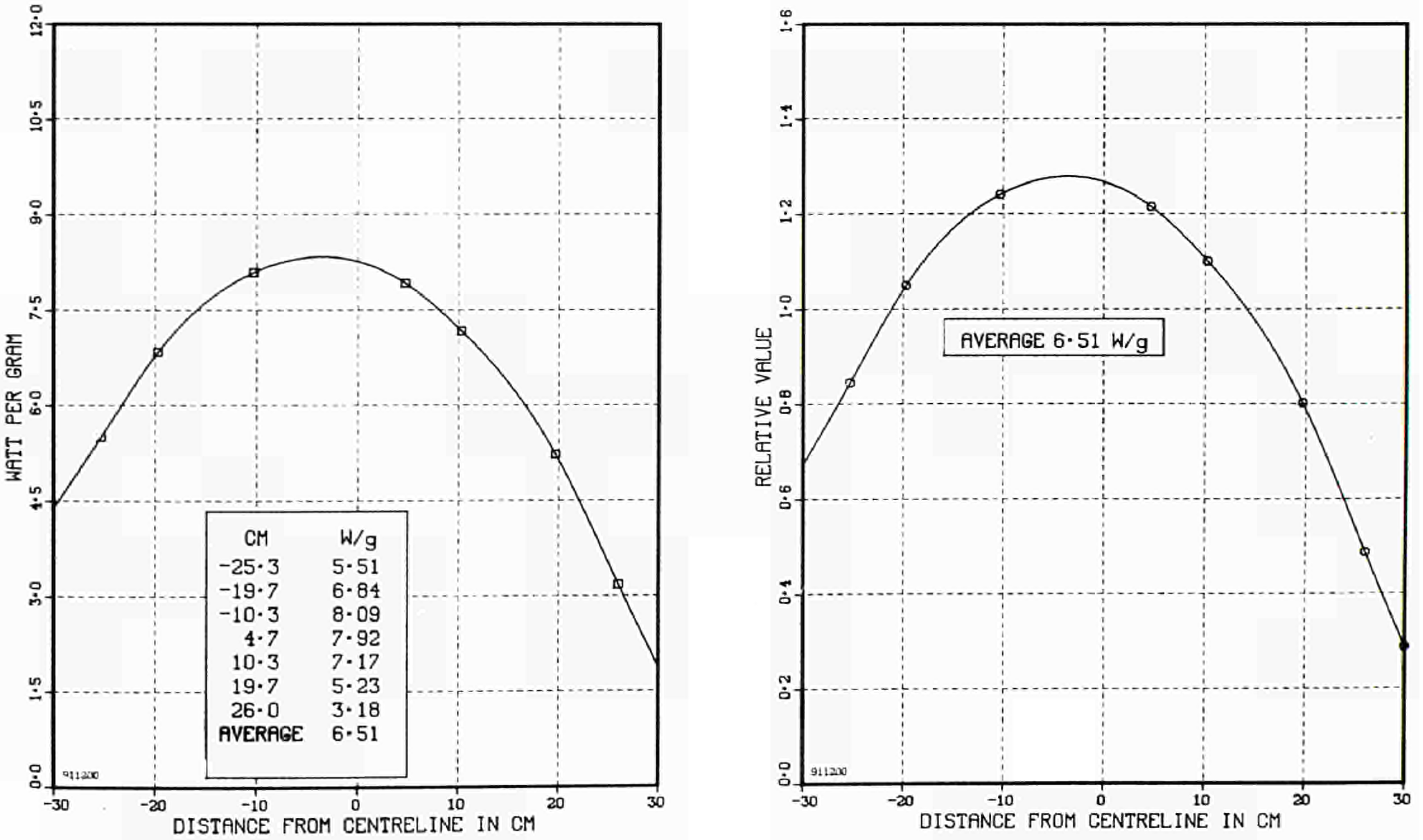
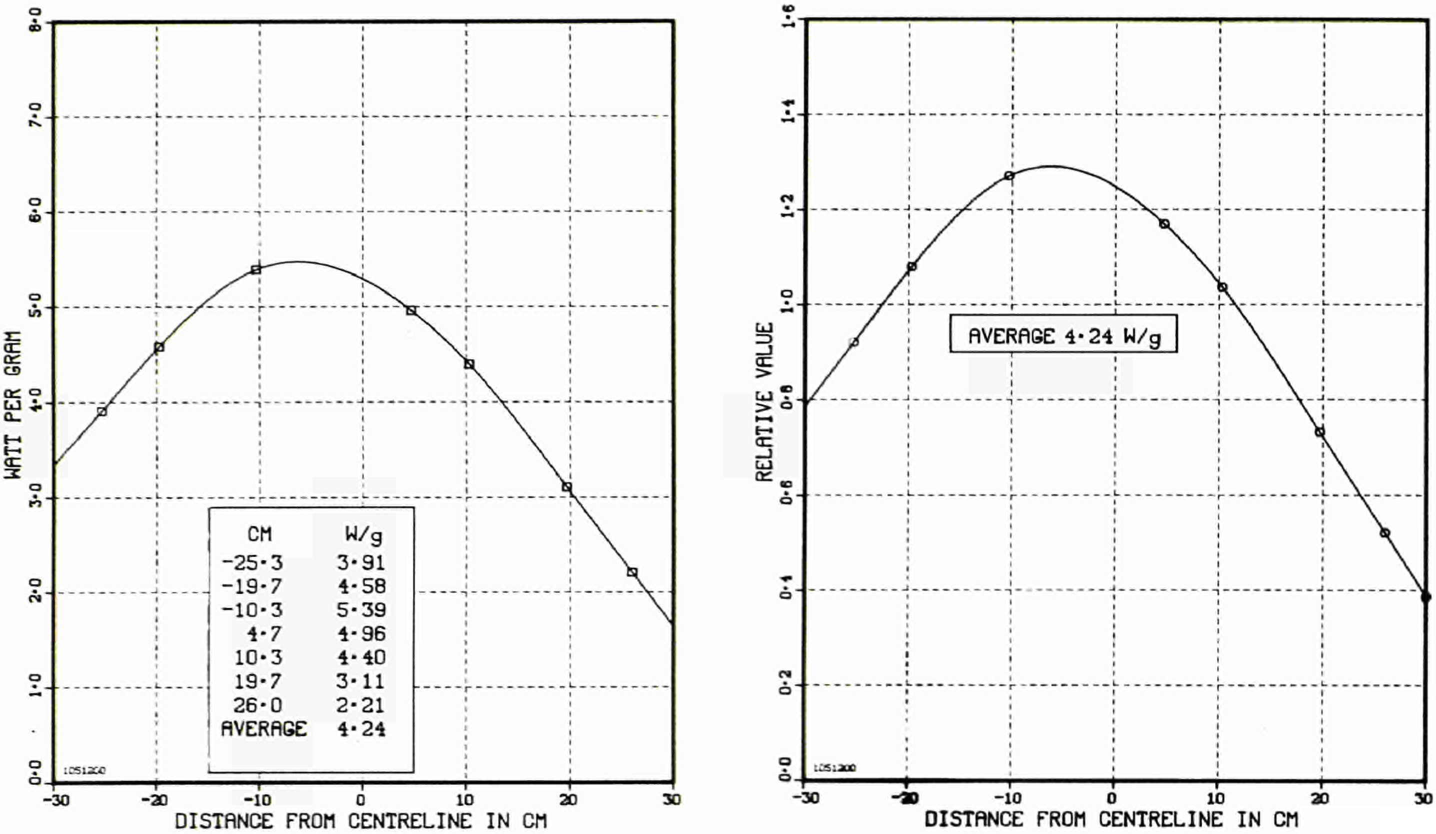


Fig. 2.18 Nuclear heating in graphite. Small samples in position G5.



CM	W/g
-25·3	3·91
-19·7	4·58
-10·3	5·39
4·7	4·96
10·3	4·40
19·7	3·11
26·0	2·21
AVERAGE	4·24

Fig. 2.19 Nuclear heating in graphite. Small samples in position F2.

Calibration of nuclear heating sensors in "TRAMP" rig.

The calibration of the calorimetric sensors for nuclear heating measurements is part of the TRAMP-project. The TRAMP (TRAvelling Monitoring Probe) rig contains two vertically movable sensors, one for the upper and one for the lower half part of the HFR core. The design of the rig is such that a defective sensor can be replaced.

The nuclear heating sensors are based on the calorimetric principle and resemble very much the CADO sensors. The CADO sensors use graphite only as heater sample; for the TRAMP sensors graphite and three other materials (SS, Al, Pb) will be used. The TRAMP sensors will be calibrated using the experimental set-up of the CADO calorimeters.

Due to the small size of the calorimeters there is no possibility of calibration under steady state conditions, which would be the most appropriate one.

It will therefore be necessary to calibrate under dynamic conditions, because then a measurable heat input in the sample is not needed. This method, however, requires a very precise knowledge of the specific heat of the sample material.

A dynamic condition is accomplished by a sudden cooling of the heated capsule under a waterjet. The temperature cooling curve contains the information of the unknown capsule parameters. The cooling curve data will be recorded by a wave form recorder. For the processing of data supplied by the recorder a computer programme has been written. This programme fits the unknown capsule paremeters to the cooling curve data by means of a non-linear least squares method. The programme also calculates the calibration constants, taking into account the temperature dependency of the conductivity of the gas around the sample and the specific heat of the sample.

Safety aspects

Consequences of loading of non-borated fuel elements.

On request of the local safety committee an evaluation was made of the thermal and nuclear safety aspects of the application of a fresh fuel element, but without boron-poison, in the HFR core. A comparison of the available thermal safety margin at 45 MW with the local power increase, which application of a 390 g ^{235}U fuel element without B^{10} would cause in the most unfavourable core position, revealed that only in some hypothetical cases of very low probability (one particular core position, all "hot spot" uncertainty factors active in a negative sense, "summer" cooling conditions, etc.) a flow-instability induced "over-power" problem could occur.

The reactivity consequences of the loading of a full-zone batch of (6) non-borated fuel elements would not lead to violation of any of the applicble safety criteria.

Comparison between calculated and measured flux densities in HFR core box walls.

The comparison between calculated and measured flux densities is connected with the investigation of the change in material properties of the HFR core box due to neutron irradiation. This investigation concerns a materials testing programme (RX-92 experiment) establishing the relation between the neutron fluence and material properties like tensile strength, strain and yield of samples from the same material as the core box walls, and on the other hand the determination of the neutron fluences of the core box walls.

In two well defined cores flux measurements have been performed with thermal and fast flux detector wires placed between the beryllium elements and the core box at a number of different core positions and in the poolside facility wall.
The calculations were carried out with the computer codes MICROFLUX and GAM to account for the spectrum influences on the detector materials and the computer code HIP-TEDDI has been used for the determination of the flux densities.
The results of the calculations are compiled in Table 2.8.

Table 2.8 Comparison between calculated and measured flux densities.

Wire	$\Phi_{th}^{Cu} \times 10^{14}$		$\Phi_{f}^{Ni} \times 10^{14}$	
	Calculated	Measured	Calculated	Measured
Core 486				
G9	1.51	1.15±.11	.097	.070±.005
H9	1.07	.86±.12	.087	.056±.090
PSF	1.44	1.59±.08	1.138	.996±.004
Core 490				
E1	1.35	1.39	–	–
I2	.88	.49	–	–
I5	1.31	.63	–	–
I8	.86	.51	–	–
C9	1.64	1.14	–	–
E9	1.42	.85	–	–
G9	1.09	.74	–	–
PSF	1.80	1.59	1.262	1.147

From the evidence compiled , the following tentative conclusions can be drawn:

- the error in the flux measurements is about 15 ^{o}/o
- the discrepancies between calculations and measurements can be explained by the presence of the beam tubes
- the adopted value of the flux over 1 MeV suits very well the calculated and measured values
- the adopted value of the flux under 0.623 eV was 20 ^{o}/o lower for the poolside facility wall and 14 ^{o}/o for the other core box walls.

Consequences of (hypothetical) bottom grid failure

The effects on core reactivity of a number of postulated partial or total failures (due to irradiation damage) of the core support grid on the HFR tank have been analyzed. The conclusion of this exercise, was that only in the technically incredible case of a failure of the entire grid (requiring all of the 24 support blocks around the grid to be torn off), a supercriticality situation ($k_{eff} = 1.10$) may arise. A somewhat more moderate case, again of extremely low probability, i.e. a partial failure due to which twelve fuel elements would fall down in one batch (with the control rods remaining in their withdrawn position) would not result in a critical configuration ($k_{eff} = 0.97$).

Short leakage rate measurement of HFR containment building.

A short leak rate test of the HFR containment building was carried out in the night of February 22, 1977.
The containment was pressurized to about 0,1 kp/cm^2 overpressure. After a stabilization period of about three hours the actual measurements started at 20.00 hrs on February 22 and lasted untill 04.30 hrs the next morning.
During the stabilization period leak tests of most penetrations were carried out. Some minor leakages were detected and could be repaired at once.
The actual measurements resulted in a final leakage rate of $- 46 \pm 160$ Nm^3/day at an overpressure of 0,5 ato (see Fig. 2.20).
Considering the criteria for these short leak tests the results do not necessitate any further action.
For the continuous analysis of the measuring results of leakage rate tests a programme for the HP-9810 desk calculator was written.

Fuel cycle

General

A contract is being negociated covering the "external" part of the HFR fuel cycle, viz.

- transport of irradiated fuel elements
- reprocessing
- uranium supply and enrichment
- transport of 93^{o}/o enriched UF$_6$

During the reporting period, numerous contractual details have been adjusted. The final version is expected to be ready by September, 1977.

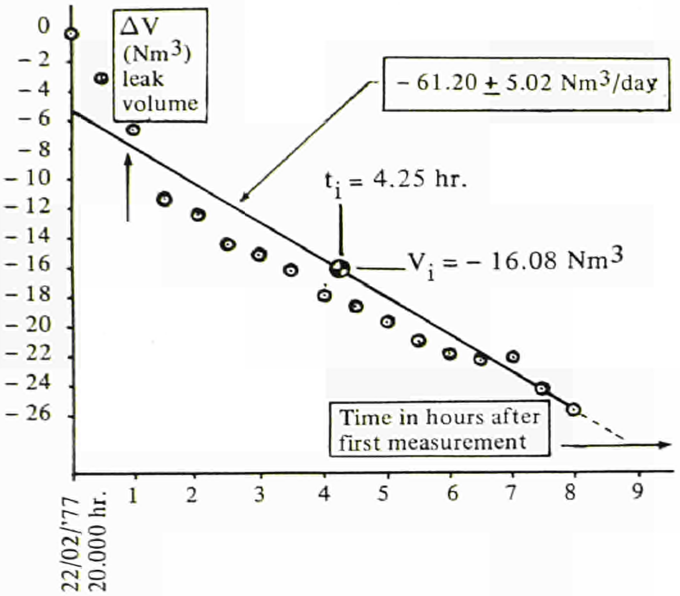


Fig. 2.20 Leak volume as a function of time calculated with the LERAM-2 programme.

Analysis of application of low-enriched fuel elements.

The multiplication factors of various core configurations with fuel elements of low uranium enrichment (20 °/o and 5 °/o) have been calculated.
Assuming that present U-235 weights per element could be maintained, it appeared that the present core configuration would still be operable (k_{eff} 1.10) with 20 °/o enriched fuel but not with 5 °/o enriched fuel. In the latter case the number of fuel elements in the core must be increased, leading, obviously, to a decrease in available neutron flux densities. A thermal analysis of the various fuel options is under way.

Plutonium and Neptunium 237 content of spent HFR fuel assemblies. (see section 2.1.3.2).

In the near future (August 1977) reprocessing of HFR fuel will take place at Savannah Rives (USA).
As a consequence of this change more fuel data, in particular with respect to the actinide content, must be provided. For this reason the FUTRAN programme had to be adapted, leading to "PUTRAN".
Apart from some minor changes the modification mainly consists of the calculation of the Pu and ^{237}Np isotopic contents.
For a representative set of 42 spent HFR fuel elements a total contents of 51 gr. Pu and 4 gr. ^{237}Np has been calculated.

Miscellaneous developments.

Design study for new HFR vessel.

A working group of ECN and J.R.C. staff has completed the first set of design specifications, Accordingly a design study has been undertaken. The present result is shown in Fig. 2.21.

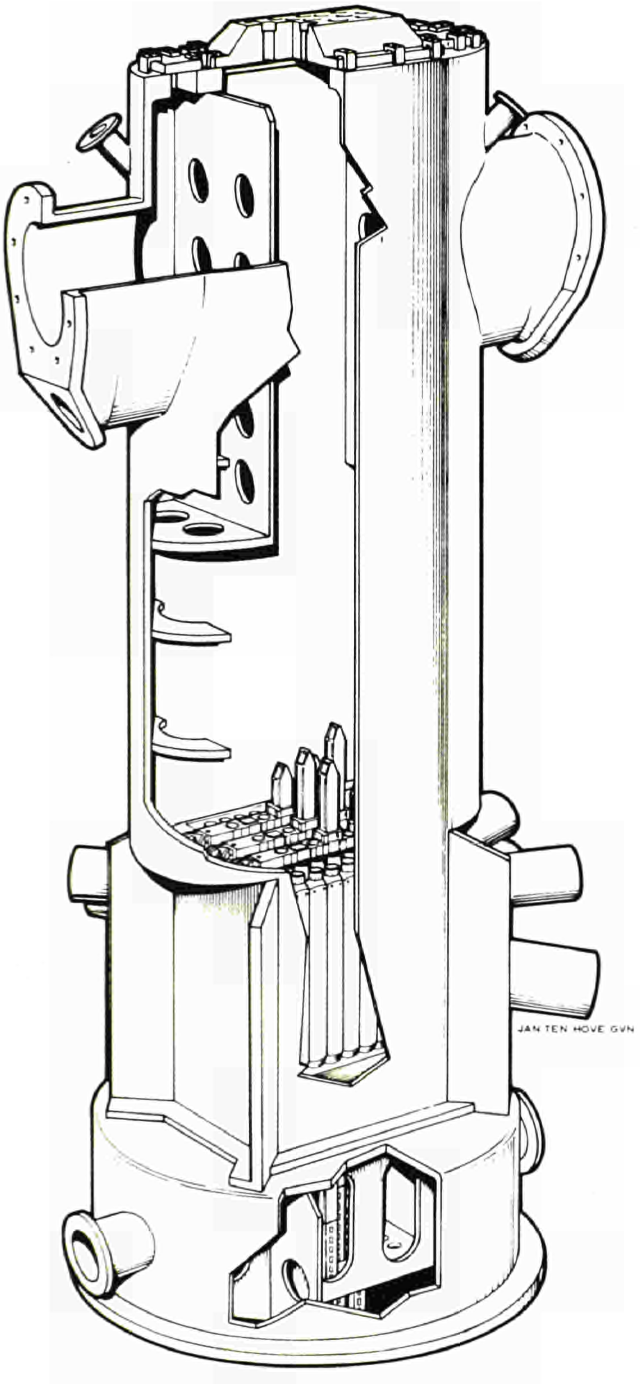


Fig. 2.21 Present Proposal of the Future HFR Vessel.

The vessel consists of the following modules:
- bottom, cylindrical, same diameter as present vessel, reduced height,
- core box, rectangular with supporting fins,
- bulk, two flat walls in line with the core box, two cylindrical walls, baffle plates opposite to flow inlet,
- top, one central lid as present one, two lateral lids.

The future vessel will preserve the present:

- pressure and direction of flow,
- fuel elements, control rods and grid bars,
- bottom flange and top lid.

The main improvements concern the:

- size, flexibility and access of irradiation facilities,
- Inspection of the vessel and components,
- handling of irradiation devices,
- primary flow inlet.

A preliminary stress analysis has yielded encouraging results.

Services to HFR users.

Maximum epithermal and fast fission power of in-core experiments (see section 2.2.3.5).

As part of a design study for some future LMBFR fuel irradiations, further calculations have been carried out to determine the maximum attainable fission power of MO_2 (15°/o Pu, 85°/o U, 90°/o enriched) fuel pins in a TRIO type irradiation facility in core position G5.
In order to avoid thermal fission each fuel pin must be surrounded by a thermal absorption shield.
Three types of absorbers have been considered, i.e. Cd, 90°/o Cd/10°/o Na mixture and Hf.
From table 2.9, in which some of the calculation results have been listed, the conclusion can be derived that high power with a large fast/epithermal fission contribution and moderate reactivity can be obtained with the postulated Cd/Na mixture.

Table 2.9 Calculated linear power densities and reactivity effects of a U/PuC fuel pin irradiation.

Property	Absorber type		
	Cd	H_f	Cd + Na
Max. linear power density in Watt/cm	1286	94,4	1236
Power contribution in °/o due to:			
fast neutrons	10.2	12.9	11,9
epithermal neutrons	82.5	11.2	87,1
thermal neutrons	7.3	75.9	1,0
reactivity influence in pcm	– 1250	– 1640	– 840

Maximum power of LMBFR-TOP fuel pins in PSF.

In preparation of the LMBFR fuel pin over power experiments (TOP, see section 2.2.3.5), planned for execution in the poolside facility, the maximum power density in a UO_2 pin (20°/o enriched ^{235}U) has been calculated for two cases, namely for one with a stainless steel and for a Mo shroud. The irradiation position selected is PSF 8 and the distance from the centerline of the fuel rod to the core box wall is taken as 3 cm.
Starting from a (measured) unperturbed thermal neutron flux of 2,3 x 10^{14} $cm^{-2}s^{-1}$, the maximum attainable linear power densities appear to be 1006 and 1021 Watt cm^{-1} for the SS and Mo shroud, respectively The contribution of the epithermal neutron flux and the nuclear heating are only 40 and 6 Watt cm^{-1} respectively.
These calculations will be continued with other enrichments of ^{235}U and also with less absorbing construction materials of the containments.

Reactivity effect of flooding HB0.

The influence on the core reactivity has been considered in case the CO_2 space in the large beam tube facility HBO would be flooded with H_2O due to a leakage.
According to the calculations, the difference in reactivity is negligible.

Improvement to thermal analysis code.

A special programme has been written in order to check the input data for the 2 DT computer code for the thermal analysis of irradiation experiments. This new programme BCHECK also produces a printed layout of the model, which is quite helpful in checking and correcting input errors.

Radiation Metrology Development

"External" dosimetry

The experimental and analytical study of the merits and drawbacks of neutron fluence dosimetry just outside, instead of inside, of irradiation rigs has been pursued by means of two irradiations in each of the two core positions C3, E5 and H2.
Cobalt and Nickel wires were applied as neutron detector material.
The irradiations were performed at 450 KW. The data treatment of the counting results is in progress.

Reactor core dosimetry standards

An invited review paper on this subject has been written and presented at the International Specialists Symposium on Neutron Standards and Applications, held in Gaithersburg from 28-31 March, 1977.
The following conclusions have been given in the report (ECN-77-027):

a) Different reactor development programmes require accuracies in integral data (fission rates, burn-up, fluences, damage effects) of 2 to 5 °/o.

b) An internationally accepted starting point for data treatment in neutron metrology work is the ENDF/B-IV dosimetry file, which has been made available in a world-wide scale through the four international nuclear data centers (Brookhaven, Saclay, Vienna, Obninsk).

c) Appreciable discrepancies exist between measured and calculated average cross section values in the ^{235}U fission neutron spectrum.
The representation of the high energy tail (above $\approx$8 MeV) of this spectrum needs further study.

d) Dosimetry reaction in categories I and II and classes of benchmark neutron fields have recently been reviewed by the IAEA 1976 Consultants' Meeting. The accepted tables constitute the basis for a critical analysis of integral measurement date which is or becomes available.
The benchmark field approach can serve to detect discrepancies and inconsistencies to arrive at a better quality of cross section data, and to improve spectrum determinations by the unfolding technique.

e) Many integral experiments in several benchmark fields, based on interlaboratory and international cooperation, are needed to arrive at the requested accuracies of 2 to 5 °/o.

Nuclear Data Guide for Reactor Neutron Metrology.

A document was prepared about nuclear data within the framework of the activities of the subgroup "Nuclear Data" of the Euratom Working Group on Reactor Dosimetry (EWGRD).
This document lists numerical data on activation detector materials, on detector reactions involved and on radionuclides produced. The data are mainly taken from evaluations. Where evaluations were missing, unknown or out-of-date, data from more recent literature sources have been taken.
The detection reactions considered were selected based on available information on its use for reactor neutron measurements.
The Euratom Working Group on Reactor Dosimetry thinks that this. document may contribute to a common data set for all laboratories working in the field of reactor neutron metrology. It is expected that after one or two years an updated and revised guide will be issued.

Spectrum unfolding calculations.

The Programme SAND-II (the neutron spectrum unfolding code) has been extended with two new functions for the fission spectrum part.

The DOSCROSS77 library contains 49 reactions. It is the intention to update the library every year with new recommended data. A description of the library will be given within the next six months.

- Damage cross section library DAMSIG77.

The results of a conversion of the data of damage cross sections of various materials from different libraries to a data format which can be applied as a library for the programme SAND-II have been given in the report ECN-77-012.
The materials which are available in this library are graphite, stainless steel, aluminium, silicium, chromium iron, nickel, copper, zirconium, molybdenum, tungsten vanadium and niobium.

γ-spectrometry.

IDENT libraries

The programme IDENT is used to identify the presence and the amount of radionuclides in a measured gamma-ray spectrum. Programme IDENT needs several libraries with nuclear data. The following libraries have been composed with data taken from the MEIXNER library:

NUCL: This library contains the general information about different nuclides i.e. the decay constant.
EBYN: This library contains the gamma-ray energies and the gamma yields per disintegration arranged in order of increasing proton number
EBYE: This library contains the gamma-ray energies arranged in order of increasing energies extended with gamma yield and decay constant.

The IDENT libraries have been described in ECN-77-054.

