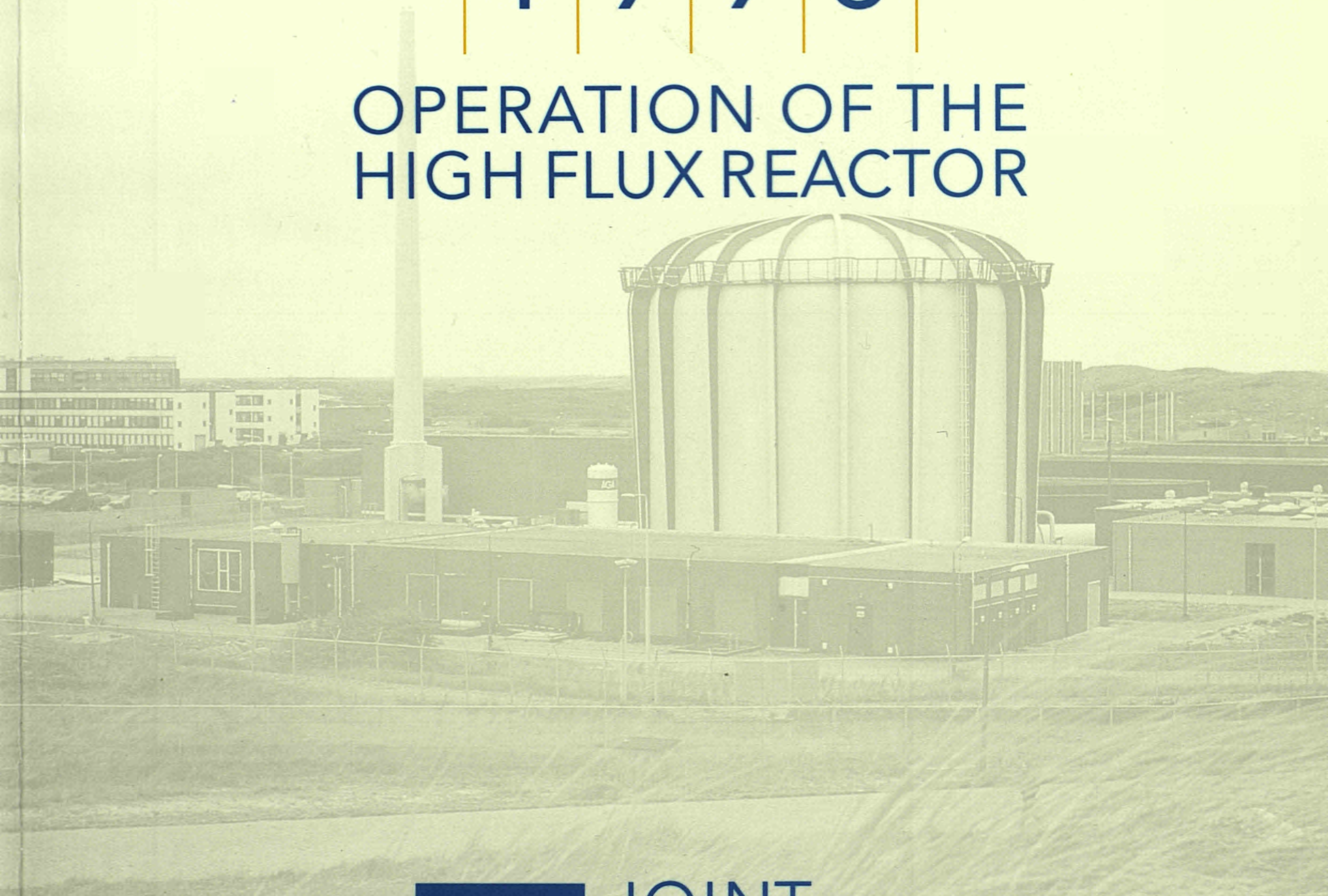
ANNUAL REPORT 1990

OPERATION OF THE HIGH FLUX REACTOR



JOINT RESEARCH CENTRE

COMMISSION OF THE EUROPEAN COMMUNITIES

ANNUAL REPORT 1990 OPERATION OF THE HIGH FLUX REACTOR