To be able to update the IDENT libraries several update programmes have been written. To update the library EBYE the following programmes are now available: DELEN and ADDEN.
To update the library NUCL the programmes DELNUCL and ADDNUCL are written. All these programmes are stored on the user library packet MBSPROG.
A description of these updated programmes has been given in ECN-77-052.

2.1.4 .Conclusions

The operation of HFR Petten has been resumed on January 1st, 1977, in accordance with the 1977/80 JRC Programme Proposals.

The reactor operated within few percent of the cycle calendar established by the end of 1976.

Perturbances originating from a rather large number (13) of unscheduled scrams only resulted in negligible additional outage times (1.4 °/o). However, these interruptions are undesirable both for reactor and for irradiation experiment operation, and measures are being desired to improve instrument reliability (most of the scrams being caused by instrument failures).

Work carried out during the annual reactor maintenance period confirmed the satisfactory state of health of the plant. On a routine basis, a large number of items have been replaced, including worn-out in-core components.

Calculations and in-pile measurements by activation detectors and calorimeters have further improved the accurate knowledge of the reactor's nuclear characteristics.

As far as fuel and fuel elements are concerned the US embargo on the supply of highly enriched uranium could be overcome due to a long-term stockpile policy applied by JRC Petten. However, the resumed supplies during the reporting period came in the nick of time to prevent reactor outages in 1978.

A survey of future schedules is given below.

References

1. A. TAS, G.J.A. TEUNISSEN: "Users report of HIP-TEDDI, a two-dimensional, four group code for the calculation of the neutron fluence in experiment positions and operating data of the materials testing reactor HFR at Petten." ECN-77-058. To be published.

2.2 Reactor Utilisation

2.2.1 Objectives

The reactor can be considered as a large testing facility for material specimens and components and as a neutron source for fundamental research. The work in and around HFR Petten therefore is oriented towards

- the testing of materials under reactor conditions, in support of nuclear power plant development and reactor safety research,
- fundamental investigations into material properties under irradiation,
- nuclear and solid state physics research,
- radioisotope production and activation analysis.

The key objectives for the reporting period have been (with the number of experiments):

- start of new irradiations	15
- continuation throughout the reporting period	3
- unloading after end of irradiation	11
- short term transient irradiations	17

- eight horizontal beam tubes in permanent use, installation of a mirror system into beam tube HB0,
- three isotope facilities in permanent use, installation of two new facilities.

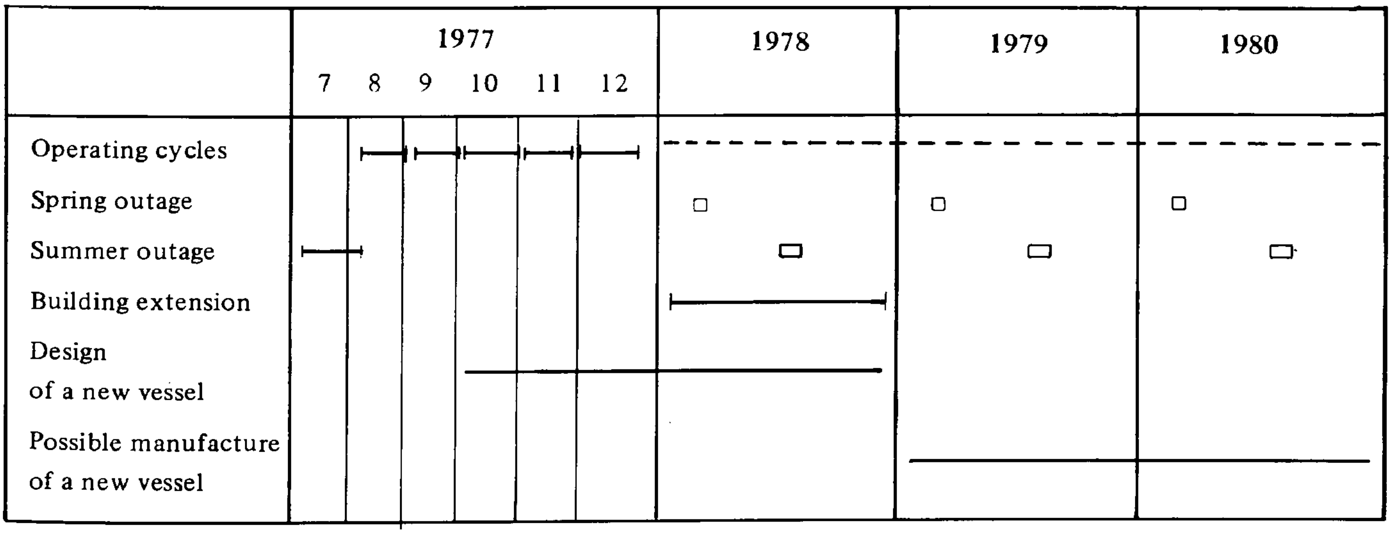
2.2.2 Methods

Irradiation projects come into existence by request of experimenter (JRC or external organization).

They then pass through the following main stages

- Design study (feasibility study)
- Detail design and calculations

Survey of future schedules.



- Safety analysis and assessment;
- Machining and purchase of material;
- Assembly and testing;
- Commissioning, loading, and connecting in HFR;
- Irradiation and surveillance
- Unloading, dismantling
- Post-irradiation examens (PIE)
- Reporting.

More detailed project management schemes have been elaborated, featuring about 100 steps per project.
Considering that about 30 irradiation projects are handled simultaneously one can easily judge the work volume involved. It has turned out during the years that the reactor occupation by irradiation experiments is limited by the available staff rather than by experimenters' requests.

2.2.3 Results

2.2.3.1 Graphite

Unstressed Graphite Irradiations.

ER005 "DRAGON" graphite irradiations.
(ECN project 1.530) Dragon-32

The last irradiation in this series was completed early in 1977 after an irradiation period of three cycles in core pos. C3. In spite of the earlier reported heater failures, reasonably satisfactory temperature control could be achieved by gas mixture variation.
From the thermocouples in the middle of each drum the average temperature per 12 irradiation hours has been plotted as function of the total irradiation time over the three reactor cycles (see Fig. 2.22).
The derived median temperatures of all thermocouples are presented in Table 2.10.

Table 2.10 Thermal behaviour of ER005-32 irradiation.

Position	Drum 3 °C	Drum 4 °C	Drum 5 °C	Drum 7 °C
Top	843	1159	1375	1158
Middle	880	1193	1343	1096
Bottom	985	1265	1304	1074

An irradiation survey is in preparation.

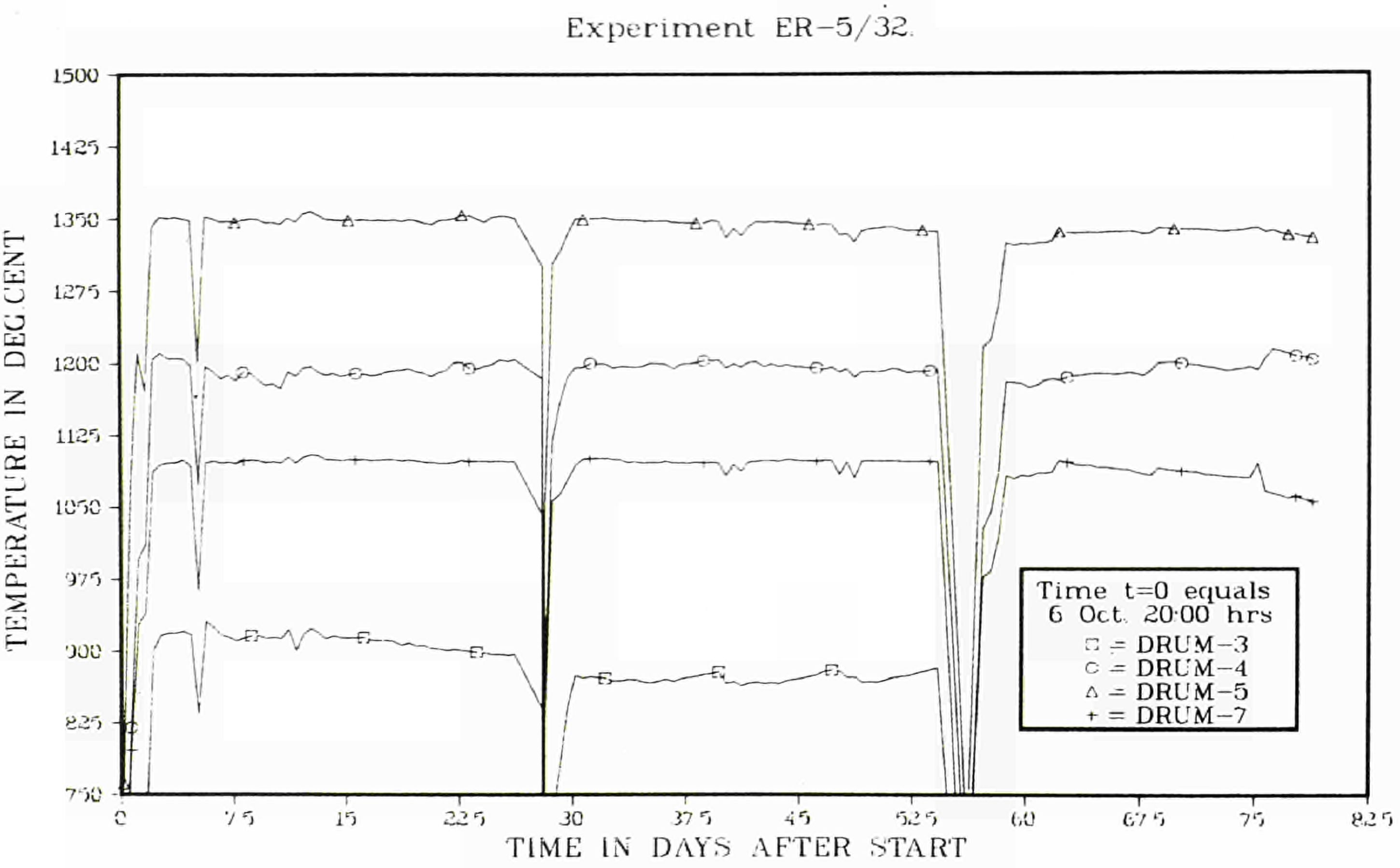


Fig. 2.22 "DRAGON" Graphite Irradiation Nr. 32. Temperature History.

D085 Series (KFA fundamental properties programme)

D085-15 , the 1250°C graphite irradiation in one TRIO leg, that was started during December 1976, continued irradiation until the scheduled end after cycle 77-04, i.e. May, 9th. Post irradiation neutron radiography showed, that the upper sample carrier drum (1 out of 4) was displaced upwards by 5 or 6 mm, which probably was the explanation for the heat losses at the upper end. The temperature drop at the bottom of the sample holder could not be explained.
The rig has been dismantled and all samples recovered. The achieved fast fluence was 2,5 x 10^{21}cm^{-2}.

D085-16 , was a full TRIO irradiation, aiming one temperature per TRIO leg, 900, 1050 and 1150 °C, respectively. The target fluence was 3 x 10^{21}cm^{-2}. Started in September 1976, the rig performed well until January 1977, when several thermocouples in the 1150 °C carrier failed. The irradiation was interrrupted for 1 cycle (77-02) and the 1150 °C sample holder was unloaded. The two remaining carriers continued during cycle 77-03, at the end of which they had reached the target fluence. All three sample holders were dismantled, the samples sent to KFA Jülich.

D085-17 is a new experiment which, at 1100 °C, shall give a comparison between the irradiation behaviour of reactor graphites of different origines.
The sample holder is a new design consisting of one Nb carrier of 400 mm length and 28 mm Ø, foreseen for a TRIO channel and equipped with PCD's at both ends. Design and calculation work was performed during the reporting period. The start-up is scheduled for October, 1977, the irradiation will last four cycles.

D085-22 the low temperature (300 °C) graphite rig continued irradiation during the whole reporting period. The originally defined temperature accuracy of ± 30 °C could be reduced to ± 15 °C.
The experiment is scheduled to continue till the end of 1977.

D085-23 is another low temperature irradiation, consisting of three TRIO sample holders for 300, 400 and 500 °C. Based on the design D085-22, the sample holder D085-23 has been calculated and designed as one long aluminium drum with PCD's.
Start-up is planned for December, 1977.

D085-24 is identical to D085-23, yet designed for higher temperatures: 400, 500, and 600 °C. Instead of aluminium the sample carriers are made of copper, again being long drums with PCD centering.
Start-up will be in December 1977.

D085-27 an intermediate temperature irradiation (750 - 900 - 1050 °C) started in cycle 77-03 in two different TRIO thimbles: Whereas the two higher temperature rigs are scheduled to run for 4 cycles (2.10^{21}cm^{-2}), the 750 °C sample holder will continue till the end of 1977. (4,5 . 10^{21}cm^{-2}). Therefore it was placed together with D085-22 in one TRIO (pos. C5), the other two sample holders being irradiated in E5.
The samples were pre-irradiated in D085-30, -29, and -28, having accumulated, a fast dose of approximately 4,5 . 10^{21}cm^{-2}.

In-Pile Graphite Creep Studies

D 122 Creep Assembly with On-Line Measurement.

The lower portion of the creep machine has been dismantled in the LSO.
A handling tool had to be designed and fabricated with which the reference parts then were disconnected from the tensile sample (Fig. 2.23).

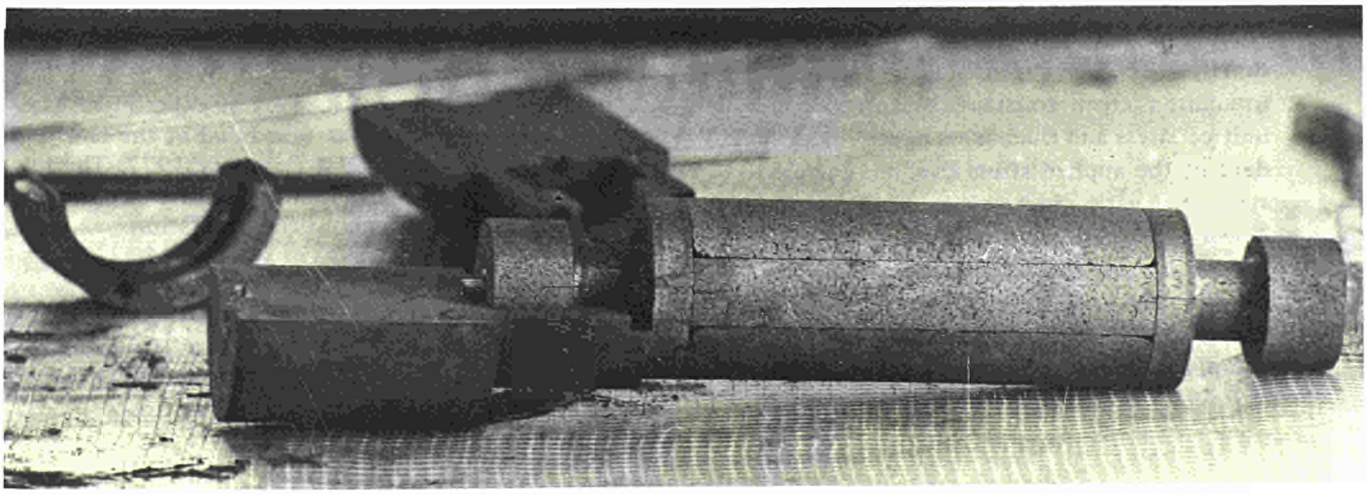


Fig. 2.23 Graphite Creep Experiment D 122. Hot Cell Photograph of the Irradiated Specimen Assembly.

Shrinkage of reference samples and creep strains of tensile samples have been measured in a glove box. Additional provisions had to be taken for these measurements due to the high gamma radiation of the samples (5 R/h on contact).
The measured shrinkage values correspond with the material data sheets. The measurements proved that the measuring system was well functioning all the time of the irradiation but that the specimen was no longer stressed after the first 1000 hrs of irradiation due to seizing of the tensile mechanism. The creep strain measured during this time has completely recovered in the remaining 1200 hrs of irradiation. The results of the in-pile measurements are compiled and elaborated [1].

D 133 Creep Assembly with discontinuous Measurements.

All experimental results of two irradiation campaigns have been compiled [2].

To continue the investigations with further irradiation steps it was proposed to repair the tensile sample which was damaged during dismantling after the second irradiation. A solution was found in cutting special threads on the neck of the broken top section and the surface of the lower head, which then are gripped by molybdenum alloy counter parts.
Preliminary laboratory tests on cold samples resulted in ultimate tensile strengths between 55-65 kp. corresponding to about 20 ^{o}/o of the irradiation load.
Work on this project is not continued at present .

R 135 Graphite Creep Experiment.

The analysis of the results has now been completed and the final report will be issued shortly. The report concludes that the irradiation creep constant (creep strain per unit of stress and fluence) is largely independent of the applied stress level but decreases strongly with increasing neutron flux density. It also confirms that the creep process has not caused mechanical deterioration of the graphite. A summary of this report will be presented at the 13th American Conference on Carbon to be held at Irvine, California, during July 1977.

D 156 DISCREET Graphite Creep Series.

Orders have now been placed by KFA Jülich, for rigs for irradiation steps 2, 3 and 4.
Component manufacture for the first rig is well advanced but delays have been encountered with delivery of the sample holder tubes and some graphite pieces. Assembly has begun with the available components. Both the tensile and compressive samples have been tested.
Due to the high activity levels found on other graphite samples from the same manufacturing source, it has been necessary to redesign the sample dimensional measuring equipment to operate in a hot cell. Delivery of the components for this equipment is scheduled for 1st August, and this is expected to delay the start of irradiation by one cycle (start now: cycle 77.08 - September).
The load control gas panel has been completed and test work with the associated electronics equipment is now progressing.

References

1. H. HAUSEN, Technical Note P/10/77/8
2. R. LOELGEN, Technical Memorandum IT/77/713

2.2.3.2 HTR Fuel

Coated Particles

R137 BATAVIA. Irradiation of Coated Particle Fuel in an Advanced TRIO Facility

The irradiation of BATAVIA experiment has been terminated as scheduled at the end of cycle 77.02 on 21st February 1977. The in and out pile irradiation facilities operated smoothly throughout the irradiation.

The achieved data were:

- neutron fluence (E > 0.1 MeV)	: $1.24 \times 10^{22} ncm^{-2}$
- irradiation time	: 286.37 EFPD
- peak burn-up	: 73 ^{o}/o fima

An overall histogram in Fig. 2.24 shows the average temperatures and the evolution of the R/B values in each sample holder. The final irradiation report is presently under preparation and will be published during the second half of 1977.

Post-irradiation work started on schedule. Completed PIE activities are:

- neutron-radiography of each sample holder,
- γ-scan of each sample holder,
- dismantling of each sample holder and recovery of all drums (Fig. 2.25),

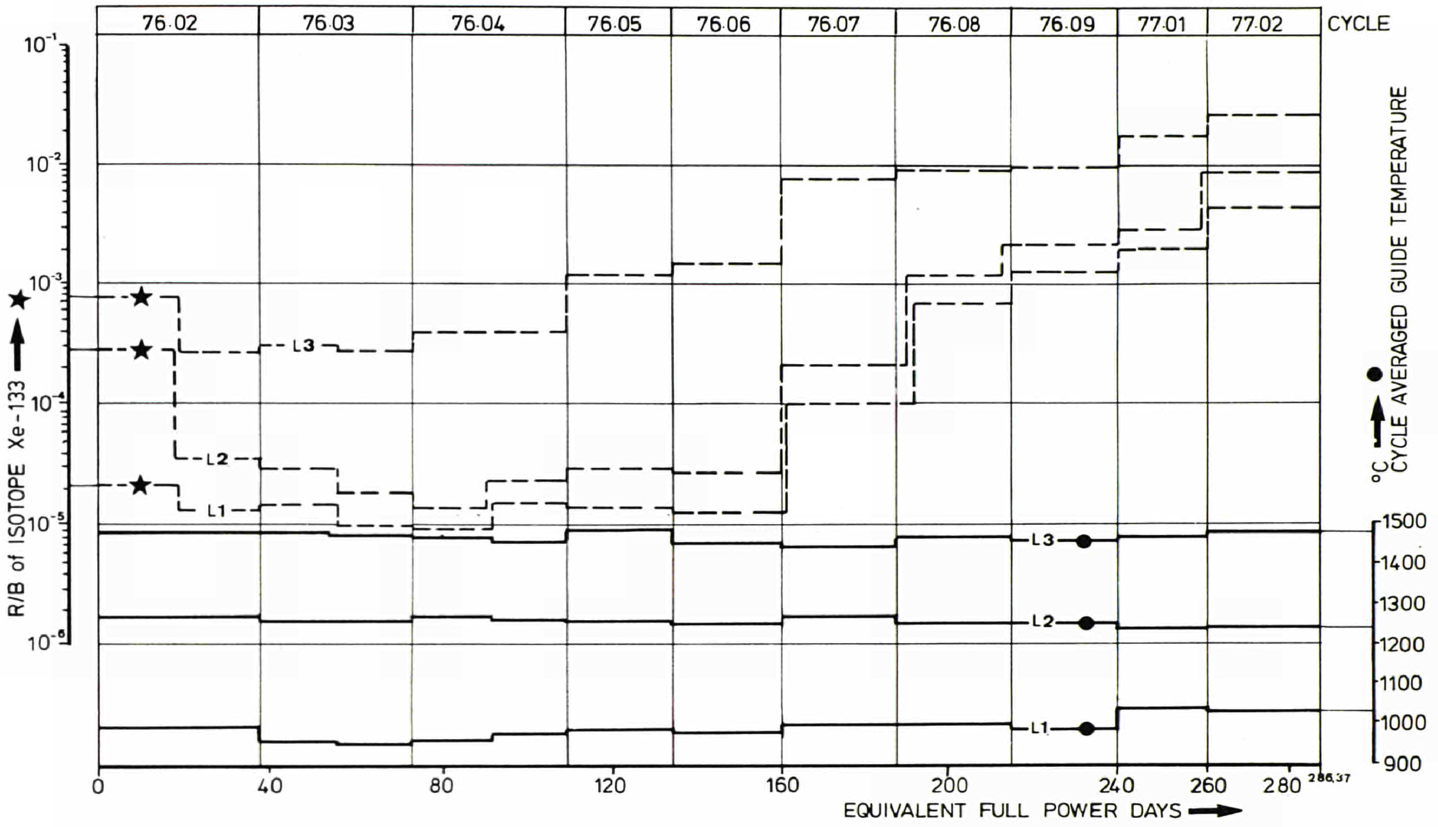
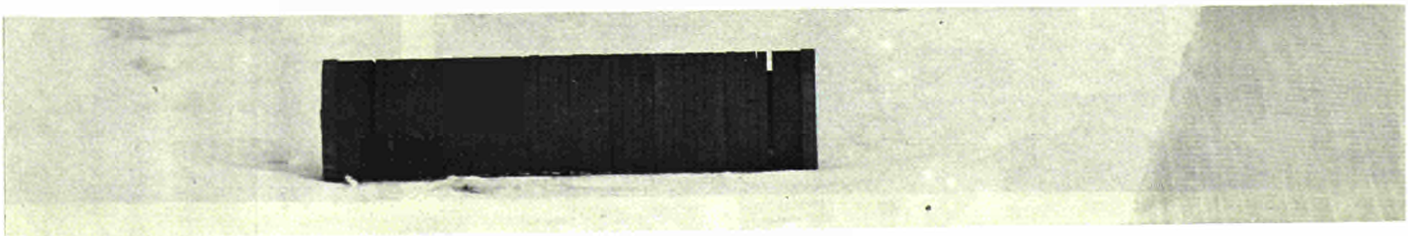


Fig. 2.24 "BATAVIA" Final R/B values & average temperature vs. irradiation time. Sample holders L1, L2 and L3.

Dismantling of Sample holder L1.



Appearance of Drum L1 after Unloading.

Fig. 2.25 BATAVIA. Hot Cell Photographs.

- recovery of dosimetry detectors,
- recovery of sample holder materials e.g. typical thermocouples, tubes, heat shields,
- γ-scan of unloaded drums.
- visual inspection of all rig and sample holder materials,
- transfer of drums to G5/G6 hot cells,
- unloading of coupons of drums no. L1-1, L1-2, L1-3, L1-4 (Fig. 2.26),
- visual inspection of all coupons and loose particles trays (Fig. 2.26),
- microradiographies of all coupons of L1 (Fig. 2.27),
- photos of all recovered and unloaded material,
- progress report of first PIE results.

D 162 ARTEMIS*)

Irradiation of Process Heat Reactor Coated Particle Fuel for failure mechanism investigations.

This new irradiation experiment is carried out with variants of feed-kernel coated particle materials for the PR-3000 reference fuel element under conditions which could be responsible for failure mechanism, i.e. kernel migration, SiC corrosion, and/or gas pressure failure.

The irradiation parameters are:

- fuel temperature : 1200 - 1500 °C
- radial temperature gradient : max. 300 °C/cm
- burn-up : 50 °/o fima
- irradiation time : 150 EFPD.

The specimens are coupons of 2 mm thickness stacked on top of each other to about 350 mm, with diffusion barriers between different fuel types.

A feasibility study has been carried out, showing that the irradiation parameters can be realized with an existing rig design, i.e. a modified FSC-rig.

A draft irradiation proposal has been submitted to KFA Jülich.

The design work is presently being started. The irradiation is planned to start in April 1978, in position C7.

Fuel Elements

D 138 Irradiation of Spherical HTR Fuel Elements for Nuclear Process Heat Reactor Development.

The final irradiation proposal has been distributed. The thermal analysis, the design and machining of parts has been terminated as scheduled.

Some assembly work, e.g. rig head, "boa" and high temperature vacuum brazing of the capsule caps has been finished. Due to a delay of the specimen fabrication, the start-up is postponed to cycle 77.09.

The safety report is being prepared. An illustration of the irradiation device is given in Fig. 2.28.

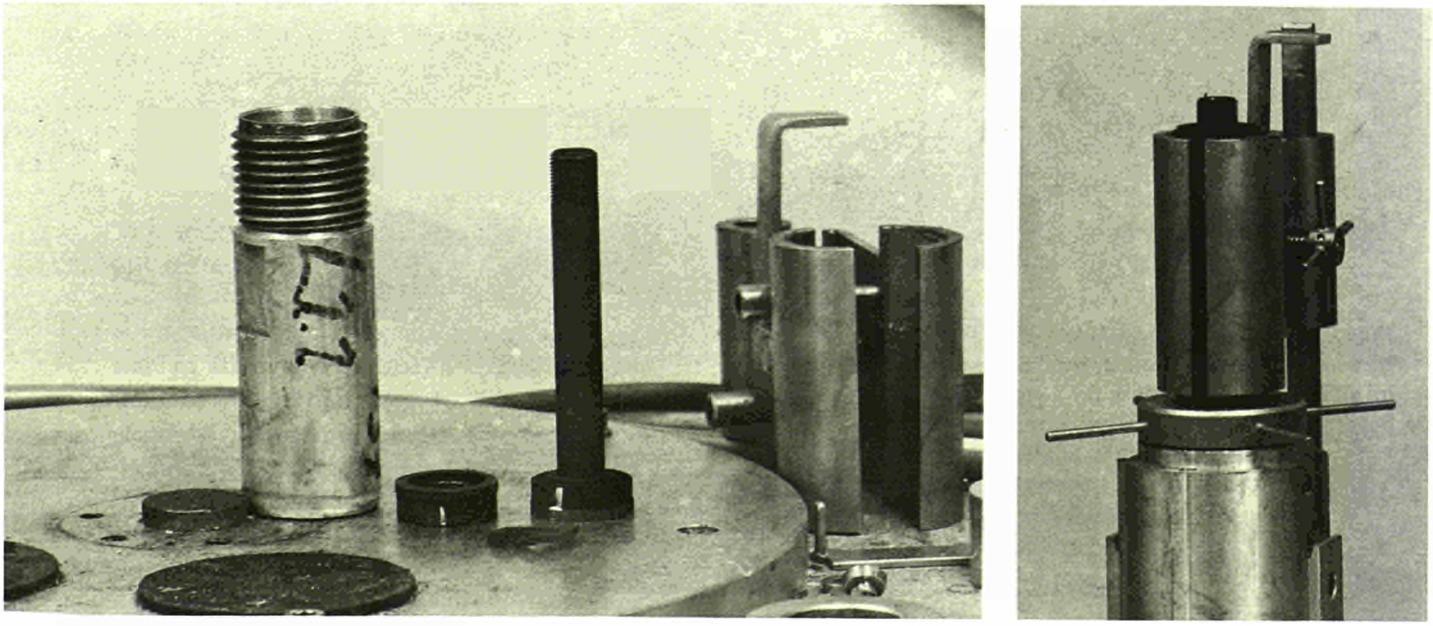


Fig. 2.26 BATAVIA. Unloading Jigs.

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*) ARTEMIS Amoeba Rig Test Experiment on kernel Migration. In-Pile Simulation.

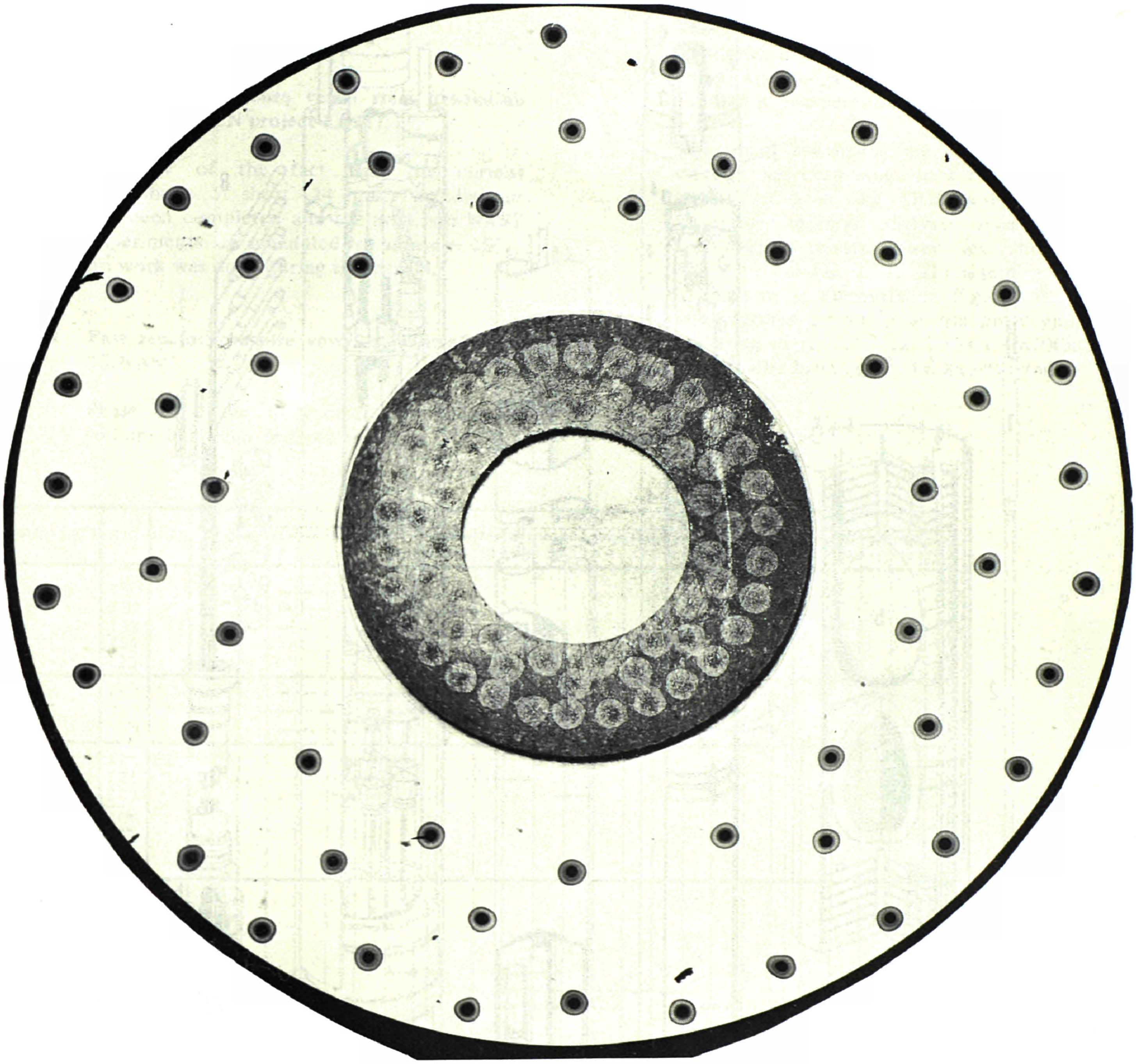
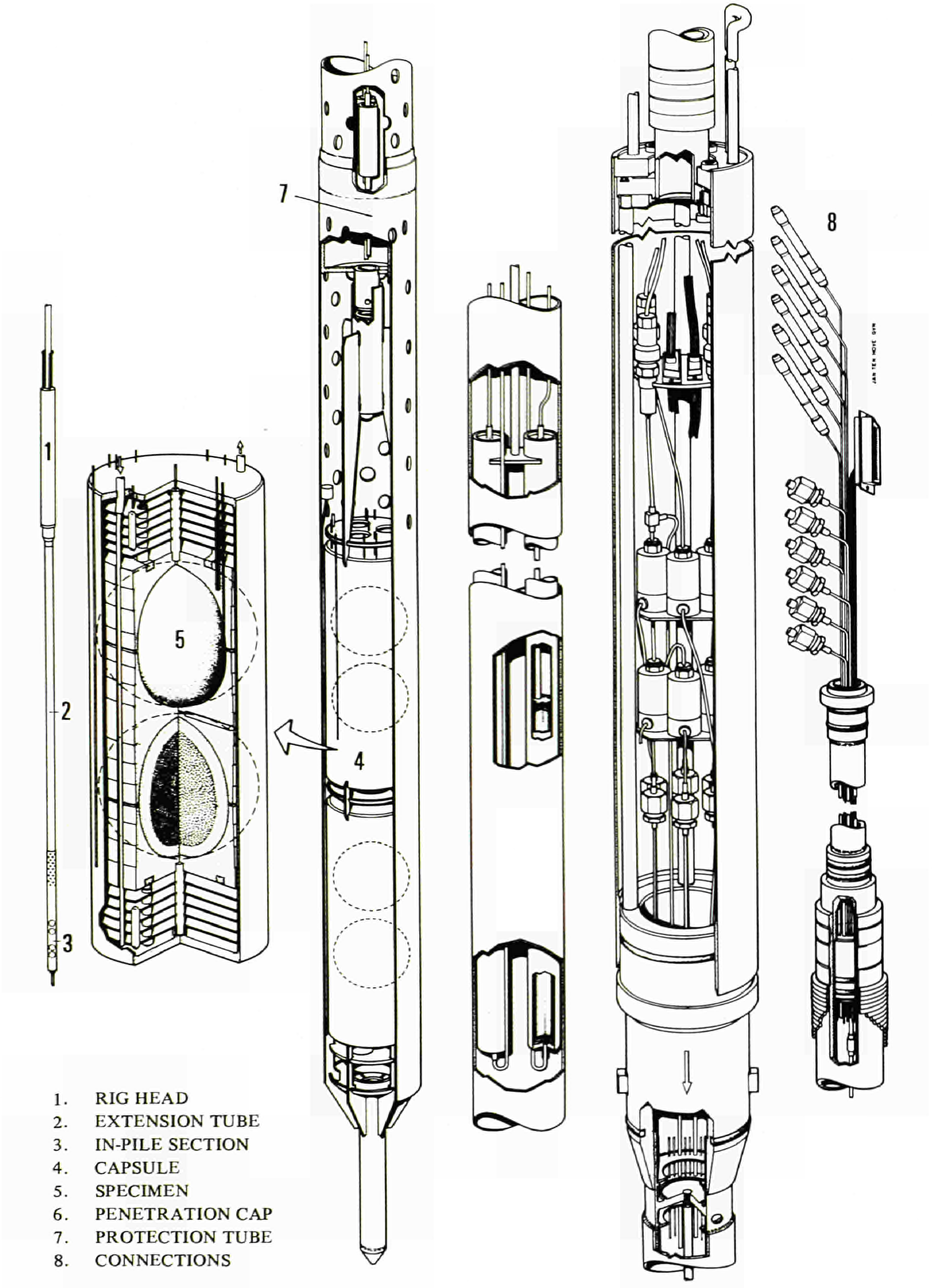


Fig. 2.27 BATAVIA. Magnification of Microradiography and Appearance of Coupon L1-1-21.



1. RIG HEAD
2. EXTENSION TUBE
3. IN-PILE SECTION
4. CAPSULE
5. SPECIMEN
6. PENETRATION CAP
7. PROTECTION TUBE
8. CONNECTIONS

Fig. 2.28 Irradiation device for special HTR fuel element testing.

2.2.3.3 Structural Material

Stainless Steel Specimens

R 120 Fast ractor pressure vessel steel irradiation "NAST". (ECN project 1.421).

In view of the fact that the current programme of short (24 hours) irradiations has been completed and the next two NAST experiments are scheduled for as late as 1978, no work was done during this period.

R 139 Fast reactor pressure vessel steel irradiation "SINAS"

Phase 4 of the ECN steel irradiations in sodium has been ordered in spring '77. The irradiation programme includes 27 sample holders for TRIO facilities and one for a 70 mm REFA.

Fig. 2.29 shows the overall time schedule. There are low cycle fatigue specimens to be irradiated in two different reactor positions, creep specimens and CT specimens. The irradiation temperature is in all cases 550°C ± 20°C.

The creep specimens are less bulky. An attempt has been made to accommodate 15 instead of 5 in one TRIO sample holder. Extensive thermal analyses have yielded encouraging results. They are shown in Fig. 2.30 and Fig. 2.31. The assembly of the in-pile part is presented in Fig. 2.32. The temperatures measured in the prototype rig operating in 139-21 (Fig. 2.33) are within an even smaller band (± 8°C) than expected.

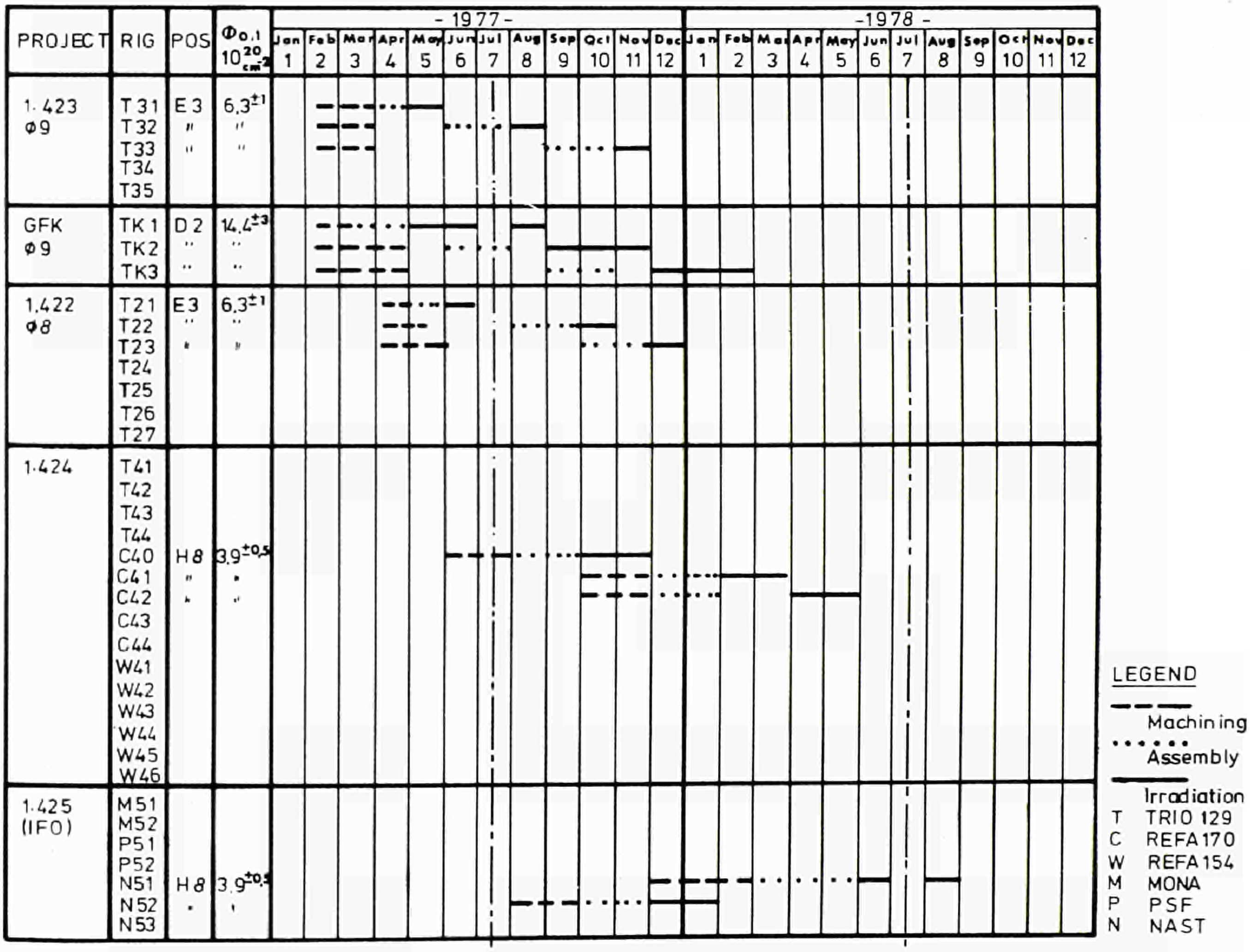


Fig. 2.29 Planning of project R 139.

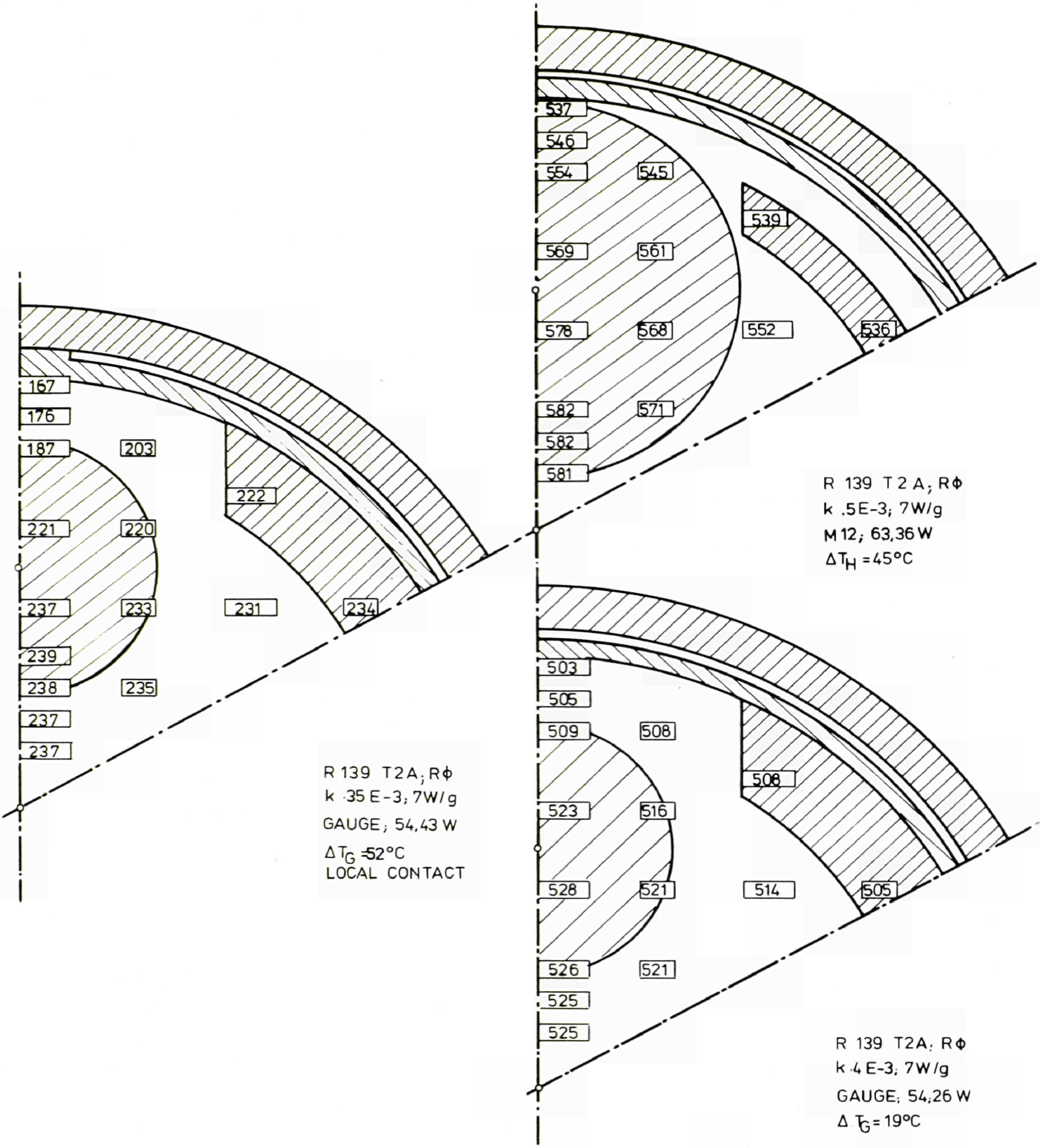


Fig. 2.30 R139-2A, calculated temperature patterns for head section, gauge section and local contact.

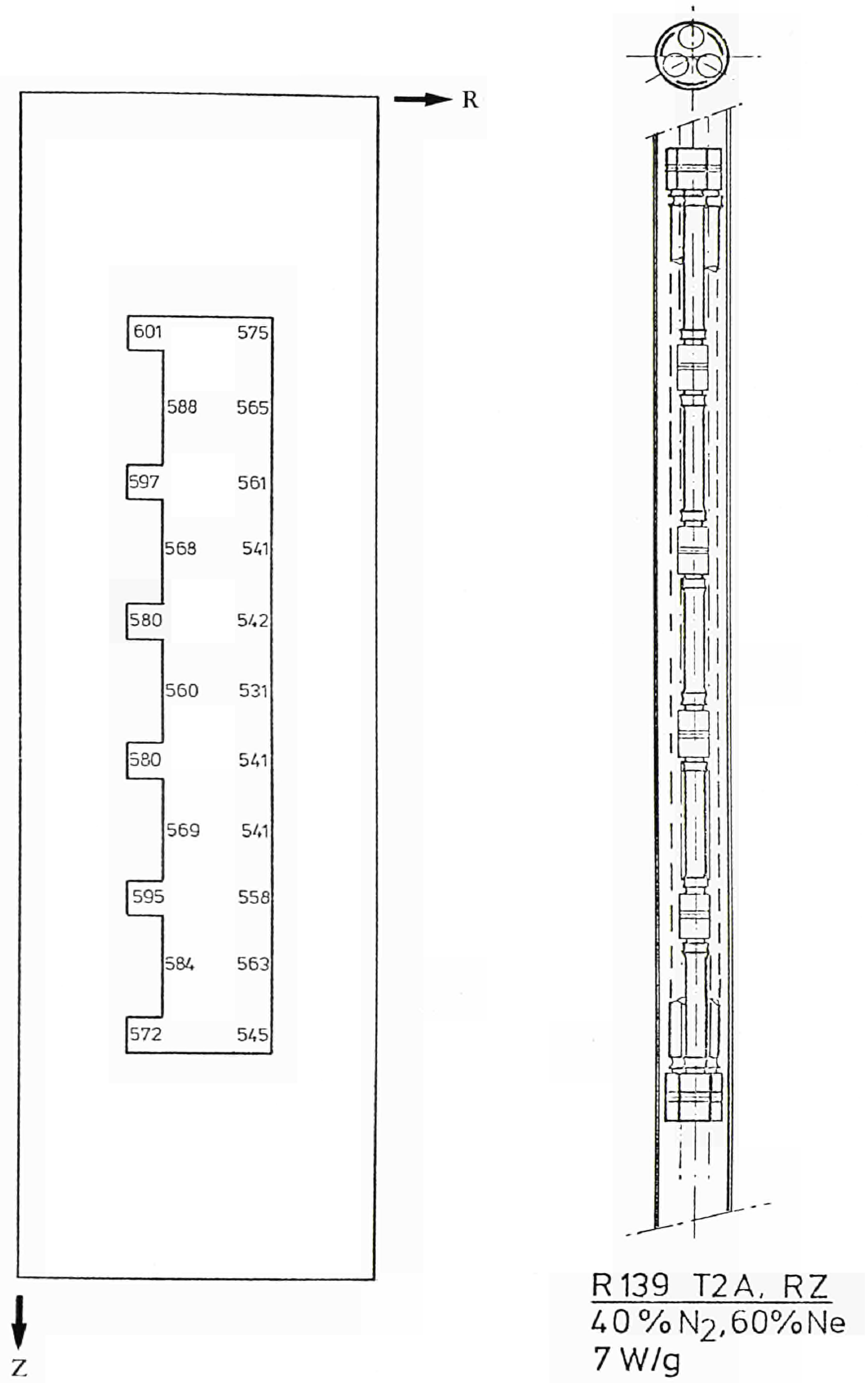


Fig. 2.31 R 139-2A, calculated axial temperature pattern.

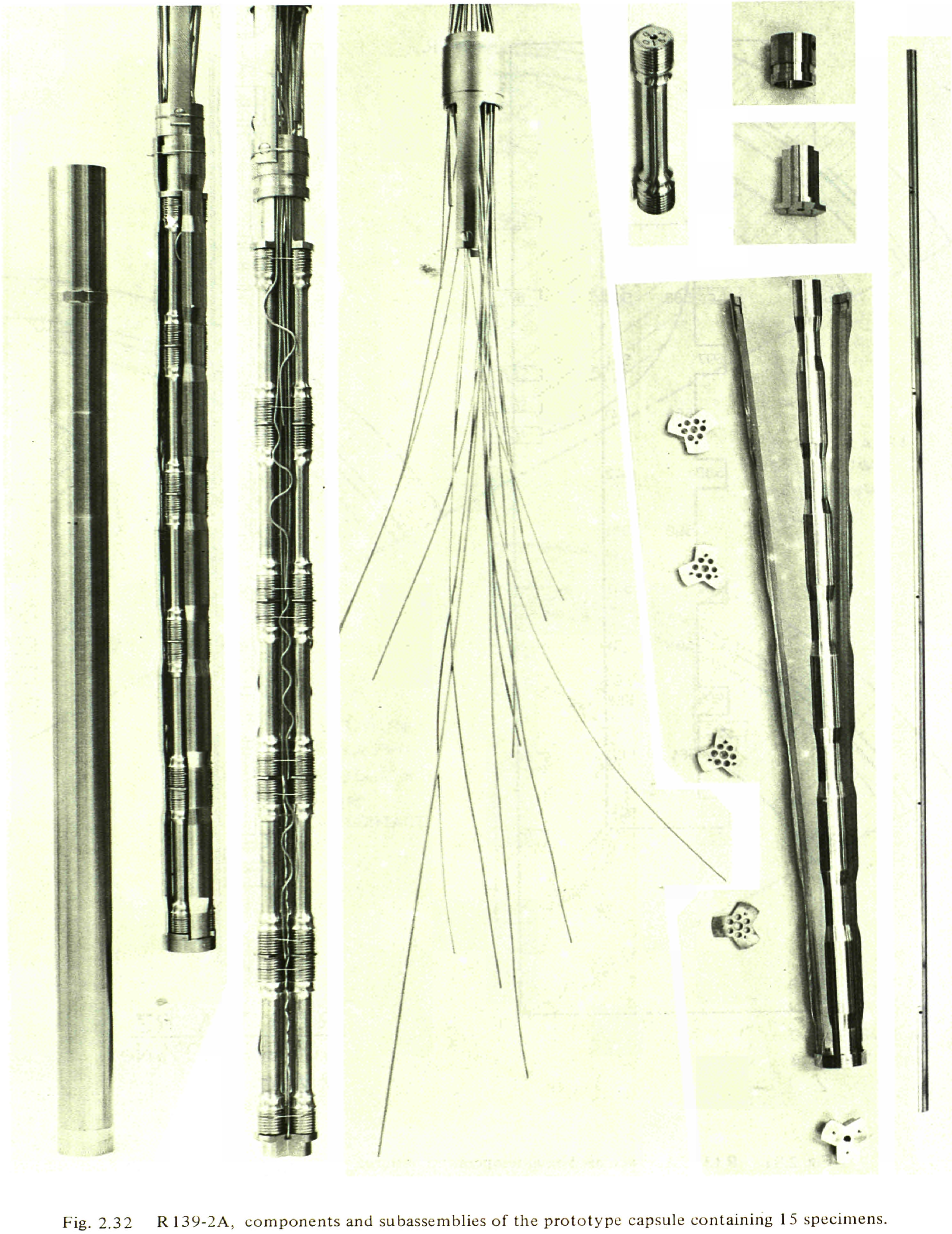


Fig. 2.32 R139-2A, components and subassemblies of the prototype capsule containing 15 specimens.