J. AHLF, A. GEVERS,
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Petten Site

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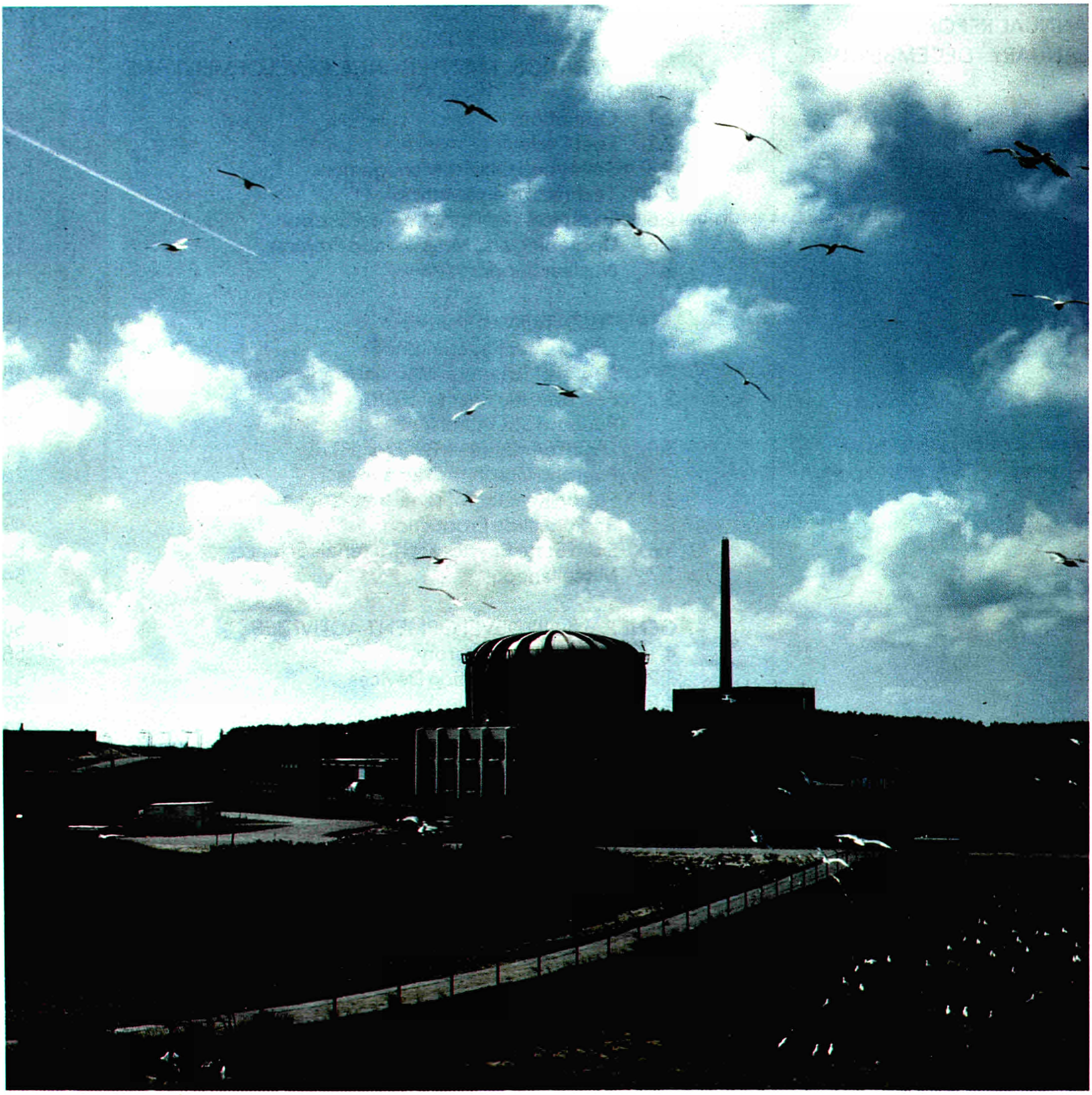


The HFR Petten.