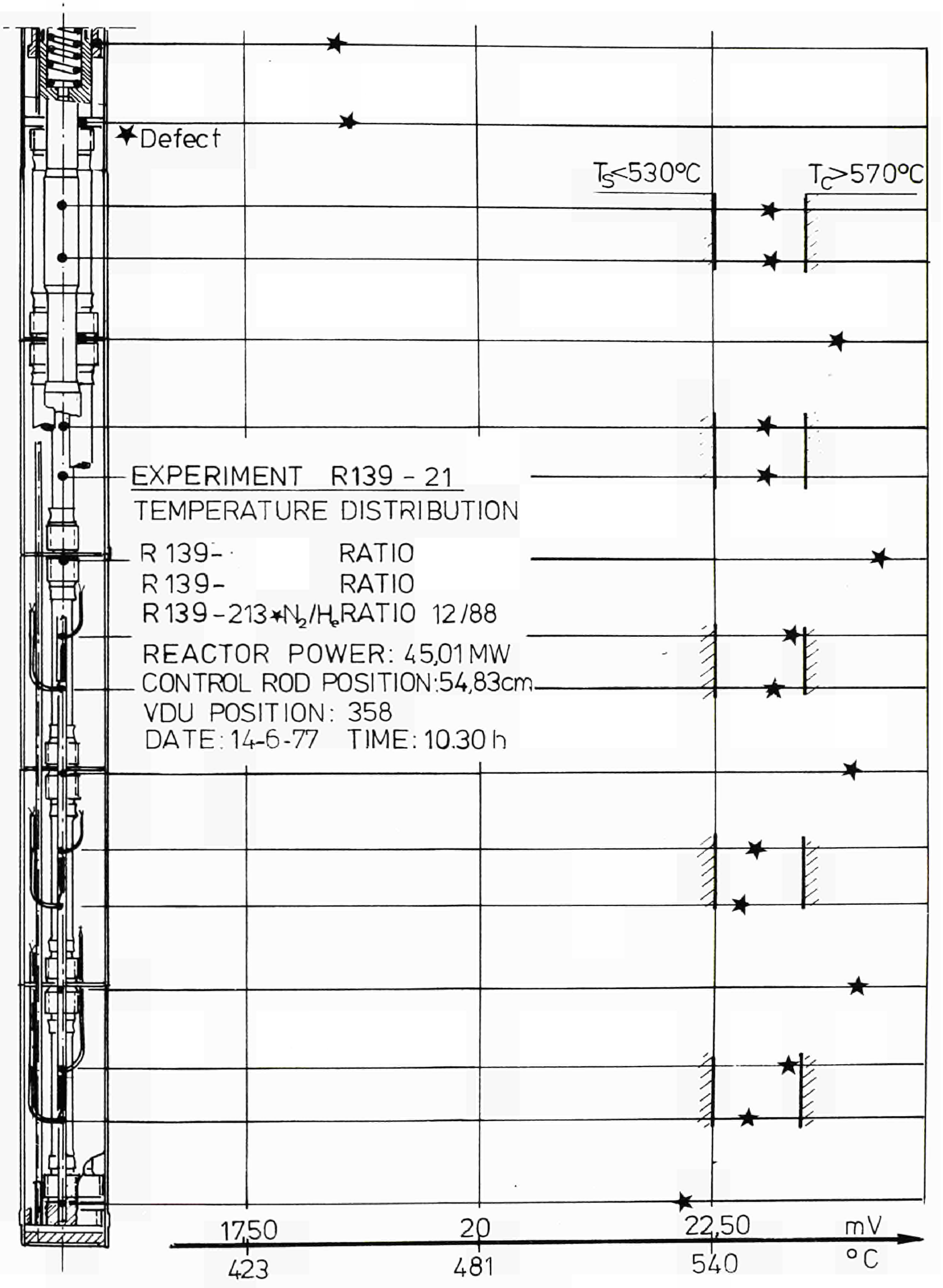


Fig. 2.33 R139-2A. Measured temperature distribution.

Irradiation of one TRIO (31) has been completed and two (K1,21) are at present being irradiated. Production of rigs, data processing for performance reports, dismantling and preparation of specimens is following in due course. The programme for 1978 is currently discussed. Irradiation in CT and WOL capsules will come up if the prototype rig C40 meets the requirements.

E 145 "AUSTIN" Irradiation of Austenitic Steel Specimens for Strain Rate Studies (JRC Ispra)

This experiment continued irradiation throughout the reporting period. A distorsion of the axial temperature profile is observed principally at the end of each cycle. This distorsion seems due to the fact that the axial flux profile is not exactly the same as used for the design calculation.

Vanadium, Niobium

E132-6 the uninstrumented low temperature vanadium irradiation, ended after cycle 77-02. It had, during 270 days of full power irradiation, accumulated a fast neutron fluence (> 1 MeV) of 3,5 x 10^{21} cm^{-2}.

Dismantling showed that from the 9 samples only 2 were still intact, whereas 2 had been heavily damaged due to water penetration, and 5 had been corroded and dissolved in the reactor water. The remaining 2 samples were sent to Ispra for PIE.

R151 "NIRVANA"

The Nb and V irradiation on behalf of ECN Petten [1], continued the preparative work: The thermal calculations were completed (see Fig. 2.34), design work was finished and

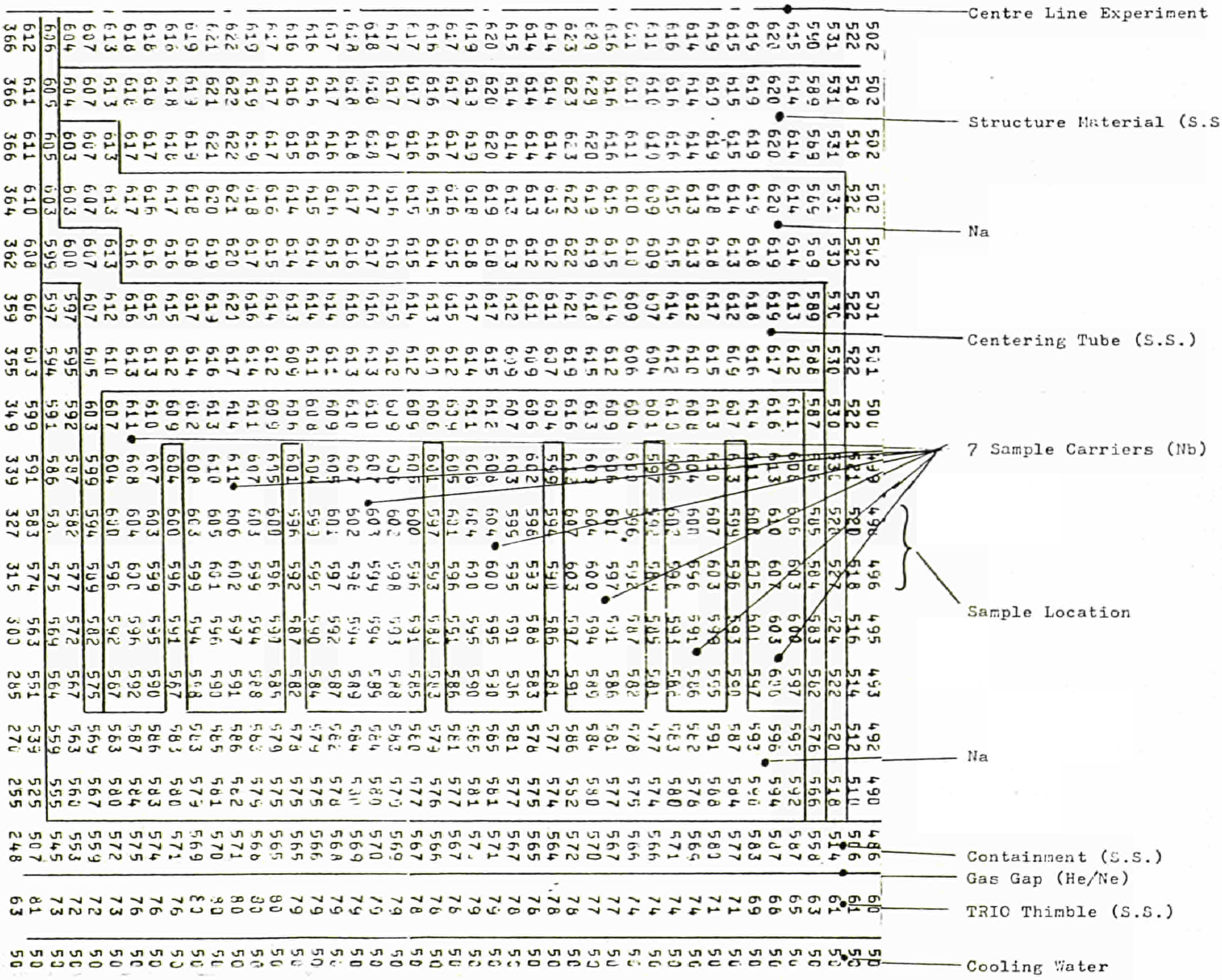


Fig. 2.34 R151 "NIRVANA". Results of two-dimensional thermal calculations for the 600 °C specimen carrier. (Normal operation, He/Ne = 50/50).

machining of the rig components started.

Start-up of the first TRIO-capsule R151-2 is scheduled for cycle 77-07, i.e. August, 11th. An out-of-pile test at 900 °C and in Na environment proved the satisfying leak tightness of the Nb 1^{o}/o Zr sample carriers, but showed also slight self diffusion effects on the samples. Therefore the irradiation temperatures were lowered somewhat; they are now 450-600-725-850 °C.

R151-2 will be irradiated during 2 cycles in E7 followed by R151-1 during 1 cycle (77-10).

LWR Fuel Element Components

R103 Irradiation Facility for LWR Fuel Components "BERO". (ECN Project 1076).

In order to increase the water temperature in the BERO facility the secondary cooling system has been modified. As a result the average cooling water temperature reached ~ 250 °C, which is acceptable for the present programme.

In Fig. 2.35 some typical average water temperatures, as obtained during reactor cycle 77-02 and 06, have been presented.

At the end of reactor cycle 77.05 a fluence of 2.2 x 10^{21} cm^{-2} (E >1 MeV) has been accumulated on the irradiation samples.

In HFR memo 77.05 the thermal behaviour of the facility has been evaluated.

R158 Zircaloy Cladding Creep Collapse ('HOBBIE') (ECN Project 1.085)

After the completion and approval of the project plan for this experiment, in which the basic specifications and the major organisational, budgetary and planning details have been laid down, much effort has been put into a proposal for the out-of-pile gas supply and removal systems and the associated in-pile and out-of-pile instrumentation. Several rounds of discussion with the local assessment committee as well as with the ORNL (Oak Ridge) design staff, who is responsible for the overall design, have lead to a definite proposal at the end of the present period. Components for these systems have been ordered. Also the handling tools for active manipulation of the capsule and the in-reactor thimble are being manufactured.

Due to miscellaneous difficulties, in particular with respect to the design, testing and assembly of the eddy-current sensors at ORNL and the design and safety analysis of the in-pile facility, the trial irradiation of the non-pressurized prototype rig will be delayed to late 1977. The first pressurized prototype rigs are not due before 1978.

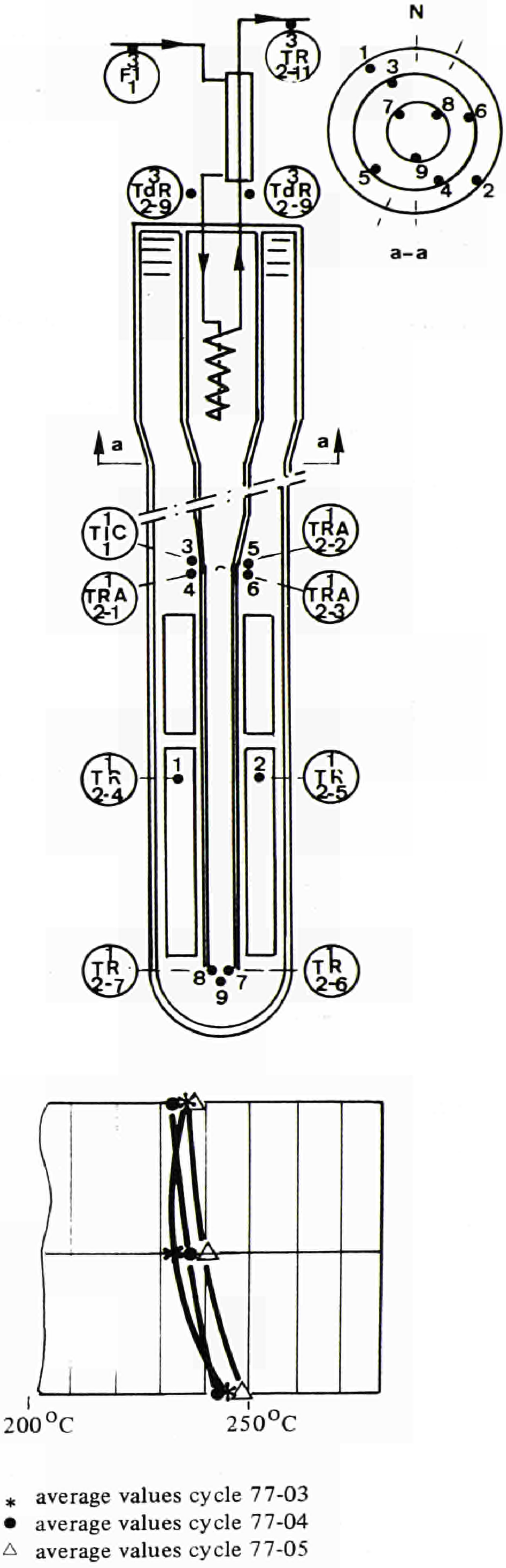


Fig. 2.35 Sketch of Bero facility and presentation of the average water temperatures during cycle 77-03, 77-04 and and 77-05.

References

1. H. SCHEURER: 'NIRVANA. Niobium and Vanadium Samples Irradiation in Sodium. Experiment R151. Design and Safety Report.' Technical Note P/10/77/27 (June 1977).

2.2.3.4 LWR Fuel

D125 Power ramp tests of pre-irradiated LWR fuel pins.

The irradiation programme for power ramp testing of pre-irradiated LWR fuel pins to be performed at JRC Petten consists of three main parts:

- Non-destructive investigations on the pre-irradiated fuel pins at the hot cells in Petten (visual inspection, profilometry),
- Non-destructive investigations in the HFR pool (neutron-radiography, eddy-current check) before and after the irradiation experiment.
- Ramp tests under irradiation,
- Non-destructive investigations in the hot cells at Petten (visual inspection, gamma-scan, profilometry) and preparation for transport of the fuel pins.

Two types of ramps have been performed (see Fig. 2.36 and 2.37) : In-situ ramps and start-up ramps.

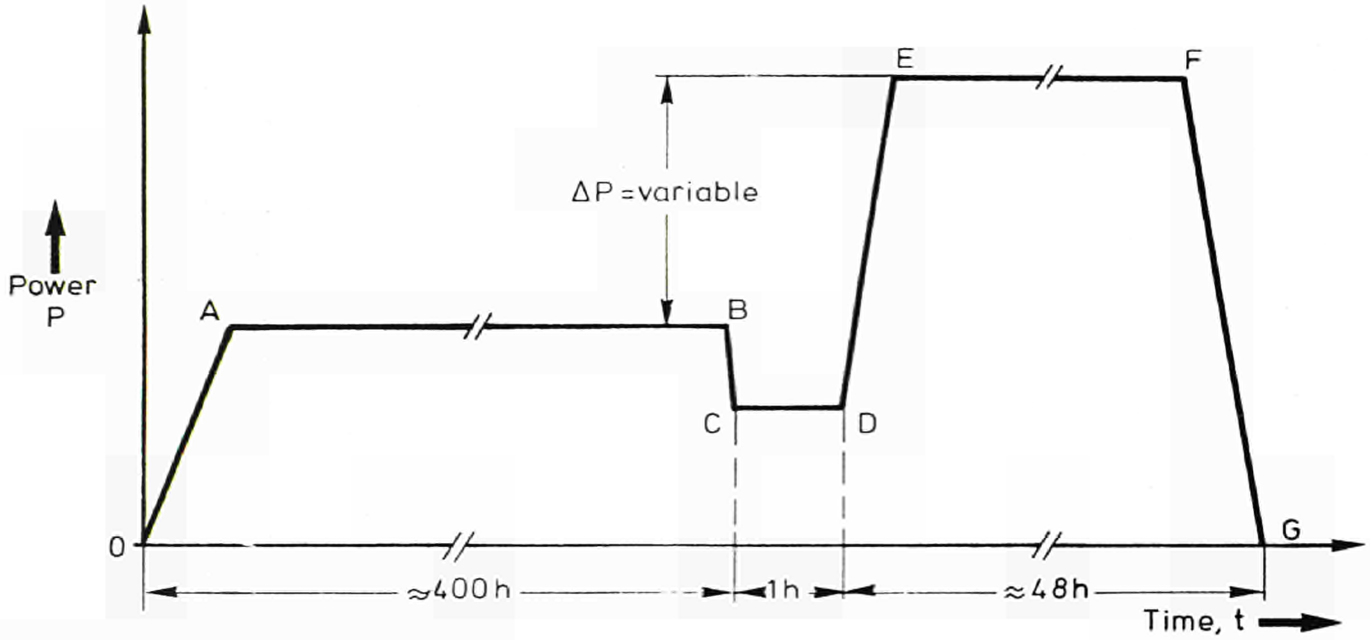


Fig. 2.36 Typical in-situ ramp profile.

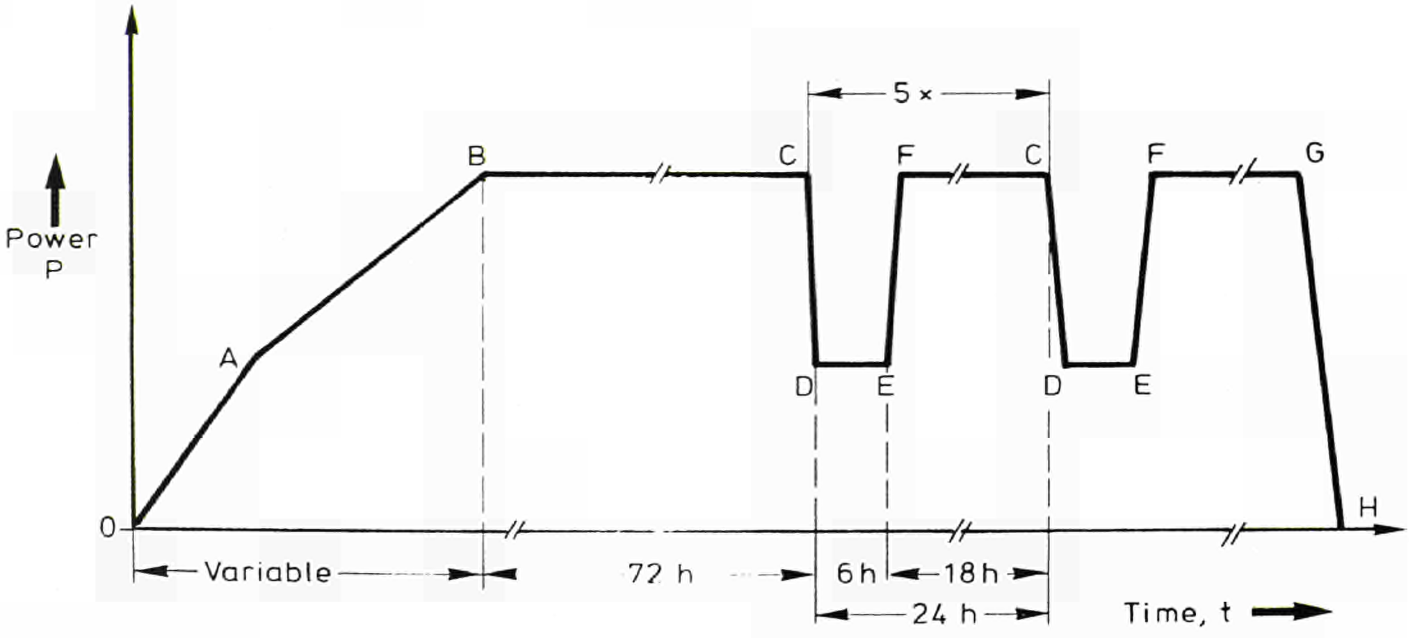


Fig. 2.37 Typical start-up ramp profile.

At the hot cells, 21 fuel pins have been prepared and checked for irradiation at the HFR.

15 ramp tests were completed in the reference period. About 50 $^{o}/o$ of the tests lead to a fuel pin failure due to either ramp speeed or ramp power. Ramp tests were done with PWR fuel pins of different design and pre-irradiation burn-up levels representing up to 2 power reactor years. The handling of defective fuel pins in the reactor was without any major problems. About 30 eddy-current checks and 60 neutron radiographies were made in the reporting period.

PIE on about 20 ramp-tested fuel pins is now completed. Fig. 2.39 shows a defective area of a fuel pin after ramp testing. In June a delivery of 32 pre-irradiated fuel pins was received, and stored at the hot cells.

Approximately 500 PWR- and BWR fuel pins of various design are still in the pre-irradiation phase.

The first results of the ramp test have been reported on the Enlarged Halden Programme Group Meeting in March 1977, and in KWU contributions (mainly surveys about LWR fuel element technology) at Reaktortagung 1977, IAEA-Conference on Nuclear Power and its Fuel Cycle in Salzburg and the ANS topical meeting on Water Reactor Fuel Performance in St.Charles/USA in May 1977.

The computer programme for evaluation of irradiation data on punch tape became fully operational. About 450 tapes have been processed on the PDP-15 computer. An example of a typical plot is shown in Fig. 2.38.

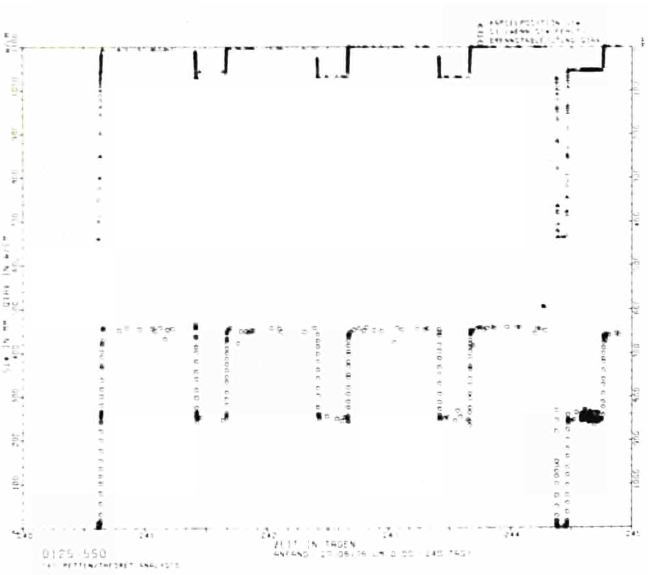


Fig. 2.38 D125. Computer plot of a cycling test.

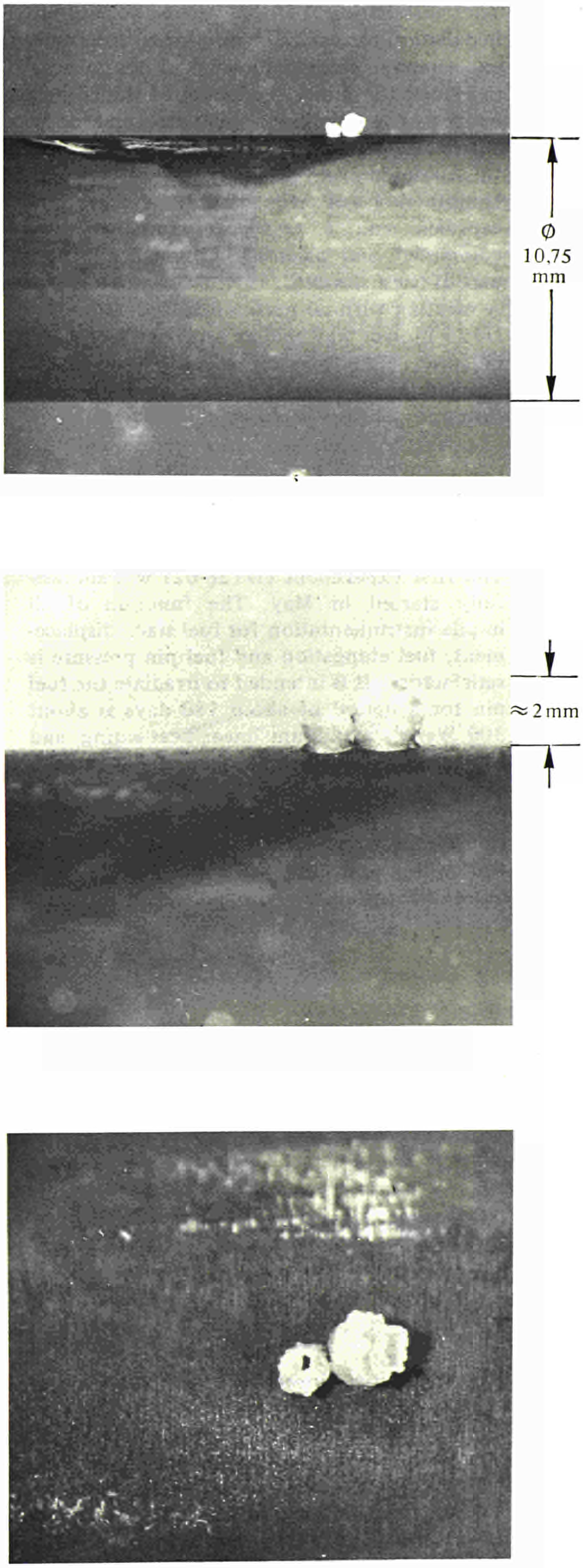


Fig. 2.39 D125. Power ramp tests of pre-irradiated LWR fuel pins. Defect in zone of max. power (pellet interface).

The installation of the second out-of-pile installation for parallel operation of four more experiments was completed and commissioning started in June. Machining of the components for a combined diameter and eddy-current measuring device for the HFR pool was completed and assembly started.
Manufacture of 10 capsule carriers, 10 capsules, and 6 transport containers was completed and assembly commenced for a part of these devices.
A meeting with all parties involved within the D125 project was held at Erlangen, Germany, in June. This meeting specified the future programme for ramp testing at HFR, and reviewed the tests performed.

D128 In-pile measurement of PCI* on LWR fuel pins.

The first experiment (D128-02) was successfully started in May. The function of all in-pile instrumentation for fuel stack displacement, fuel elongation and fuel pin pressure is satisfactory. It is intended to irradiate the fuel pin for a period of about 180 days at about 300 Wcm^{-1} maximum linear heat rating, and to perform in-situ power ramp test at the end of the irradiation period.
Fig. 2.40 gives a schematic view of the irradiation device. The second experiment is ready and will be started after the 2nd BWFC-out-of-pile installation is operational.

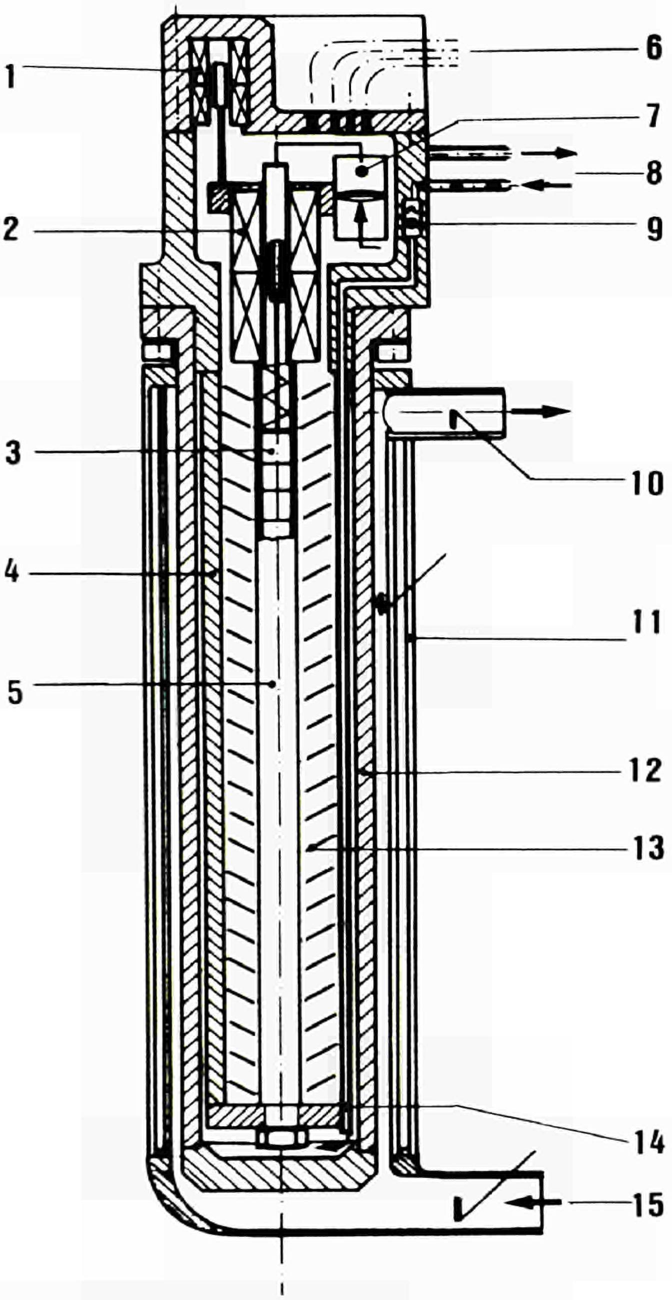
2.2.3.5 Fast Reactor Fuel

Safety Tests

R054 Fast Reactor Fuel Tests at High Temperature ("SHOT"). (ECN Project 1.413)

R54-F41/F43

Post-irradiation inspection of these two experiments has confirmed that a decrease in gas gap width caused by permanent radial expansion of the Na-containment tube has been responsible for the fact that the required Na-temperatures could not be achieved during irradiation. The reason for the radial expansion is believed to be the thermal expansion of the Na during start-up.
Due to an earlier design change, introducing more material above the fuel pin in order to flatten the axial temperature gradient, axial expansion of the Na during start-up was more or less blocked. This probably resulted in the radial expansion, which caused the deterioration of gas thermal resistance. In view of this problem future capsules have been remodified to provide for better Na expansion possibilities.



1. LD-transducer (fuel pin length)
2. LD-transducer (fuel stack displacement)
3. Fuel stack
4. Fuel pin and discs support
5. Fuel pin
6. Instrumentation lines
7. Membrane pressure transducer
8. Primary water circuit
9. Check valve for tube fracture protection
10. Thermocouples
11. Capsule carrier
12. Pressure vessel
13. Discs of steam bubble stabilizer
14. Inlet primary water
15. Cooling water

Fig. 2.40 D128. Instrumented Boiling Water Fuel Fuel Pin Capsule.

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*) PCI = pellet-cladding interaction.

F38

Capsule F38 has been assembled in the central workshop.
After the acceptance tests the irradiation could start on June 1. The Na-temperature at the middle of the fuel pin is 690 – 10 °C, while at the top and bottom end the temperature is 625 °C, both at a linear power of 600 W/cm.
After some days of operation several thermocouples failed.

F37

Capsule F37 is under construction and will be ready at the end of September.

F44 and F45

Capsules F44 and F45 have been ordered.

R063 Fast Reactor Loss-of-Cooling Experiment "LOC". (ECN Project 1.413)

R63-15

At the end of cycle 77.02 a burn-up of 63 MWd/kg UO_2 has been reached.
The transient has been performed at the beginning of cycle 77.03 at the following conditions:
- sodium pressure : 3.5 atm
- fuel pin internal pressure : 8 kg/cm^2
- LOC time : 17.5 sec.

The transient itself proceeded quite satisfactorily but the data print-out from the magnetic tape was not quite in order. Among other things, several parity errors were recorded.
After considerable testing and trouble-shooting work a series of magnetic tapes has now been made without any error and apparently the problem has been solved.
In Fig. 3.20 and 3.21 the Na-temperatures vs. time is given.

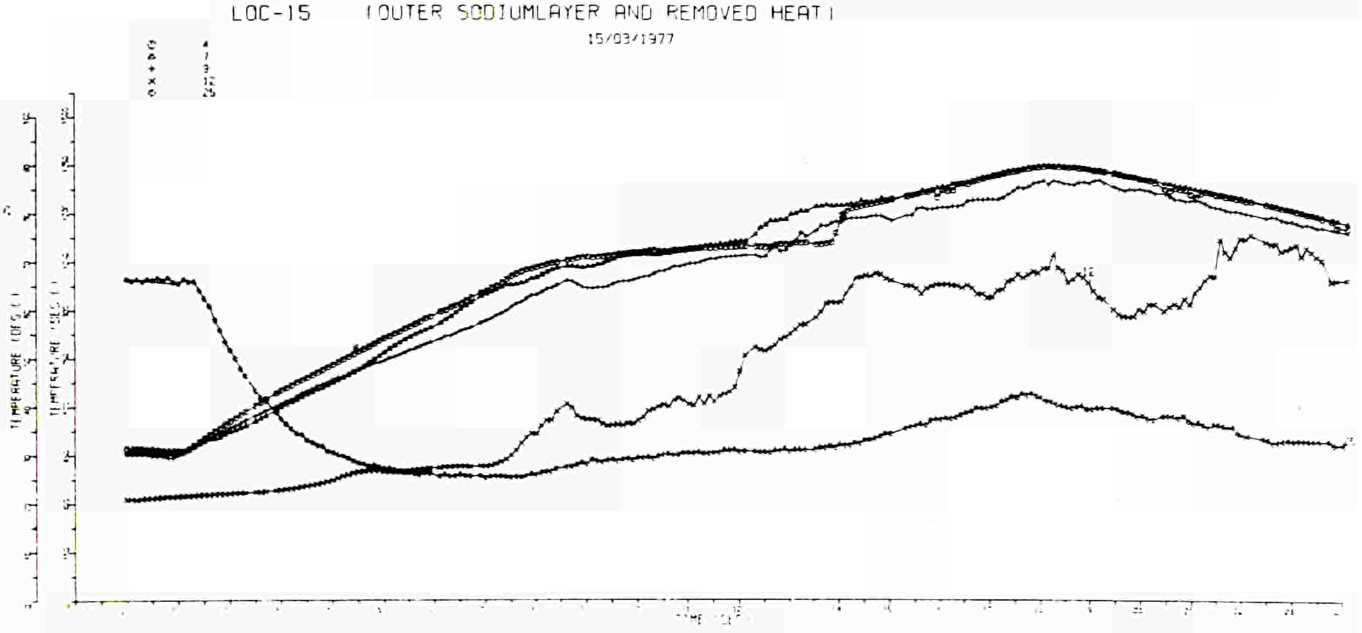

Fig. 2.41 Outer sodium layer temperature as function of time.

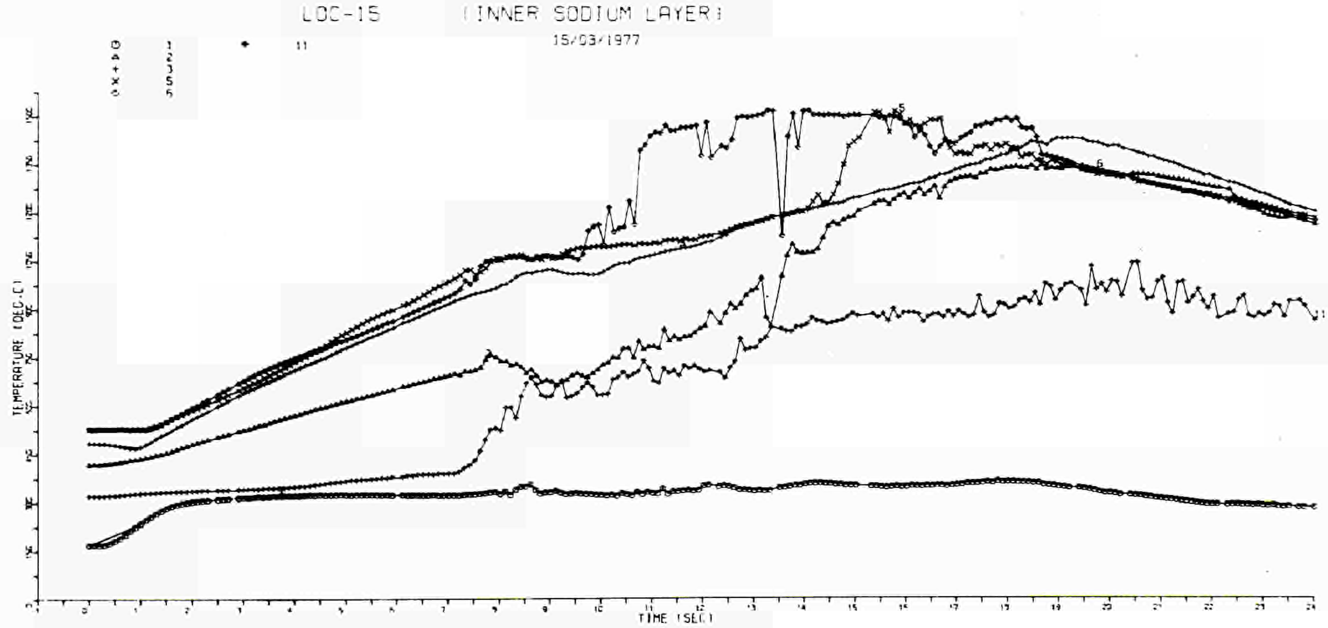

Fig. 2.42 Inner sodium layer temperature as function of time.

R63-17

The pre-irradiation of capsule L17 has been continued.
Unfortunately a number of thermocouples failed for, as yet, unknown reasons.
At a burn-up of 27 MWd/kg UO_2 a leakage developed in the gas containment. The experiment was temporarily taken out of operation, pending a decision on the acceptability - from a safety viewpoint - of further irradiation. It was decided not to continue the pre-irradiation and delay the transient with this capsule as long as practicable, in order to decrease the iodine activity and the associated hazards in case of transient-induced capsule failure.
The advantage of this procedure is that the capsule can be transported to the hot cells nearly immediatedly after the transient. The decision has no influence on the time-schedule of the post-irradiation programme.

R63-18

Capsule L18 has been assembled and has been connected to the gas supply station and instrumentation panel.
Due to difficulties with the data handling system the LOC-transient has been delayed to June 22. Unfortunately, certain print-out difficulties were again experienced with the data-output.

R63-19

As reported previously, six thermocouples failed during the assembly of L19.
In order to replace these thermocouples it was necessary to disassemble the capsule completely. For this and certain other reasons the LOC-19 irradiation schedule has been delayed considerably.

R124 Fast Reactor Fuel Pin Transient Overpower Test (TOP). (ECN Project 1.417).

Much time has been spent on specification, planning and organization of the work to be carried out for the feasibility study of a TOP loop in the PSF.
Specifications for the instrumentation of fuel pin and coolant channel have been drawn up for the loop process instrumentation. Based on these specifications, a preliminary specification for the data transmission and handling system is under discussion. The technical preparations, as far as carried out by the ECN irradiation technology group, will comprise:

a) the development of a BF_3-type dynamic neutron shielding facility (see below),
b) selection and development of in-core instrumentation, followed by trial irradiation in a series of test rigs "INTEC" (see experiment R163),
c) design and irradiation of a power calibration rig (see experiment R165).

Work on the BF_3 shielding facility has been concentrated on the development of a fast-acting electromagnetic valve for the controlled release of the shield pressure. The desired linear-pressure-drop-versus-time type release can be approximated by a "staircase curve", which is obtained in the following way:
the pressure measurement signal voltage is compared with a linearly diminishing reference voltage, generated by a "sawtooth" generator. When both signals are equal, the voltage comparator initiates opening of the solenoid valve. As soon as the pressure signal drops beneath the reference voltage the comparator yields a closing signal to the solenoid valve. The same sequence is then repeated as many times as required by the prescribed reference voltage transient.
In the beginning, when the shield pressure is high, the pressure drops rapidly after opening of the valve and the valve must close practically immediately. Because of the relatively slow mechanical action of the valve the closing action will be a little too late and the pressure will drop too far.
At a later stage, with lower gas pressure in the shield, the valve has to remain open longer for the same pressure drop.
By modifying solenoid, moving masses and bypass channels of a standard 6.4 mm bore indirect action solenoid valve, a decrease in opening and closing times from ~ 100 msec to 8 msec for opening and 14 msec for closing has been achieved.
Based on present experience, an even faster valve with larger bore will be developed and tested in the next quarter.
An interim report of the work done so far, has been prepared.

Experiments in Support of R124 (ECN Project 1.417).

a. R163 Instrumentation Test Rig (INTEC)

The design of this series of three rigs, in which various types of in-core instruments, intended for application in the R124 ("TOP") experiment will be tested under irradiation, has been started. Several instruments have been ordered.

b. R165 Power calibration Rig.

The design of the rig, which will initially be used for determination of the maximum attainable power of a "TOP" type LMBFR fuel pin (exp. R124) and later for subsequent power calibration of TOP-experiments, is well under way.

"Mild" Transient Experiments.

D147/ D148 **Carbide fuel pins in PSF and tank positions.**

The American "embargo" on highly enriched fuel supply has delayed these experiments in particular. No deadline has at present been set, but the manufacture of the irradiation devices has been resumed. Meanwhile, calculations on alternative neutron screens have been carried out. They show that a 16 °/o perforation of the Cd screen of D147 (PSF) would yield a maximum linear power of 800 Wcm^{-1} including ≈ 33 °/o of thermal fissions. The irradiation of D148 in G3 yields a power of 1024 Wcm^{-1} at a reactivity loss of 851 pcm. These values are perfectly satisfactory. Two other solutions have been studied: A Hf screen seems to be of poor efficiency. An internal Na-Cd screen is advantageous with respect to reactivity, influence and neighbouring experiments, and overall space requirements, but presents severe engineering problems.
For further results, see Table 2.9 in section 2.1.3.3.

– **Oxide fuel pins**
(see section 2.3.3.3 of this report)

Thermal In-Pile Measurements.

E154 **"CARSON" Mixed Carbide Fuel Pins with Ultrasonic Central Thermometers (JRC Karlsruhe)**

The manufacture of all components (Capsule, molybdenum cylinder and BWFC support) was carried out. The design and safety report has been compiled.
The assembly of the fuel pin with the molybdenum cylinder in Karlsruhe is scheduled for 15th September 1977.

2.2.3.6 Miscellaneous

E160 **Irradiation of plastic materials. Experiments "PLAISIR" 01, 02 and 03 (JRC Ispra)**

In order to check the application of plastic containers for in-pile irradiation in the reactor ESSOR at Ispra, various thermoplastic materials were irradiated at various thermal fluences in the pool side facility of HFR Petten.
Three series of samples were irradiated and the thermal fluences required were 1 x 10^{18} and 5 x $10^{18} cm^{-2}$. The irradiation times were respectively 5 hours, 10 hours and 25 hours. The three experiments were irradiated from March 21, to March 25, 1977.
Fig. 2.43 shows the samples and the sample holder before and after assembly.

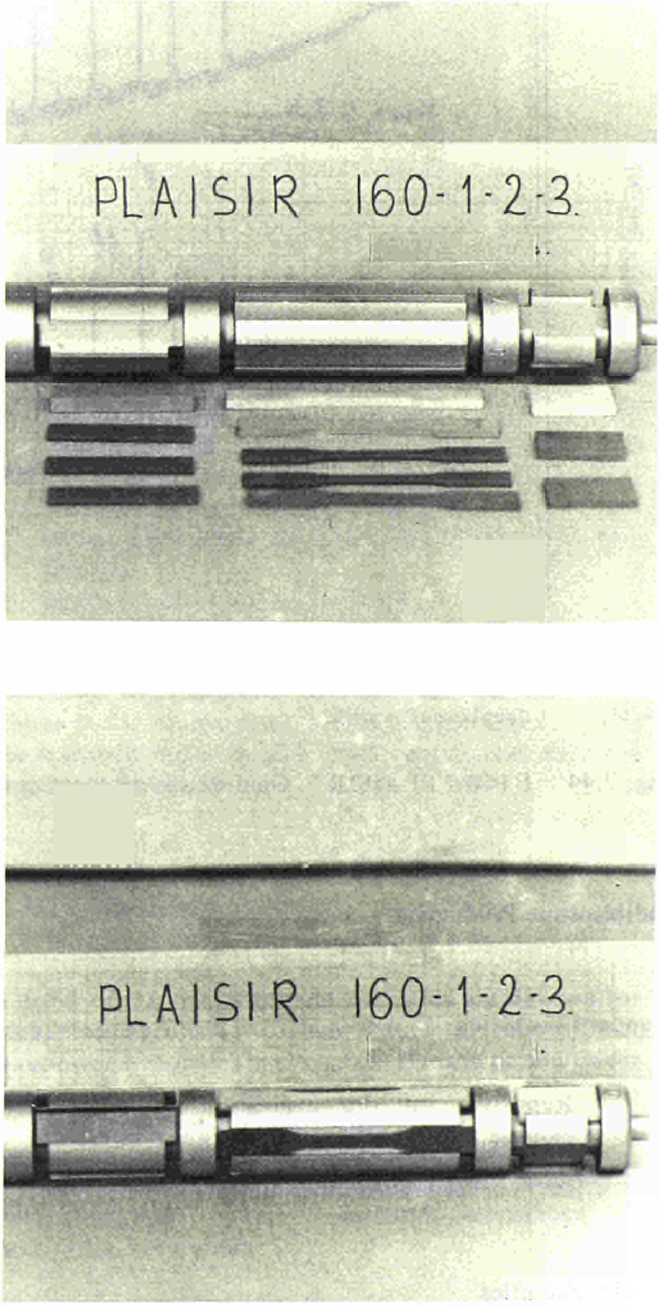

Fig. 2.43 E160. Plastic material irradiation samples and sample holder.

After the end of the irradiations 01 and 02, a gamma spectrometry was carried out on several samples in order to determine the

activity due to impurities and its decrease vs. time. Fig. 2.44 gives an example of gamma spectrum measured 7,8 hours and 3,1 days after the end of the irradiation.
All samples were transported to Ispra for mechanical testing.

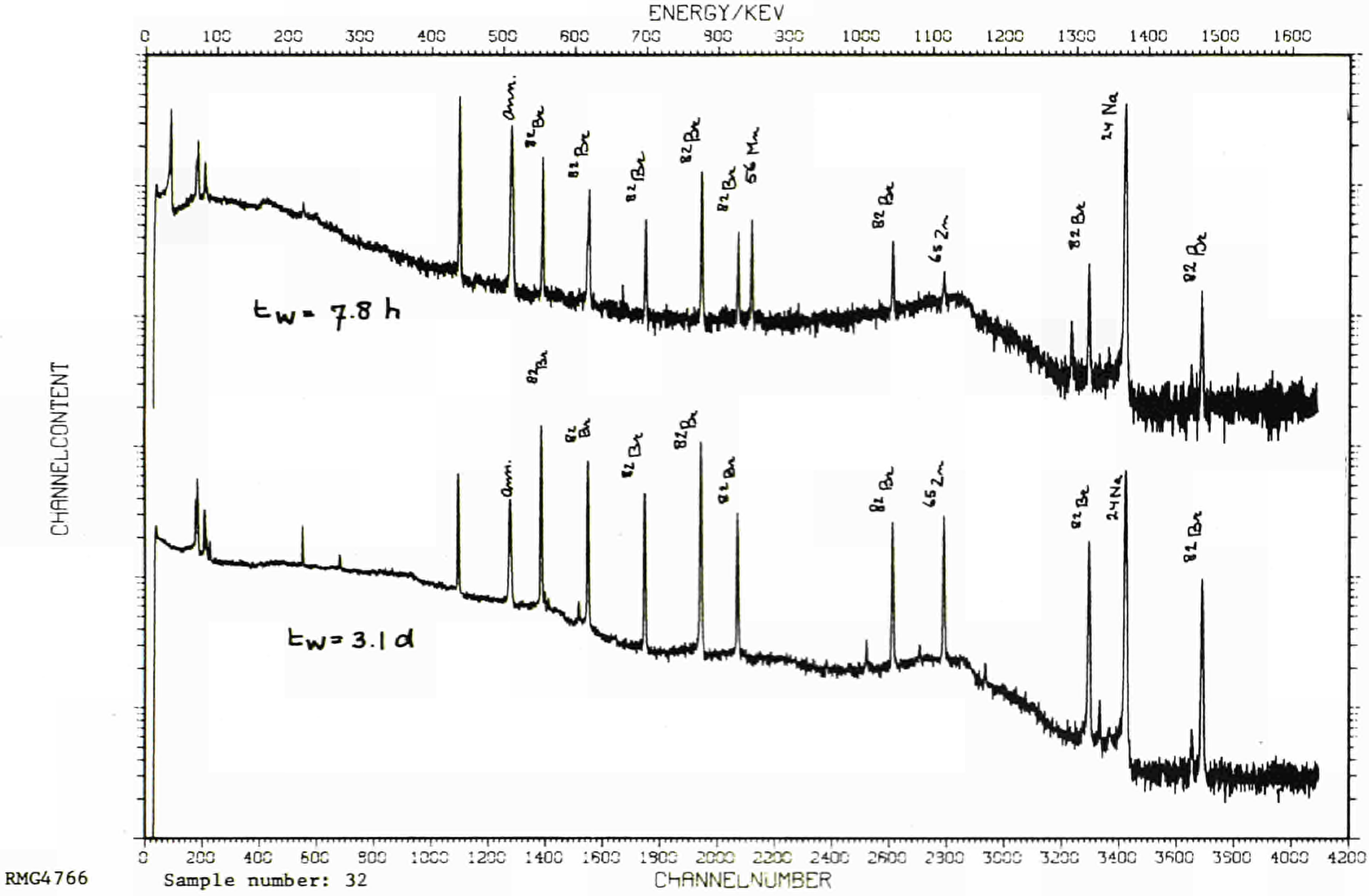

Fig. 2.44 E160 "PLAISIR". Gamma spectrum of sample nr. 32.