1. INTRODUCTION

The High Flux Reactor Petten belongs to the Institute for Advanced Materials of the Joint Research Centre of the European Communities.
The reactor is operated and exploited in support of research programmes of the European Community and of its Member states.

The expenses for the HFR are covered to a large proportion by a supplementary programme funded by the Governments of the Federal Republic of Germany and the Netherlands, with a considerable addition from the common programme of the JRC. Although the contribution of public funding is by far the largest, there is an increasing income from services of the HFR offered to third parties inside and outside the European Communities.

As in the past the HFR Petten is operated and exploited as a multi purpose research reator. The programme covers the fields of nuclear fission energy with special regard to safety aspects, thermo-nuclear fusion, fundamental research with neutrons in fields of nuclear and solid state physics and materials science, large scale radioisotope production for medical and industrial applications, neutron activation analysis, neutron radiography, and cancer therapy (Boron neutron capture therapy). Safe and efficient operation of the reactor is in itself an expressed programme objective.

In 1990 the performance indicators of the HFR have been impressively high again:
- High availability, 262 nominal power days
- High utilization, 71% of capacity
- Good progress on maintenance and upgrading of the reactor itself, its ancillary equipment, and the experimental facilities.

The execution of the irradiation programme has been succesful too. The achievements are reported in detail in the following chapters. The following are mentioned here as outstanding examples:
- First in-pile tests to investigate iodine release from PWR fuel under loss of coolant accident conditions
- Start of a series of reference tests from fuel elements for the German HTR module with simulation of power plant operating conditions
- Remarkable fresh momentum to the fast breeder fuel irradiation programme from the European Fast Reactor Project
- Successful continuation of the large fusion materials programme, with new emphasis on welded joints from steel 316 and successful in-pile tests of a redesigned creep rig
- Remarkable increase of radioisotope services, mainly for the medical sector
- Important progress on the Boron Neutron Capture Therapy project, installation of an epithermal neutron filter into the large cross section beam tube HB11.