Radioisotope Production

Standard Facilities

Reporting on the utilization of standard isotope and rabbit facilities is given in section 2.1.3.1 (Table 2.4).

Special Facilities

ER136 "FIT". ^{99}Mo production from fissile targets.

At present, 40 irradiations have been carried out at a rate of 4 irradiations per month, and transported to the reprocessing plant in Belgium. The irradiation time has been changed from 72 hours to 96 hours per irradiation. The users anticipate, in a later stage (1979), to increase the nuclear power to 20 kW, by an increase of both fission rate and target diameter. Studies are carried out at present, to investigate the possibility to irradiate in the tank. A special capsule, using the EXOR cooling system, is in study.

ER144 "HIFI", High flux isotope capsule.

The "HIFI" device tested on its mechanical resistance in the test loop under normal and maximum flow conditions, proved that the new design of the facility is satisfactory, and none of the tested capsules was damaged. At present some measurements about the speed of the cooling flow and cooling conditions in the filler element, with the HIFI devices are carried out.
The design and safety report ER144 is being compiled.

2.2.4 Conclusions

Although the absolute figure of the average HFR occupation during the first half of 1977 was satisfactory (66 ^{o}/o), it remained below the target figure (74 ^{o}/o). This is due, for the most part, to a permanent work overload in the services directly involved in development, design, manufacture, and operation of irradiation equipment, viz.

project engineering
computers
electronics
operations
drawing office
workshops
assembly and testing
dismantling

Subcontracting has been applied since several years for handling the bulk work of detail drawing, machining, electronic component fabrication, but these possibilities are practically stretched to their limits.
Due to severe limitations of authorized staff level, the reactor remains occupied below its possibilities whereas new projects cannot be taken up according to the demands. Moreover, the ancillary services to irradiation experiments (surveillance, data acquisition and treatment, evaluation, reporting) could not in all cases be supplied in adequate quality and quantity.

Most significant achievements

- Structural materials

The irradiation of a large number of stainless steel specimens for safety investigations on the SNR vessel continues with a remarkable accuracy in timing and fulfillment of experimental specifications.

- LWR fuel

Significant contribution to reactor safety research comes from the series of power ramp experiments on pre-irradiated fuel pins from commercial nuclear power plants. Fifteen transient tests have been carried out during the reporting period, bringing the total number to 30.

- Fast Reactor fuel

The long-standing series of fast reactor safety experiments has been continued by the ECN loss-of-coolant (LOC) transient, supplying valuable information on fuel pin behaviour in a sodium dry-out situation and on fuel-coolant interactions.

- Instrumentation

The joint JRC Karlsruhe/ JRC Petten experiment with an ultrasonic high temperature sensor confirmed the viability of this thermometer under reactor conditions.

Scheduled future activities

Detailed project planning networks exist for all experiments and most of the general activities (e.g. Fig. 2.29). They cannot be reproduced within the scope of this report. However, some significant data can be given:

a. 2nd half of 1977 (with number of experiments)

- start of new irradiations	20
- continuation throughout the considered period	5
- unloading after end of irradiation	21
- short term transient irradiations	18
- nine horizontal beam tubes and three isotope facilities in permanent use, three other isotope facilities in intermittent service.	

b. 1978/80

The specific planning data for 1978 indicate a reactor occupation of more than 70 ^{o}/o, with several double claims. It can be anticipated that this situation will not change essentially for 1979/80.

2.3 General Activities

2.3.1 Objectives

Considerable effort has to be placed into keeping equipment and competence on the required level.
The general activities within the HFR Project include

- operation and maintenance of ancillary services and laboratories (e.g. workshops, hot laboratories, general purpose control panels),
- design studies and development of new irradiation devices,
- irradiation technology and other research,
- project management,

i.e. support work not directly linked to a specific irradiation experiment.
About 8 ^{o}/o of the annual HFR budget and 30 ^{o}/o of the scientific-technical JRC staff capacity are allocated to general activities.

2.3.2 Methods

A total of 12 to 15 general activities are defined for each year, according to their nature (see above), and manpower + money are allocated. For the period under review, these have been

- operation and maintenance

testing and commissioning
experiment operation
dismantling cell
electronics, computers
neutron radiography
post-irradiation examens
assembly, workshops

- design studies and development

standard irradiation devices
in-pile instrumentation
transient condition facilities
HTR sweep loops
feasibility studies
creep facilities
LWR test facilities
computer codes

- irradiation technology and other research
in-pile behaviour of high temperature thermometers*)

- project management
documentation and editing
CPM planning of irradiation experiments
reactor utilisation management

2.3.3 Results

2.3.3.1 General-purpose equipment

Basic control equipment (Project 300).

Two new TRIO type gas panels are under contruction. The gas connection panels on the pool wall of the reactor were renewed. These now provide the possibility to connect 112 gas lines for in- and outlet of gases for in-core experiments.
In order to improve the reliability of the data logger output some new type digital voltmeters were ordered as well as parts to increase the number of channels of one data logger by 50 channels up to 100.
A special panel to operate the new pneumatic centering devices (PCD) is under construction.

General experimental facilities.

High Pressure Loop in HFR.
(ECN Project 8.294)

On the basis of the uncertainties reported upon in the previous progress report, the Reactor Safety Committee decided to make the submission of a positive recommendation with respect to continued operation of the circuit dependant on the results of an analysis of the consequences of a (postulated) total rupture of the in-pile section. In view of the considerable effort which would be required to make such an analysis and in view of the fact that only one irradiation experiment was still to be carried out in the loop it was decided to abandon further attempts to get the Safety Committee's approval and, instead, definitively take the circuit out of operation.
Dismantling and unloading of the in-pile section has taken place during the maintenance shut-down in March. Disassembly of the out-of-pile circuit is still under way.
An extensive post-irradiation analysis of the in-pile pressure tube material has been scheduled.

H.F.R. Neutron radiography installation.
(ECN Project 8.293).

- During the past half year 22 neutron radiographs have been made of E.C.N. experiments and 81 neutron radiographs of J.R.C. experiments (see section 2.3.3.1).
- During the yearly reactor maintenance period the facility has been removed from the pool for modification of the diaphragm operation system and replacement of all "nylo-seal" tubes of the hydraulic system.
It appeared that rotation of the diaphragm was hardly possible mainly due to the resistance of the 8 m long teleflex cable. Therefore a modified rotating system has been designed and constructed. This system is installed on the collimator itself (see Figures 2.45 and 2.46)

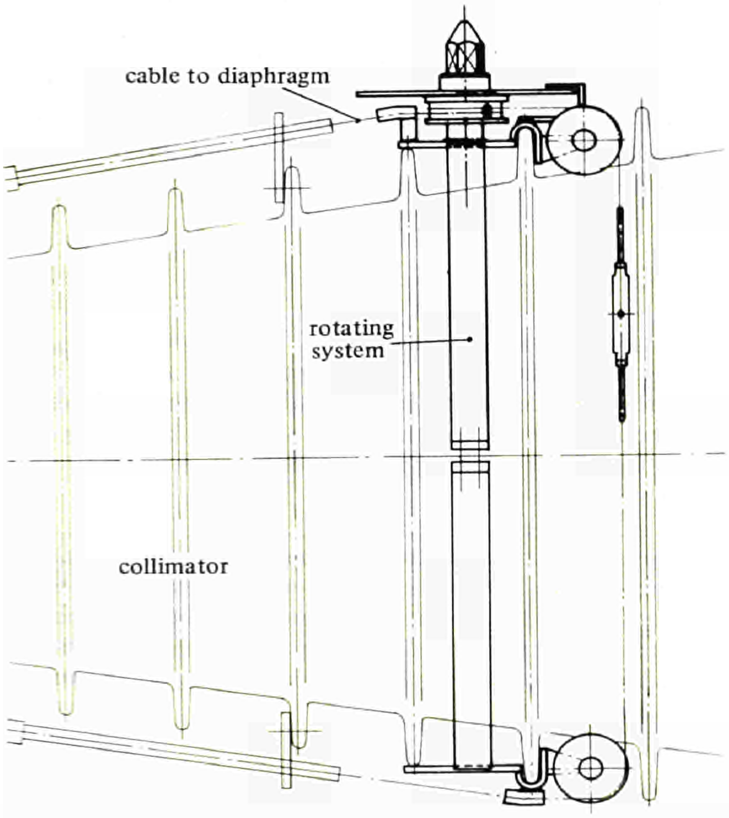

Fig. 2.45 Neutron radiography installation. Top view of of the modified diaphragm operation system.

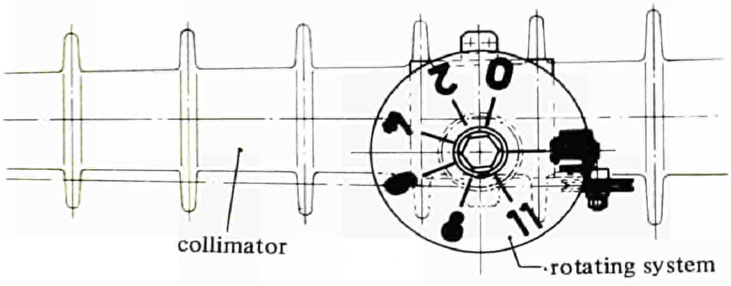

Fig. 2.46 Neutron radiography installation. Side view of the modified and relocated diaphragm operation system.

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*) Outside the HFR Project proper , ECN supply considerable contributions to irradiation technology (see section 2.3.3.5).

Rotation of the diaphragm is now performed by means of a long handling tool and the specified diaphragm position is selected and fixed by means of a snap lock actuated by a spring.

- Flux measurements have been carried out for the diaphragm positions 0 - 2 - 4 - 8 and 18 mm. Results of these measurements are given in Table 2.11

Table 2.11 Thermal neutron flux densities at the object object plane of the HFR neutron radiography facility.

Diaphragm Diameter mm	Neutron flux $\emptyset_o(n.cm^{-2}.s^{-1})$	Cadmium ratio R_{Cd}
0	$8.43.10^6$	3.038
2	$9.17.10^6$	3.273
4	$1.58.10^7$	4.604
8	$3.76.10^7$	10.148
18	$1.48.10^8$	31.435

- The experimental programme on the application of nitro-cellulose film for track-etch neutron radiogrammes will be verified at Harwell and Studvik. [1].
- In order to be able to perform neutron radiography on fuel pins from power reactors, a proposal is being considered for a second neutron radiography facility.
- A pre-design of an experimental track-etch film camera has been started by the Engineering Division.
- Working visits, during which neutron radiography state-of-the-art were discussed and experiences exchanged, were made to the nuclear centres at Risø, Studsvik and Harwell.

Dismantling cell (Project 330).

The three sets of special motors for the cell crane have been delivered and will be kept on stock as spare parts in order to shorten future possible outage times.
An oil change of the cell window has been made in order to improve the transparency.
The cell team provided the following services during the reporting period:

- dismantling of 16 sample carriers
- preparation and surveillance of 9 on site, 12 waste and 7 external transports for irradiation projects.
- 81 neutrographs on different experiments (see section 'General experimental facilities' before).

Design and development of a new horizontal posting facility have been pursued.

Remote Encapsulation System "EUROS" (Project 360).

Two different types of irradiation devices, ELLAS and TRIO have been redesigned for remote encapsulation. The capsules are pre-assembled with thermocouples and service leads and transferred into the Euros cell for loading, Na (NaK) filling and welding (Fig.2.47).

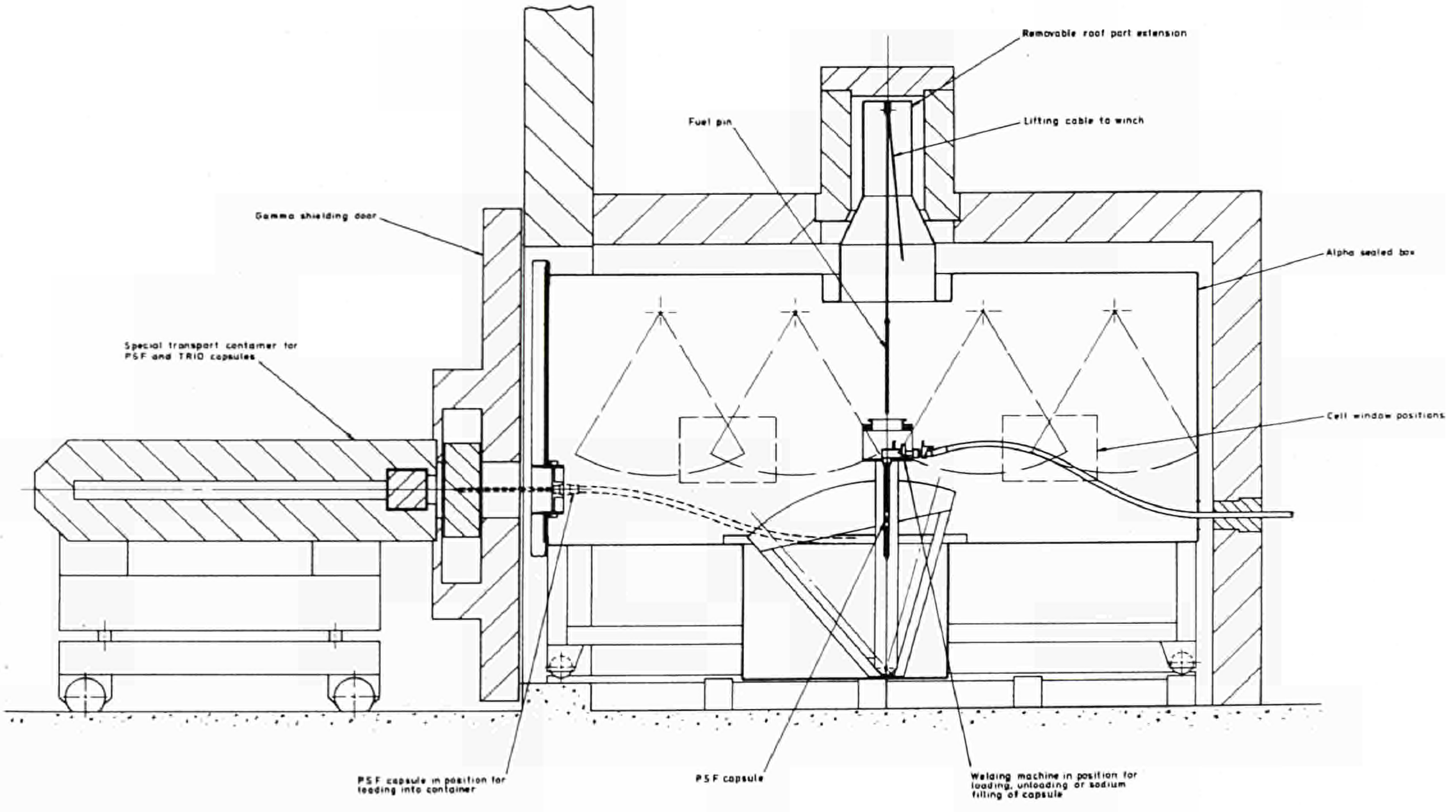


Fig. 2.47 Cross section of EUROS-cell, loading.

The final assembly and loading into the ELLAS and TRIO carrier take place using the HFR pool or the DM cell.

During the reporting period the automatic welding head, generator and programmer for remote control have been ordered. A special transport container (Fig 2.48) for the transport of the loaded irradiation capsules, from the LSO-building to the HFR pool has been designed. It will accommodate both types of irradiation capsules with their respective instrument lines. A removable shovel is part of the container. Sodium fillling tests are carried out, using a calibrated sodium container, with the required quantity of sodium to fill the capsule.

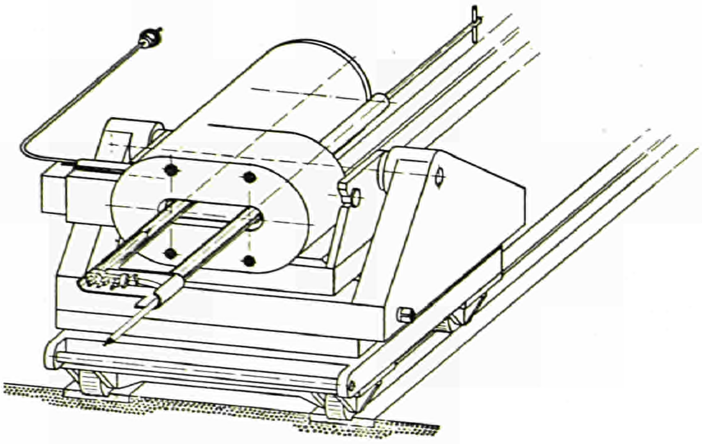


Fig. 2.48 EUROS. Transport container.

At present, the existing box (formerly known as Exor-box) is under decontamination. After that, the Euros box would be transported to the technology hall, for the equipment of the box and cold tests. For these reasons, manipulators will be installed in the box.

Standard Capsules (Project 401).

A survey of standard in-tank capsules is given in Table 2.12.

During the reporting period, six new TRIO 129 devices have been ordered. The TRIO head with central instrumentation outlet has been modified (Fig. 2.49).

References

1. I. RUYTER, H.P. LEEFLANG: "Dimensional Measurements from Neutron Radiographs of Nuclear Fuel Rods."
Technical Memorandum IT/77/756
(June 1977).

Table 2.12 Fabrication and utilization of standard irradiation rigs 1970÷ 1977.

Type serial nr.	manufacturer	operating days	remarks
Refa 134-01	CCR-Petten	114	x
,, 134-02	,,	38	x
,, 134-03	,,	380	x
Refa 14-04	CCR-Petten	38	x
,, 14-02	,,		x
,, 14-03	,,	190	x
,, 14-04	,,	95	x
,, 14-05	,,	247	x
,, 140-10	,,	114	
,, 140-11	,,	95	x
,, 140-12	,,		
,, 140-13	CERCA Romans	173	x
,, 140-14	CCR-Petten		
Refa 154-01	CCR-Petten	133	
,, 154-02	CCR-Petten	228	
,, 154-03	Vickers Swindon		
HTI 01	Vickers Swindon	399	x
HTI 02	,,	190	x
HTI 03	,,		
HTI 04	,,		
Refa 170-01	CCR-Petten	190	x
,, 170-02	,,	266	x
,, 170-03	,,	114	x
,, 170-04	,,		
,, 170-05	,,	95	
,, 170-06	,,		
,, 170-07	CERCA Romans		
,, 170-08	NTG-Gelnhausen		
Twin 129-01	CCR-Petten	171	x
Twin 132-01	CCR-Petten		
Trio 129-01	CCR-Petten	665	x
,, 129-02	CCR-Petten	339	
,, 129-03	Vickers Swindon	263	
,, 129-04	CCR-Petten	296	
,, 129-05	NTG-Gelnhausen	218	
,, 129-06	,,	182	
,, 129-07	,,		
,, 129-08	,,	182	
,, 129-09	Vickers Swindon		
,, 129-10	CERCA Romans		
,, 129-11	,,		
,, 129-12	,,		
,, 129-13	,,		
,, 129-14	,,		still in fabrication
,, 129-15	,,		
,, 129-16	,,		
,, 129-17	,,		

x eliminated for waste disposal

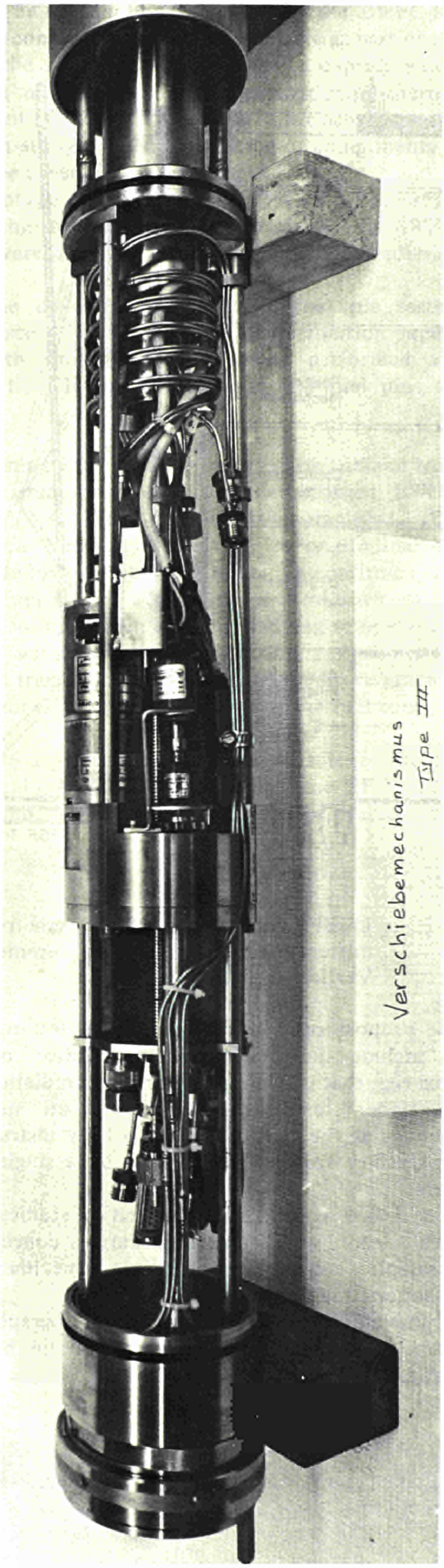


Fig. 2.49 Modified Trio Rig Head with Vertical Displacement Unit (VDU) and Central Instrument Lead Outlet.

2.3.3.2 Programme Management

A.C.P.M.

Due to delays in the formal JRC programme decision, no Advisory Committee for Programme Management meeting took place.

Planning

The HFR planning meeting was held three times and four editions of the loading chart (nos. 18-21) have been edited.
The working group on timing schedule and practical aspects for the post-irradiation phase of experiments met three times.

Documentation

The Fourth and Fifth Newsletter of the Euratom Working Group for Reactor Dosimetry (EWGRD) have been assembled and edited.
The 1977/1978 edition of the report "HFR Petten Characteristics of Facilities and Standard Irradiation Devices" is under preparation.

EWGRD

The 40th meeting of the Euratom Working Group for Reactor Dosimetry was held June 14th, 1977 at Petten. Its subgroups "irradiation damage" and "nuclear data" met on June 13th, 1977, also at Petten.

HFR Meeting 1977

A two days "Information meeting" scheduled for October 25/26, 1977 is under preparation.

2.3.3.3 Development of New Irradiation Devices

LMBFR fuel testing (Project 401).

Transient testing of fresh and pre-irradiated FBR oxide fuel pins is proposed. The pins, irradiated in DFR and Rapsodie are longer than the HFR core and Poolside Facility.

A design study (see Fig.2.50) resulted in a new device which makes use of the PSF chimney. It consists of a carrier with cooling and neutron screen and a straight capsule to be inserted. The holder accommodates two capsules in one PSF position. The horizontal motion is 160 mm, and the corresponding power ratio is 1:10. A proposal is being prepared.

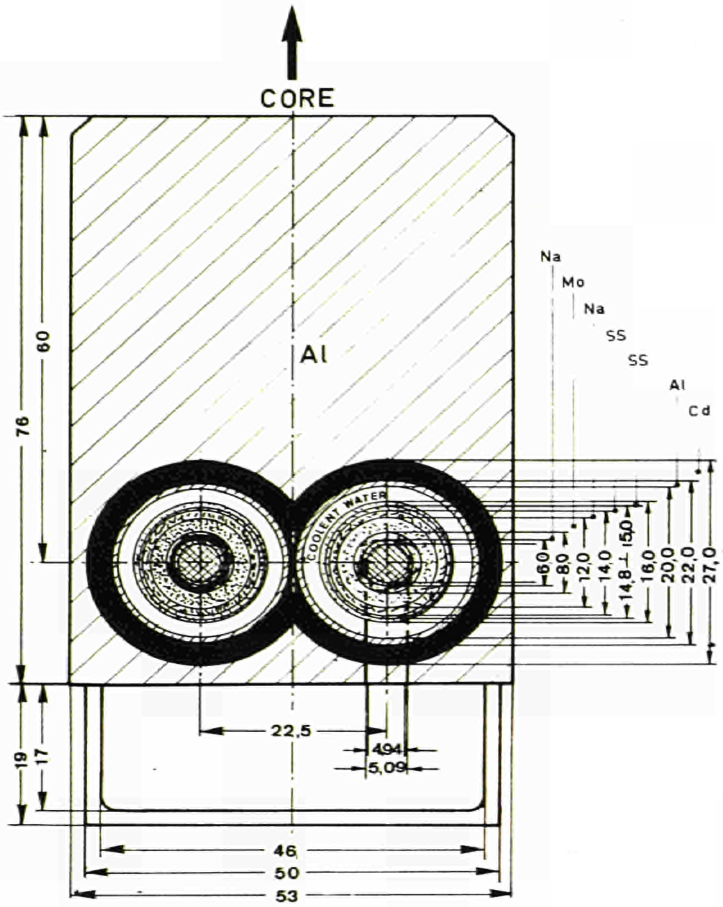


Fig. 2.50 LMBFR fuel testing. PSF capsule for power ramping of long pre-irradiated fuel pins. Horizontal section.

On similar lines a profilometer device has been designed, which allows for a single pin to be irradiated at various power levels and to be retracted for intermittent diameter gauging. Fig. 2.51 shows the general arrangement.

Contacts have been established for the supply of appropriate displacement transducers.

Reporting on the ECN project "TOP" is given in section 2.2.3.5.

Studies on Creep Rigs (Project 403).