DATE 1990	TIME OF ACTION hour	RESTART OR POWER INCREASE hour	NOMINAL/ ORIGINAL POWER hour	ELAPSED TIME TO RESTART OR POWER INCREASE h.min	ELAPSED TIME TO NOMINAL/ ORIGINAL POWER h.min	DISTURBANCE CODE 1	MW	2	3	REACTOR SYSTEM OR EXPERIMENT CODE	COMMENTS
Jan 01	08.12	08.23	08.26	00.11	00.14	MP	35	E	S	ER136	Facility handling
Jan 08	09.00	09.07	09.12	00.07	00.12	MP	20	E	S	D227-02	Experiment unloading
Jan 15	14.10	14.16	14.17	00.06	00.07	MP	35	E	S	136	Facility handling
Jan 17	10.00	10.02	10.06	00.02	00.06	AP	1	A	H	Secundary	Pump switched off by accident
Jan 18	18.45	18.52	19.00	00.07	00.15	MP	20	E	S	227-02	Experiment loading
Jan 22	00.17	00.22	00.26	00.05	00.09	MP	35	E	S	136	Facility handling
Jan 22	01.11	01.16	01.18	00.05	00.07	MP	35	E	S	136	Facility handling
Feb 05	08.55	09.06	09.08	00.11	00.13	MP	20	E	S	227-02	Experiment unloading
Feb 10	09.36	09.43	09.50	00.07	00.14	MP	20	E	S	227-02	Experiment loading
Feb 11	17.08	17.15	17.29	00.07	00.21	MP	15	E	S	206-22	Experiment handling
Feb 12	14.46	14.52	14.58	00.06	00.12	MP	35	E	S	136	Facility handling
Feb 19	00.12	00.18	00.21	00.04	00.09	MP	35	E	S	136	Facility handling
Mar 05	08.59	09.10	09.14	00.11	00.15	MP	20	E	S	227-02	Experiment unloading
Mar 05	15.02	15.03	15.05	00.01	00.03	AP	40	R	H	Off-gas	Wrong switch activated
Mar 31	10.54	11.47	12.10	00.53	01.16	MP	23	E	S	215-12/13	Experiment handling
Apr 04	13.09	13.32	13.35	00.23	00.26	MP	35	E	S	136	Facility handling
Apr 11	00.25	00.38	00.41	00.13	00.16	MP	35	E	S	136	Facility handling
Apr 19	08.45	08.45	09.01	00.13	00.16	MP	20	E	S	227-02	Experiment handling
Apr 26	16.46					MS	0	E	R	139-587-8-9	Experiment could not be flushed
Apr 28		00.03	01.12	31.17	32.29						Experiment repaired and replaced
Apr 28	09.08	09.13	09.16	00.05	00.08	AP	25	E	I	240-33	Defective cooling air safety switch
Apr 30	09.04	09.13	09.30	00.09	00.26	MP	20	E	S	227-02	Experiment loading
May 02	14.10	14.15	14.19	00.05	00.09	MP	35	E	S	136	Facility handling
May 09	00.13	00.22	00.26	00.09	00.13	MP	35	E	S	136	Facility handling
May 21	08.50	09.02	09.05	00.12	00.15	MP	20	E	S	227-02	Experiment unloading
May 27	08.41	08.54	09.02	00.13	00.21	MP	20	E	S	227.02	Experiment loading
May 28	14.00	14.10	14.16	00.10	00.16	MP	35	E	S	136	Facility handling
May 28	14.45	14.51	14.57	00.06	00.12	MP	35	E	S	136	Facility handling
May 29	09.08	09.13	09.30	00.05	00.27	AS	0	R	I	Ventilation	Interference on gasmonitor
Jun 04	00.10	00.13	00.16	00.03	00.06	MP	35	E	S	136	Facility handling
Jun 11	11.02	11.09	11.21	00.07	00.19	MP	25	E	S	215	Experiment handling
Jun 12	17.15	17.28	17.35	00.13	00.20	MP	25	E	S	215	Experiment handling
Jun 14	10.50	10.53	10.55	00.02	00.05	AP	24	E	E	240	Cooling air disturbance
Jun 18	09.00	09.10	09.15	00.10	00.15	MP	20	E	S	227.02	Experiment unloading
Jun 21	04.22	08.53	13.55	04.21	10.03	MS	0	R	M	Core	Small particle on core pos. B7
Jun 22	14.00					MS	0	E	M	167-19	Experiment leakage
Jun 24		04.00	07.07	14.00	17.07						
Jun 26	07.12	07.19	07.45	00.07	00.33	AS	0	E	I	BWFC A	Interference spike
Jul 01	03.19	03.24	03.45	00.05	00.26	AS	0	E	I	BWFC A	Interference spike
Jul 05	22.54	22.58	23.20	00.04	01.04	AS	0	E	I	BWFC A	Interference spike
Aug 27	14.25	14.30	14.35	00.05	00.10	MP	35	E	S	136	Facility handling
Aug 27	18.02	18.15	18.23	00.13	00.21	MP	20	E	S	227.02	Experiment loading
Aug 29	14.22	14.27	14.32	00.05	00.11	MP	35	E	S	136	Facility handling
Sep 03	00.12	00.33	00.38	00.21	00.26	MP	35	E	S	136	Facility handling
Sep 03	01.25	01.40	01.45	00.15	00.20	MP	35	E	S	136	Facility handling
Sep 05	00.09	00.15	00.18	00.06	00.09	MP	35	E	S	136	Facility handling
Sep 05	01.30	01.06	01.08	00.03	00.05	MP	35	E	S	136	Facility handling
Sep 10	00.15	00.26	00.37	00.11	00.22	MP	35	E	S	136	Facility handling
Sep 13	06.40					AS	0	A	E	Mains	Mains outage, caused Xenon poisoning
Sep 15		04.00	06.35	45.20	47.55						
Sep 15	07.00	07.08				MP	30	E	I	167-19.1	Missing thermocouple readings
Sep 15	07.08	14.00	15.45	06.52	08.37	MS	0	E	I	167-19.1	Thermocouple reconnected
Oct 01	15.08	15.15	15.20	00.07	00.12	MP	35	E	S	136	Facility handling
Oct 06	16.32					AS	0	R	H	Interlock	Temperature deviation during
Oct 08		14.47	16.23	46.15	47.51						heat exchanger backflushing
Oct 08	23.00	23.04	23.07	00.04	00.07	MP	30	E	S	206-23	Experiment handling
Nov 27	18.30					AS	0	R	H	Interlock	Temperature deviation during
Nov 29		20.48	23.47	50.18	53.17						heat exchanger back flushing