A combination of measurements of radiation enhanced diffusion and irradiation enhanced creep has been suggested for the Reactor Safety and Fusion Technology Programmes of JRC Ispra.

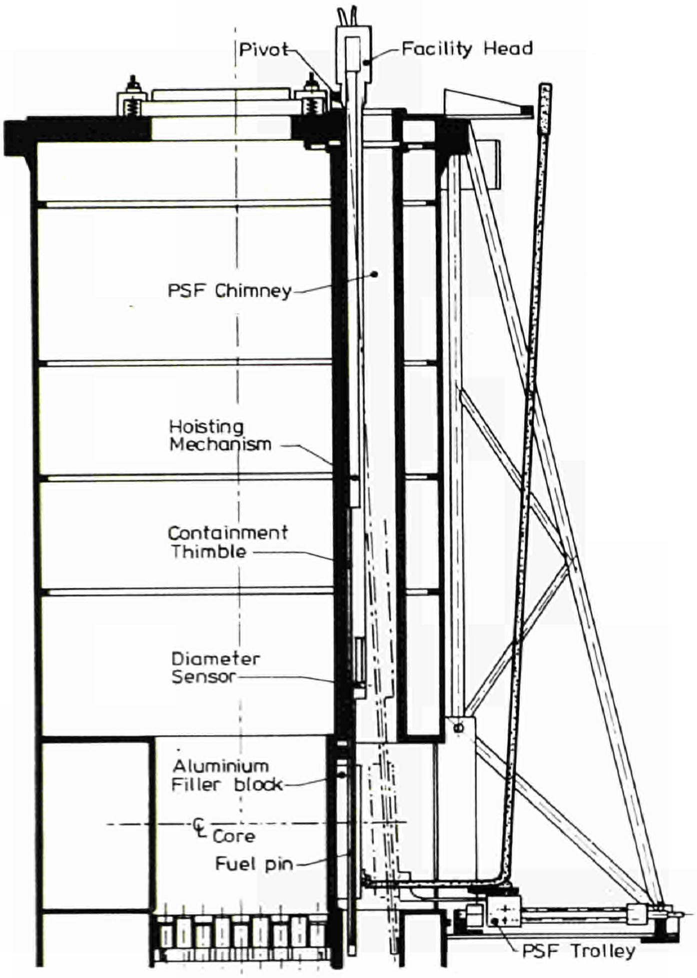


Fig. 2.51 LMBFR fuel testing. PSF capsule for intermittent fuel pin diameter measurement. Vertical section.

These propositions, which were elaborated in a paper [1], include the design and preparation of three special rigs, that is two rigs to perform irradiation creep tests under tension and bending on numerous specimens at the same time and a fully instrumented creep facility for irradiation tests on a single tensile sample.

Proper design work has commenced on studies for the tensile version with numerous samples concentrating on sample column arrangements, specimen head connections and loading mechanisms.

The possible application of neutron radiography as an off-line creep strain measuring technique has been investigated.

Development of LWR Fuel Pin Testing Facilities (Project 405).

In the frame work of standardization of components of BWFC-type capsules also two new types of instrumented BWFC-type capsules for fuel pin length monitoring have been designed. One of these new designs is in its functions identical to the BWFC-RL design but contains also the detector core as part of the capsules; the second design concerns a capsule where the length measurement is compensated for thermal dilatation of the support structure of the sensor.

The design study for standardization of components of BWFC-type capsules was terminated.

Two prototype BWFC-RL-type capsules for investigation of the thermohydraulic behaviour of BWFC-capsules were assemblied and prepared for irradiation testing.

Within the development of LWR fuel pin testing facilities (see 405) short prototype irradiation experiments with prototype capsules are performed and subsequently PIE on components and fuel pins are executed.

The remaining PIE work on the defective fuel pin from the first irradiation test with the enlarged BWFC-installation (in Febr. 76) was completed. The metallurgical investigationns on a longitudinal cut through the lower region of the fuel pin confirmed that the final fuel failure was due to a breakdown of the primary cooling, which lead to cladding temperatures ≈ 825°C within the fuel region. Fig. 2.53 shows the very short transition zone of the temperature gradient in longitudinal direction at the end of the fuel zone.

In Dec. '76 a prototype BWFC-RL capsule for fuel pin length monitoring has been tested at the HFR with a new fuel pin. Within the reporting period evaluation of the irradiation data and PIE work on the fuel pin took place. Fig. 2.52 presents a typical result from the tests. Fuel pin length changes due to relaxation during steady

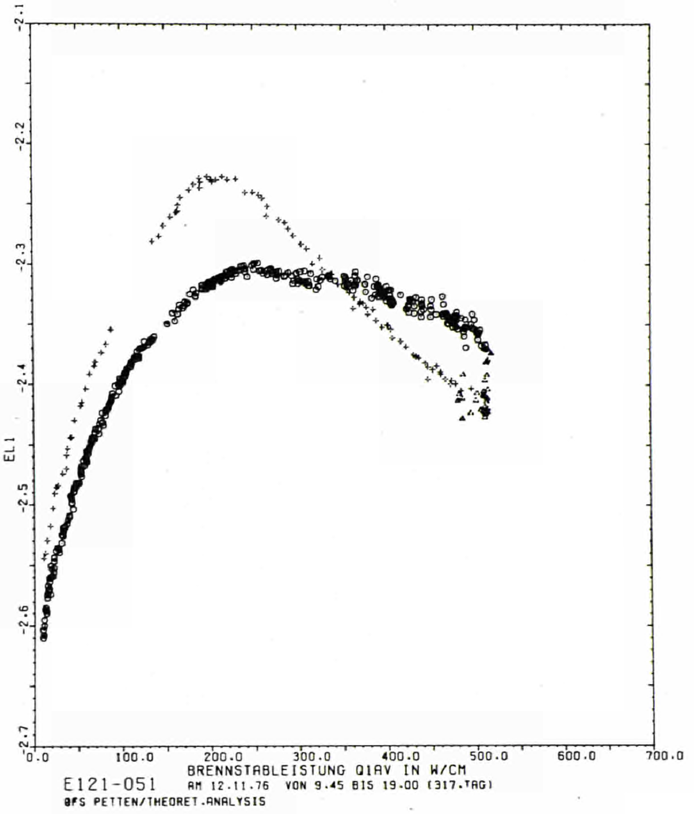


Fig. 2.52 Elongation measurement on prototype rig BWFC-RL.

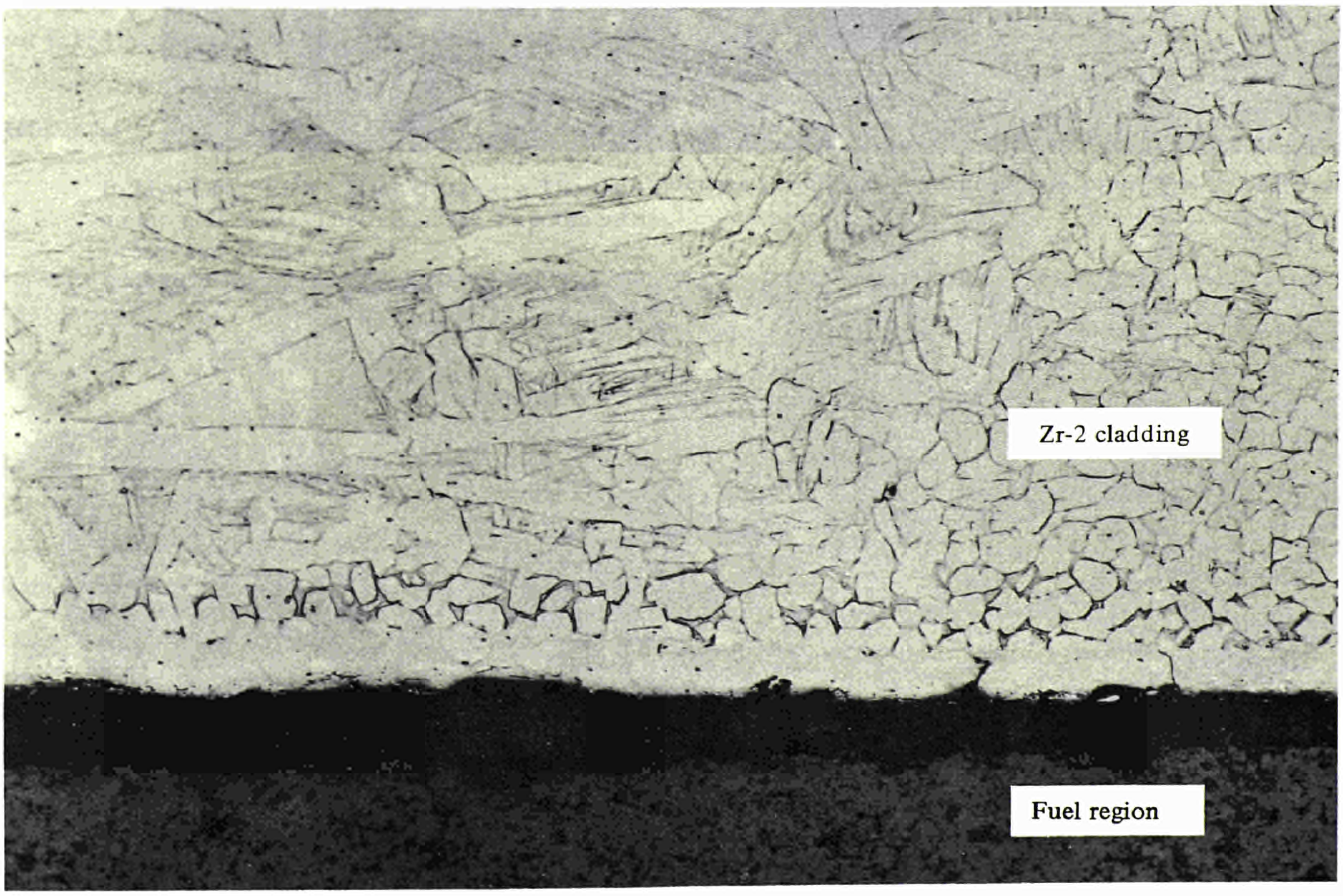


Fig. 2.53 Failed fuel pin from prototype BWFC test. Post-irradiation metallographic section showing transition zone in clad structure. Magn. x 250.

Development of a Control System for Swept HTR Experiments (Project 406).

The assembly, cabling and commissioning of the safety panels, filter units, connection boxes C and D and sampling stations has been terminated (Fig. 2.54 and 2.55).

The mechanical assembly of the gas analysis component will be finished early in July. The assembly of the control panel has started. A draft instrumentation specification has been issued. The final orders for instrumentation material are under preparation. The Design and Safety Report will be issued in September, 1977. Final commissioning of the completed installation is scheduled for the beginning of 1978.

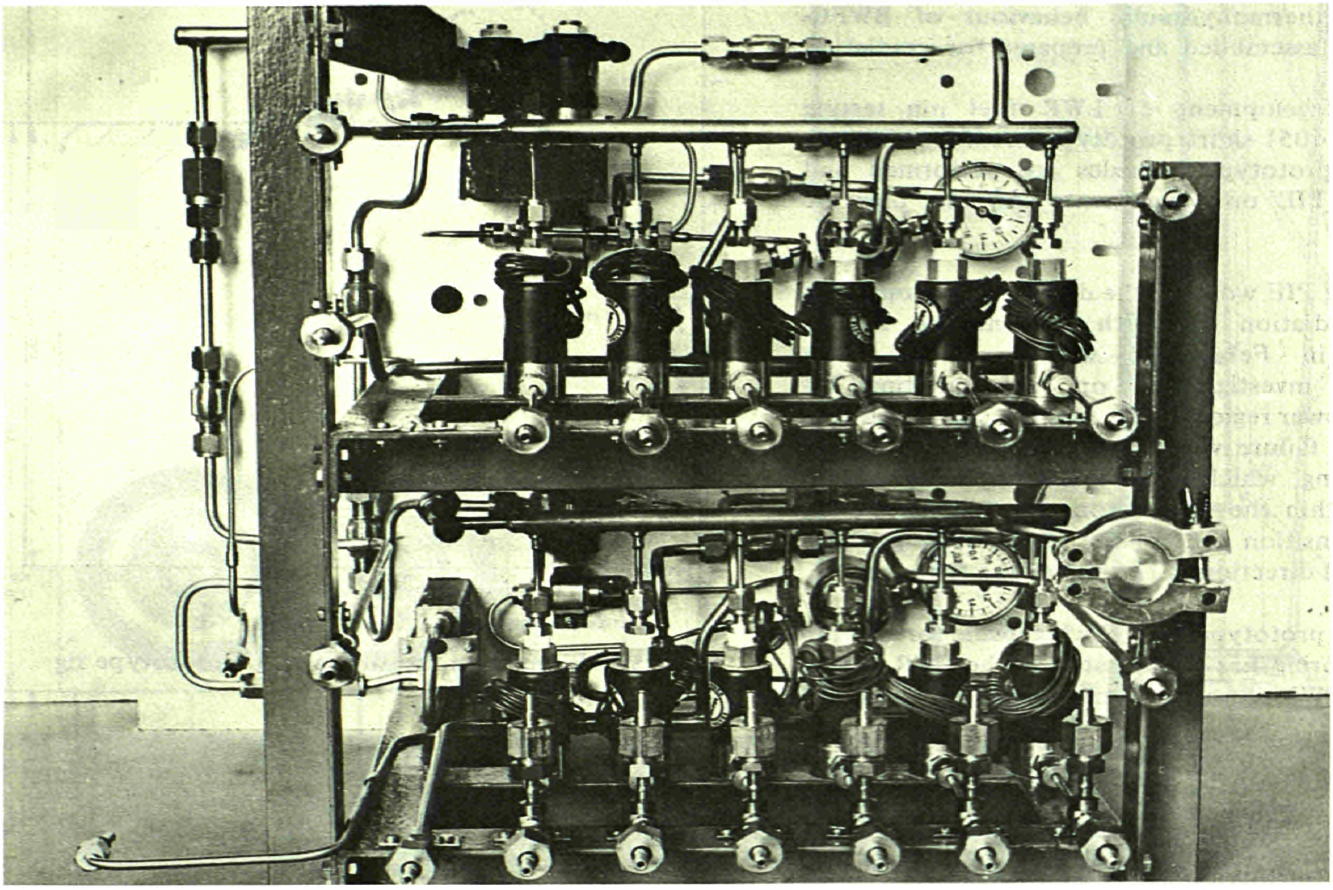


Fig. 2.54 Sweep loops. Katharometer panel during assembly.

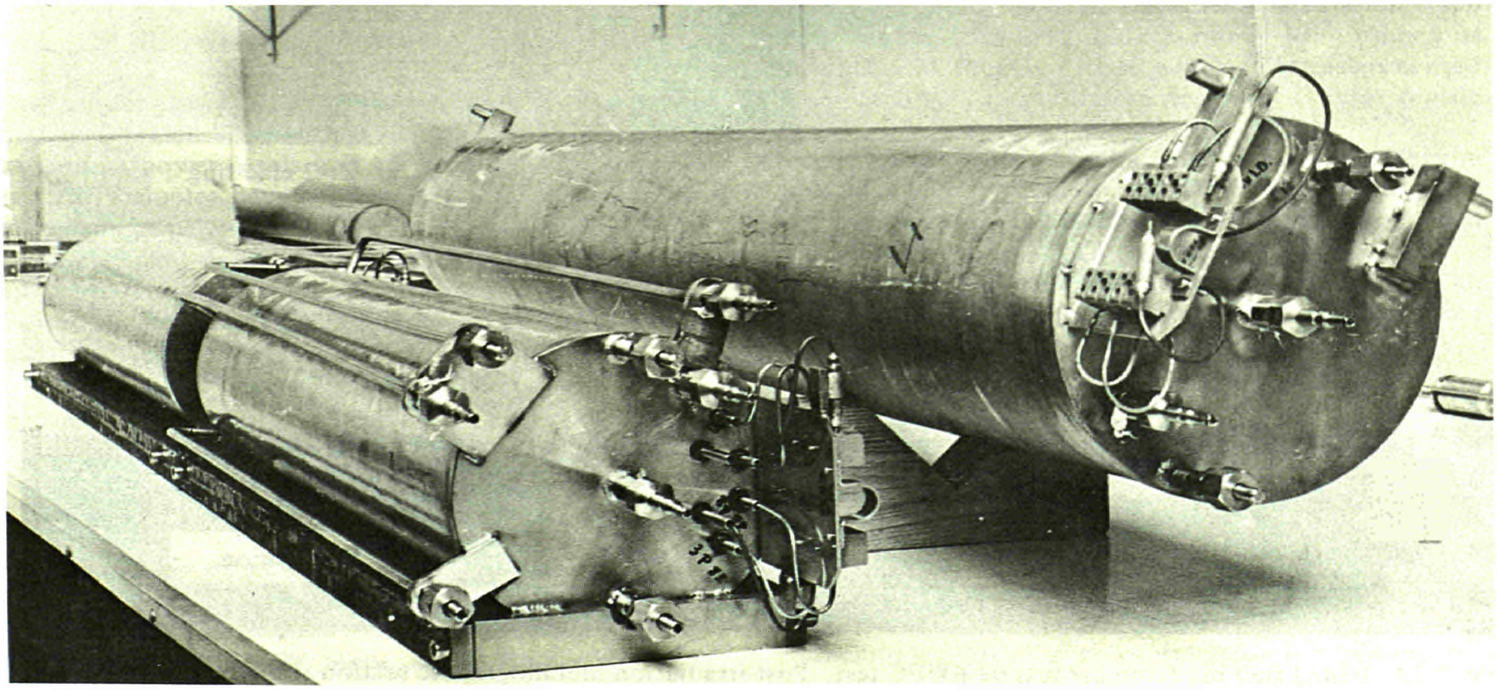


Fig. 2.55 Sweep loops. Filter units after assembly.

References

1. R.H. LOLGEN, M.R. CUNDY, W. SCHULE, "Irradiation Enhanced Diffusion and Irradiation Creep Tests in Stainless Steel Alloys." Paper to be presented at the 4th SMiRT-Conference, San Francisco, 15-19 August, 1977.

2.3.3.4 High Temperature In-Pile Thermometry (Project 402).

E094-2 This rig which had been irradiated in 1976 has now been transferred for final post-irradiation disassembly.

E094-3 This is a joint experiment, carried out with JRC-Karlsruhe [1], in which the neutron-induced decalibration of noble metal and ultrasonic thermometers will be tested, at temperatures up to 2000°C. During the reporting period, the irradiation device has been assembled (Fig. 2.56), and loaded into position C3. The irradiation started on June 10 and has so far operated satisfactorily.

For E 154, see section 2.2.3.5.

References

1. F. MASON, "EURATOM Ultrasonic Thermometer and W-Re Thermocouple Experiment. Design and Safety Report" Technical Note P/10/77/18 (April 1977).

2.3.3.5 Irradiation Technology (ECN).

Data acquisition and evaluation.

In order to obtain more universal and adaptable data requisition systems for irradiation experiments, a users' library has been set up on the CDC 6600. On this library all main programmes and subroutines which are in use for data acquisition of irradiation experiments in the HFR are placed under their corresponding identifaction. The main programmes of this library are listed in Table 2.13.

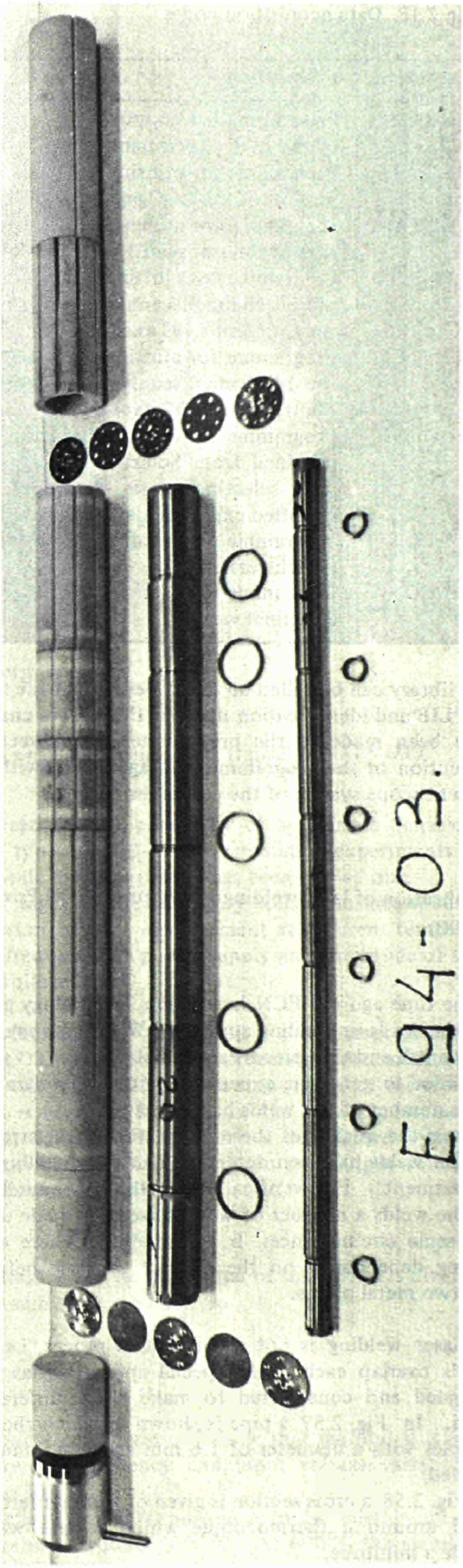


Fig. 2.56 High temperature in-pile thermometer test rig. Components prior to assembly.

Table 2.13 Data acquisition codes.

Call Name	Description
LOCAMP	Programme for copying ampex tapes of the LOC experiments.
BITPAT	Programme for printing the binary bit pattern of the LOC ampex tape.
LOCTAF	Programme for numerical data acquisition of the transient LOC experiment.
LPL 32 S	Programme for plotting the results of the 32 channel scanner datalogger of the transient LOC experiment.
LPL 14 S	Programme for plotting the results of the 14 channel scanner datalogger of the transient LOC experiment.
PUDAS	Programme for reading papertape as obtained from Solartron dataloggers and selecting data according to specified experiments.
DACON B	Programme for data conversion (batch version).
DACON T	Programme for data conversion (terminal version).

The library can be called up under permanent file name EXPLIB and identification number ID=42. No changes have been made to the programme input directives. Execution of the programme is in agreement with the present scope system of the computer.

Application of laser welding techniques. (ECN Project 8.290).

Some time ago the ECN Irradiation Technology group obtained a laser welding apparatus. With this apparatus only small and thin pieces can be welded.
In order to get some experience with the apparatus a large number of test welds have been made.
To test the quality of these welds, the tensile strength of the welds has been determined in the metallurgical department. For verification of the reproducibility of the welds a number of welds have been made under the same circumstances. It appeared that there was a strong dependancy on the contact pressure between the two metal pieces.

As laser welding is not a continuous proces, i.e. the welds overlap each other, special apparatus has been designed and constructed to make a circumferential weld. In Fig. 2.57 a pipe is shown in which thermocouples with a diameter of 1.6 mm and Ø 0.5 mm are welded.
In Fig. 2.58 a cross section is given of a circumferential weld around a thermocouple which is laser welded inside a minitube.

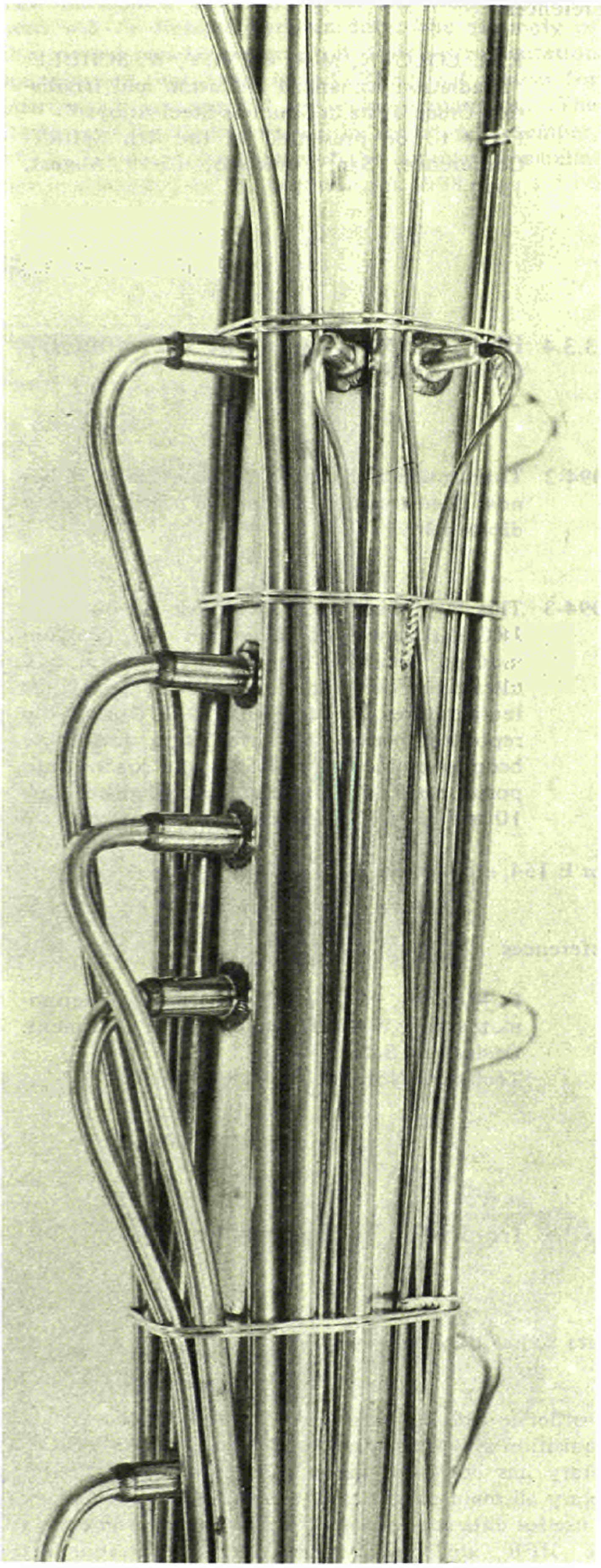


Fig. 2.57 Laser welded thermocouple penetrations in st.st tube wall.

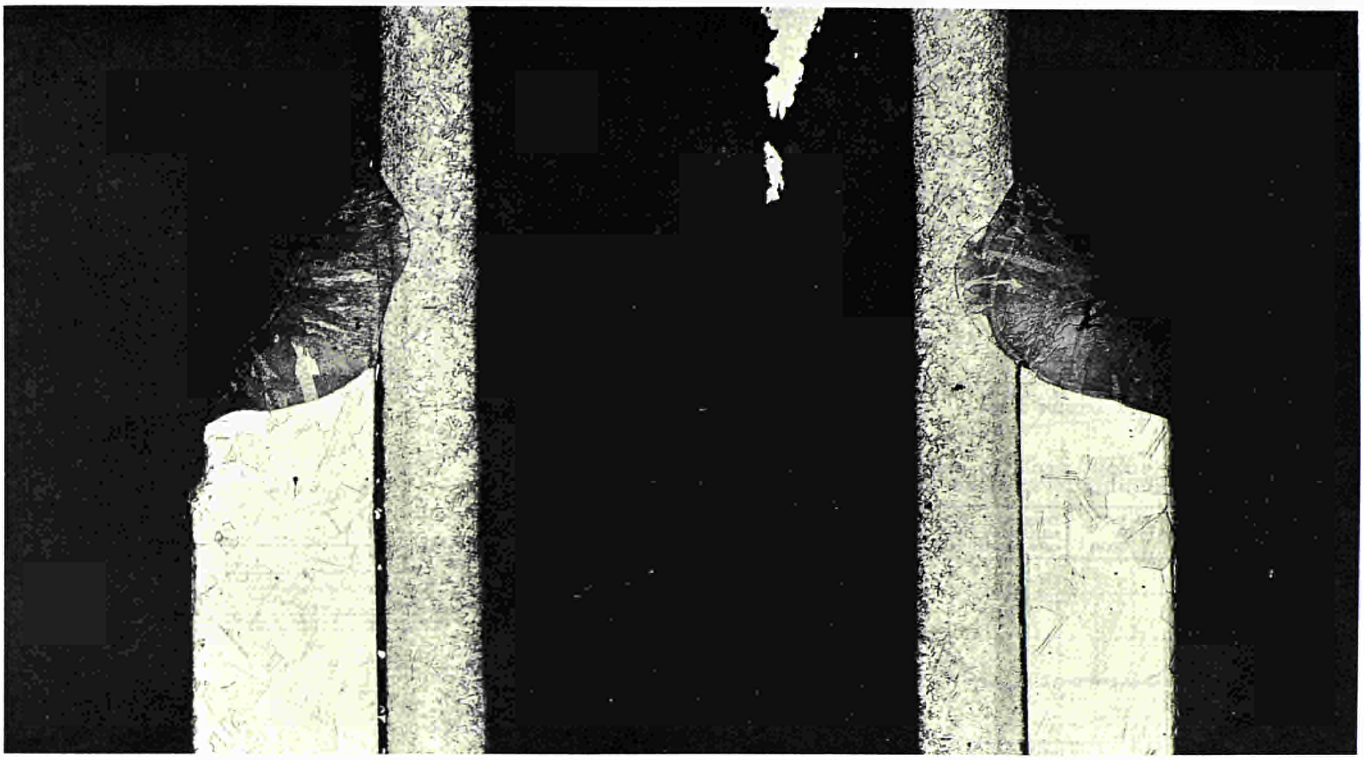


Fig. 2.58 Laser welding. St.st sleeve welded to a st.st-sheathed thermocouple.

In-core" instrumentation developments (ECN Project 8.291).

Thermocouples

On February 16 and 17, 1977, an external thermocouple course has been given. Approximately 50 people from various institutes and industries attended the course.
A great number of thermocouples has been calibrated and tested.
As an example for the now fully computerized data logging and display system a typical thermocouple response time measurement is presented in Figure 2.59.

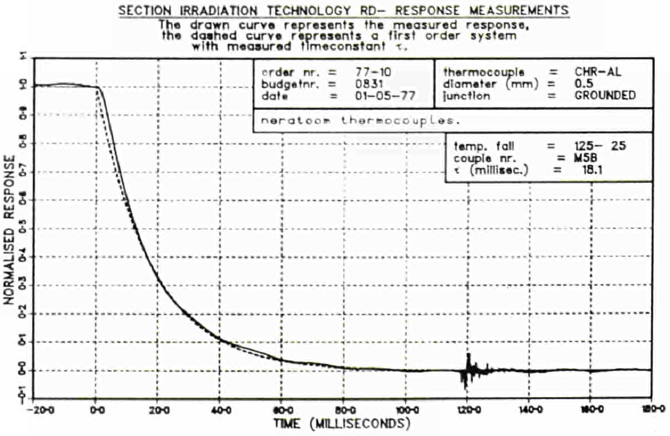


Fig. 2.59 Thermocouple response time measurement.

Linear variable displacement transducers (LVDT).

To investigate the possibility of applying a Schaevitz LVDT type 101 XS-2TR in irradiation experiments an out-of-pile test programme has been carried out.
The voltages of the secondary coils were measured as a function of core displacement at different temperatures, frequency of power supply and amplitude of the input voltage.

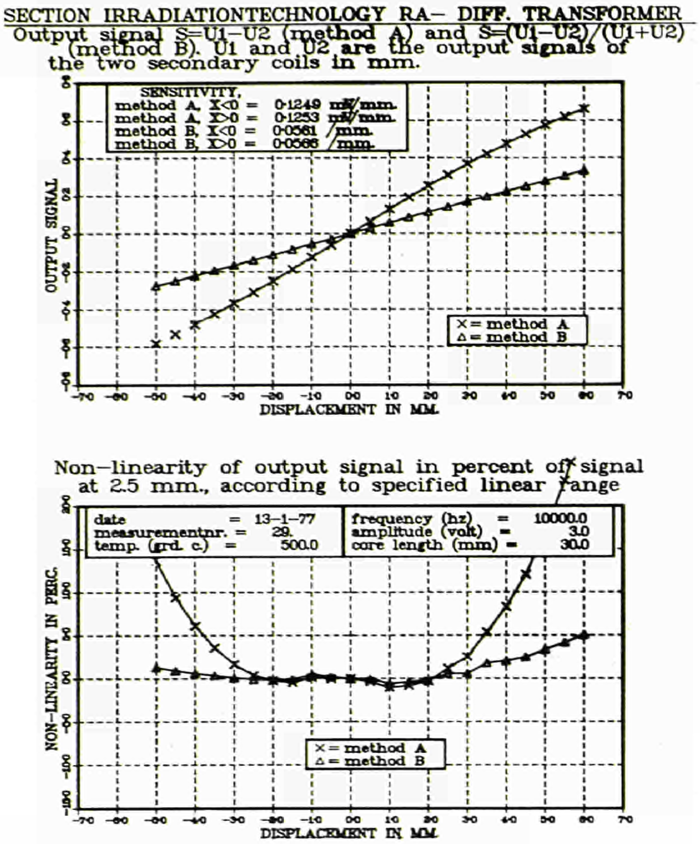
The interactive CDC-6600 computerprogramme DT PLOT was used for processing the measuring results. In Figure 2.60 the output signal of the tested LVDT is given as function of the core displacement in mm. The output signal(s) is determined by two methods. Method A subtracts the two output voltages of the secondary coils

$$(S_A = U_1 - U_2).$$

In method B the output signal of method A is divided by the sum of U_1 and U_2, so

$$S_B = \frac{U_1 - U_2}{U_1 + U_2}$$

Theoretical considerations show that method B is less sensitive for frequency and input voltage variations. See also Fig. 2.60.
The Schaevitz LVDT appeared to be reliable up to temperatures around 500 °C. At 600°C the stability of the signal decreased.
A temperature rise from 20°C up till 500°C changed the sensitivity for displacement by at least 4 °/o and at most 20 °/o, depending on the applied measuring method and frequency.


SECTION IRRADIATIONTECHNOLOGY RA– DIFF. TRANSFORMER
Output signal S=U1–U2 (method A) and S=(U1–U2)/(U1+U2) (method B). U1 and U2 are the output signals of the two secondary coils in mm.

Non–linearity of output signal in percent of signal at 2.5 mm., according to specified linear range

Fig. 2.60 Output signals and non-linearity of a Schaevitz-101-XS LVDT as a function of temperature.

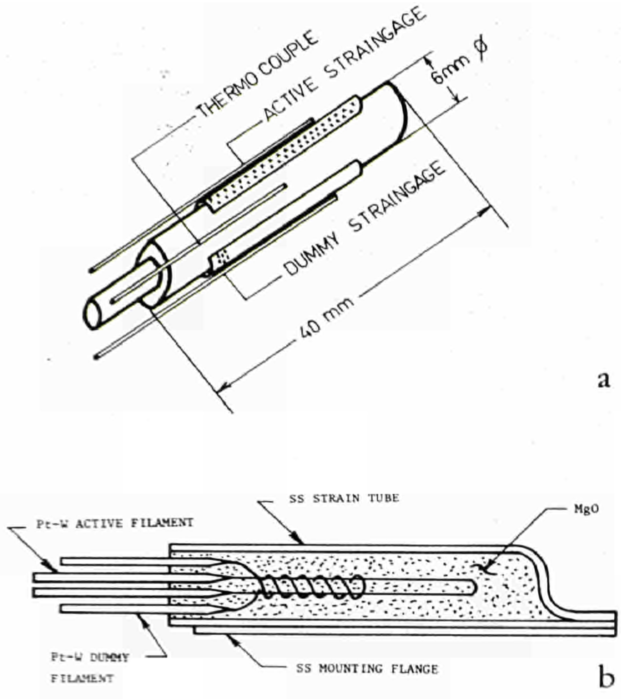


Fig. 2.61 Pressure tranducer (a) with two strain gages. Fig. b shows a schematic cross section of one of the applied Ailtech type SG-425 strain gages.

Pressure transducers

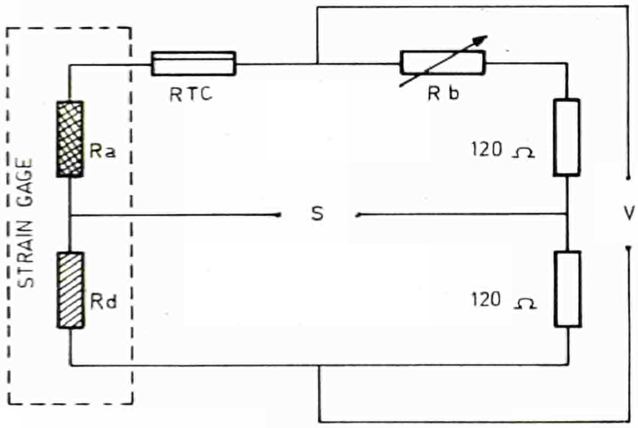
Response time measurements.

The device for measuring the response time of different types of pressure transducers has been modified.
In principle also the transfer function of a P.T. can now be determined in the same device.

Strain gage pressure transducer

The so-called "LOC" pressure transducer is rather sensitive to temperature variations. Attempts have been made to reduce this temperature sensitivity. A pressure transducer has now been developed which consists of two strain gages, one on the outside of a hollow cylinder (resistance Ra) and the other is only attached to it by means of one spotweld and has a resistance Rd.
A thermocouple measures the temperature of the cylinder (Fig. 2.61).

Measurements with a pressure transducer with one strain gage have been performed with a Wheatstone bridge as presented in Fig. 2.62. In Fig. 2.63 the



SG. = 425 strain gage
Ra = resistance of active gage filament
Rd = resistance of dummy gage filament
RTC = temperature compensation resistance
V = bridge AC voltage supply
S = output signal

Fig. 2.62 Principle of Wheatstone bridge used in the measuring circuit of the pressure transducer ducer with one Ailtech Type.

output signal is given of this transducer. In Fig. 2.64 the measuring principle is given for the new pressure transducer. Components RTC1 and 2 are the temperature compensating resistances of the two strain gages.

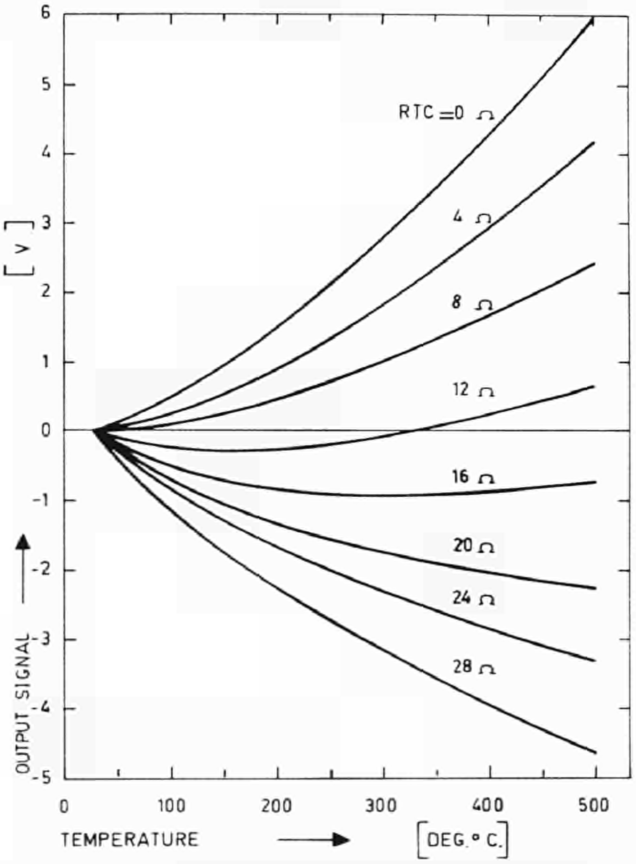
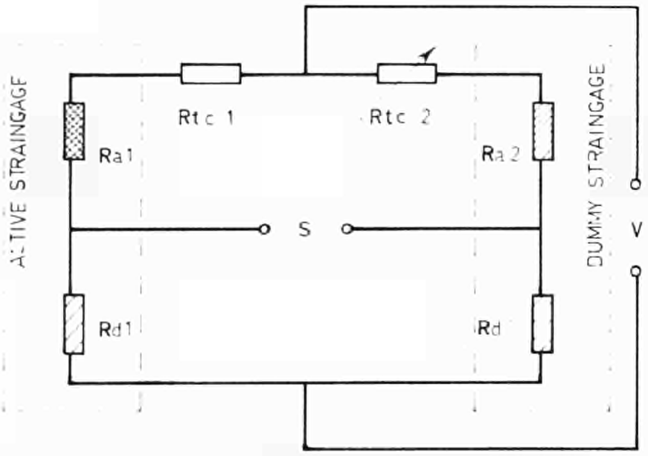


Fig. 2.63 Output signal of the pressure transducer with one Ailtech Type SC-425 strain gage as a function of temperature with different values of the temperature compensation resistance RTC.



Ra1 and Ra2 : electrical resistance of the active gage filaments of the respective gage.
Rd1 and Rd2 : electrical resistances of the dummy gage filaments of the respective gages.
RTC1 and RTC2 : temperature compensation resistances of the temperature gages.
V : bridge AC voltage supply
S : output signal

Fig. 2.64 Principle of Wheatstone bridge used in the measuring circuit of the pressure transducer with two Ailtech Type-425 strain gages.

In Fig. 2.65 the output signal is given. The sensitivity system of the used measuring system is 10 times the one in the old configuration. Only moderate temperature variations are taken into account i.e. 15°C/min.

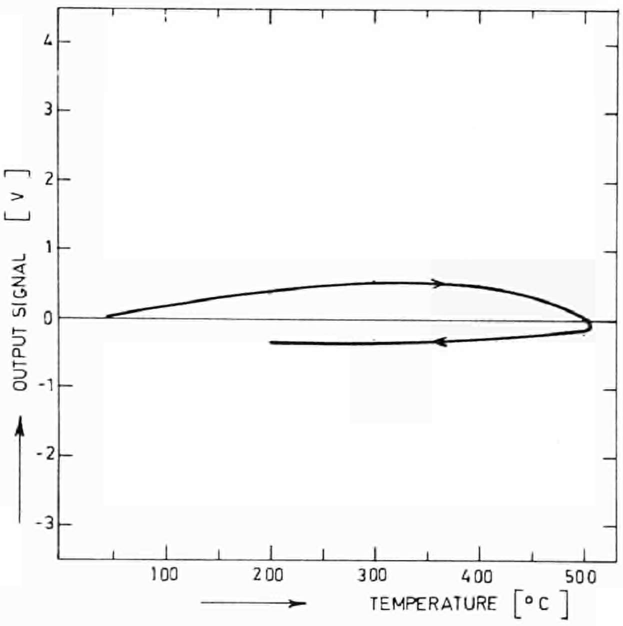


Fig. 2.65 Output signal of the pressure transducer with two Ailtech Type SG-425 strain gages. The sensitivity of the measuring system is 10 times higher than that used in Fig. 2.62. In this case RTC1 = 12.5Ω and RTC2 = 15.0Ω-

2.3.4 Conclusions

The general activities in support of the HFR project have been hampered both by the lack of personnel mentioned before and by the absence of a Council decision on the 1977/80 programme proposals (which resulted in a lack of adequate budget appropriations). Among the activities delayed or deleted were

- design studies on new LMBFR transient test facilities,
- development of in-pile measuring techniques for fuel pin diameter changes,
- in-pile instrumentation developments,
- design studies on novel safety experiment devices,
- assembly and testing of a new sweep gas installation,
- introduction of a new computer-controlled data acquisition system.

It is expected that most of these activities can be taken up during the second half of the year. However, detailed time schedules cannot be elaborated.

The valuable contribution of the ECN Irradiation Technology (see section 2.3.3.5) is gratefully acknowledged.

Conclusions

3. CONCLUSIONS

3.1 HFR Operation and Maintenance

The operation of HFR Petten has been resumed on January 1st, 1977, in accordance with the 1977/80 JRC Programme Proposals.
The reactor operated within a few percent of the cycle calendar established by the end of 1976.
Perturbances originating from a rather large number (13) of unscheduled scrams only resulted in negligible additional outage times (1.4 ^{o}/o). However, these interruptions are undesirable both for reactor and for irradiation experiment operation, and measures are being designed to improve instrument reliability (most of the scrams being caused by instrument failures).
Work carried out during the annual reactor maintenance period confirmed the satisfactory state of health of the plant. On a routine basis, a large number of items have been replaced, including worn-out in-core components. The inspection of the control rod drive mechanisms had to be postponed due to high gamma radiation fields in the sub-pile room, caused by lost ^{192}Ir pellets.
Calculations and in-pile measurements by activation detectors and calorimeters have further improved the accurate knowledge of the reactor's nuclear characteristics.
As far as fuel and fuel elements are concerned the US embargo on the supply of highly enriched uranium could be overcome due to a long-term stockpile policy applied by JRC Petten. However, the resumed supplies during the reporting period came in the nick of time to prevent reactor outages in 1978.

3.2 Reactor Utilisation

a) Survey

Although the absolute figure of the average HFR occupation during the first half of 1977 was satisfactory (66 ^{o}/o), it remained below the target figure (74 ^{o}/o). This is due, for the most part, to a permanent work overload in the services directly involved in development, design, manufacture, and operation of irradiation equipment, viz.

project engineering	drawing office
computers	workshops
electronics	assembly and testing
operations	dismantling

Subcontracting has been applied since several years for handling the bulk work of detail drawing, machining, electronic component fabrication, but these possibilities are practically stretched to their limits.

As a result of the chronic lack of personnel the reactor remains occupied below its possibilities whereas new projects cannot be taken up according to the demands. Moreover, the ancillary services to irradiation experiments (surveillance, data acquisition and treatment, evaluation, reporting) could not in all cases be supplied in adequate quality and quantity.

b) Most significant achievements

- Structural materials

The irradiation of a large number of stainless steel specimens for safety investigations on the SNR vessel continues with a remarkable accuracy in timing and fulfillment of experimental specifications.

- LWR fuel

Significant contribution to reactor safety research comes from the series of power ramp experiments on pre-irradiated fuel pins from commercial nuclear power plants. Fifteen transient tests have been carried out during the reporting period, bringing the total number to 30.

- Fast Reactor Fuel

The long-standing series of fast reactor safety experiments has been continued by the ECN loss-of-coolant (LOC) transient, supplying valuable information on fuel pin behaviour in a sodium dry-out situation and on fuel-coolant interactions.

- Instrumentation

The joint JRC Karlsruhe/JRC Petten experiment with an ultrasonic high temperature sensor confirmed the viability of this thermometer under reactor conditions.

3.3 General Activities

The general activities in support of the HFR Project have been hampered both by the limitation of authorized staff level mentioned before and by the absence of a Council decision on the 1977/80 programme proposals (which resulted in a lack of adequate budget appropriations).
Among the activities delayed or deleted were

- design studies on new LMBFR transient test facilities,
- development of in-pile measuring techniques for fuel pin diameter changes,
- in-pile instrumentation developments,
- design studies on novel safety experiment devices,
- assembly and testing of a new sweep gas installation.
- introduction of a new computer-controlled data acquisition system.

It is expected that most of these activities can be taken up during the second half of the year.

4. JRC PUBLICATIONS

1 Annual Report 1976.
Part 1 of EUR 5764e (April 1977).

2 CUNDY, M.R., VON DER HARDT, P., LOLGEN, R.: Proceedings of the International Colloquium on the Measurement of Irradiation Enhanced Creep in Nuclear Materials, Petten, May 1976.
EUR 5676 (March 1977).

3 CONRAD, R.: Prototype experiment of an irradiation facility for large HTR fuel specimens in the HFR Petten.
EUR 5456e (January 1977).

4 Newsletter of the Euratom Working Group for Reactor Dosimetry (EWGRD),
No. 4 (March 1977), No. 5 (June 1977).

5 GENTHON, J.P., ZIJP, W.L.: The damage to activation ratio for graphite irradiations in the HFR.
EUR 5795e (March 1977).

GLOSSARY

ACPM (CCMGP)	Advisory Committee on Programme Management
AERE	Atomic Energy Research Establishment
ASTM	American Society for Testing and Materials
AUSTIN	Austenitic Steel Irradiation
BATAVIA	Bilateral Advanced Trio And Vented-capsule Irradiation Assessment
BEST	Brennelementsegment-Test
BONI	Borosilicate glasses Neutron Irradiation
BR2	Belgian Materials Testing Reactor at Mol
BWFC	Boiling Water Fuel-element Capsule
CADO	Calorimetric Dosimetry
COSAC	Computerized On-line Supervision of the data Acquisition
ECN	Energieonderzoek Centrum Nederland
EEC	European Economic Community
EWGRD	Euratom Working Group for Reactor Dosimetry
FIT	Fissile Isotope Target
FOMRE	Foundation for fundamental Material Research by means of X- and electron rays
GFK	Gesellschaft für Kernforschung (Karlsruhe)
GIF	Gamma Irradiation Facility
HB	Horizontal Beamhole
HFPIF	High Flux Poolside Isotope Facility
HFR	High Flux Reactor
HIFI	High Flux Facility for Isotopes
HR	Hydraulic Rabbit facility
HT	High Temperature
HTR	High Temperature Reactor
JRC	Joint Research Centre
KFA	Kenrforschungsanlage (Jülich)
LOC	Loss-Of-Cooling
LSO	Petten Hot Cell complex
LWR	Light Water Reactor
MACRO	Computer programme for data acquisition
MTR	Materials Testing Reactor
NAST	Natrium-Stahl-Bestrahlungen
PCD	Pneumatic Centering Device
PCI	Pellet-Cladding Interaction
PDP	Trademark for "Digital Equipment Corporation" Computers
PIE	Post-Irradiation Examinations
PIF	Poolside Isotope Facility
PROF	Poolside Rotating Facility
PRS	Pneumatic Rabbit System
PSF	Poolside Facility
R & D	Research and Development
RIF	Reloadable Isotope Facility
SAND-II	Spectrum Analysis by Neutron Detectors
SHOT	Stationary High Overtemperature experiment
SINAS	Simplified NAS(T) irradiation
TEDDI	Computer programme to evaluate reactor neutron spectrum.
TRESON	Mesure de Transport d'Energie en pile par méthodes Soniques
TRIO	Irradiation device with three channels
UA	Unit of Account
WFIRO	Computer programme for two-dimensional heat transfer (r,φ)
WRZRO	Computer programme for two-dimensional heat transfer (r,z)
WUNRO	Computer programme for one-dimensional heat transfer (r)

AUTHORS

Project manager : P. von der HARDT

Contributors * :

R. CONRAD
M. CUNDY
F. GENET
K. HUSMANN
R. JOCKSCHAT
J. KONRAD
R. LOLGEN
J. MARKGRAF
F. MASON
H. RÖTTGER
H. SCHEURER
P. ZEISSER

*) The ECN contributions to this report have been compiled by R. SWANENBURG DE VEIJE they have been supplied by

J. AAN DE WIEL
F. DEKKER
C.M. DE GROOT
R. KEMPERS
W. KLERKS
A. LAST
H. LEEFLANG
F. MERELLE
H. NOLTHENIUS
A. NOLTEN
G. OLTHOFF
H. PRUIMBOOM
H. RIEFFE
A. TAS
G. TEUNISSEN
Th. V.D. KAA
G. V.D. KOOGH
N. V.D. BORG
R. V.D. POL
H. V.D. WERVE
J. VEENEMA
J. VISSER
W. ZIJP
H. ZWANKHUIZEN

For further information concerning the HFR-project, please contact the project manager,