DISTURBANCE CODE

1. LEADING TO
- automatic shut-down AS
- manual shut-down MS
- automatic power decrease AP
- manual power decrease MP

2. RELATED TO
- reactor R
- experiment E
- auxiliary system A

3. CAUSE
- scheduled S
- requirements R
- instrumentation I
- mechanical M
- electrical E
- human H

2. HFR OPERATION, MAINTENANCE, DEVELOPMENT AND SUPPORT

2.1. OPERATION

2.1.1. Operation Survey

In 1990 the regular cycle pattern, from before 1988, has been maintained throughout the year with a scheduled number of 273 operation days. The HFR has been in operation during 262 days, following a normal cycle pattern, which corresponds to an overall availablility of 72%.

Nominal operation power has been 45 MW. Total energy production has been approximately 11900 MWD., corresponding to a fuel consumption of approxumately 14.5 kg U-235.

2.1.2. Operational Characteristics

The main operating characteristics for 1990 are given in **table 1.**

An example of a core loading and a typical power pattern and control rod position for a reactor cycle is shown in **fig. 1.** Detailed information on the various irradiation experiments is given in chapter 3.

Table 1
Reactor operation characteristics during 1990

HFR cycle	Beginning of cycle	End of cycle	Time at power h.min.	Energy production MWd	Unscheduled operation interruptions
89.11		08-01-90	183.32	344.68	-
90.01	09-01-90	05-02-90	598.28	1123.18	-
90.02	06-02-90	05-03-90	612.43	1151.72	-
Maintenance period	06-03-90	28-03-90			
90.03	29-03-90	19-04-90	506.55	1018.57	-
90.04	25-04-90	21-05-90	578.37	1088.42	1
90.05	22-05-90	18-06-90	607.39	1143.88	1
90.06	19-06-90	17-07-90	571.33	1078.38	5
Maintenance period	18-07-90	24-08-90			
90.07	25-08-90	18-09-90	518.57	985.98	2
90.08	19-09-90	15-10-90	546.10	1026.90	1
90.09	16-10-90	12-11-90	569.18	1071.69	-
90.10	13-11-90	10-12-90	553.44	1041.40	1
90.11	11-12-90		435.14	817.87	-

◁ **Table 2**
Full power interruptions

2.1.3. Operational Disturbances

Deviations from nominal power level occurred 53 times during 1990. 37 of these were scheduled, mostly for handling or adjustment of irradiation facilities. The remaining 16 were related to technical failures, human interactions or experiment related events. Five of these deviations were automatic power decreases, the remaining eleven were unscheduled shutdowns. Detailed characteristics of all power disturbances are given in **table 2.**

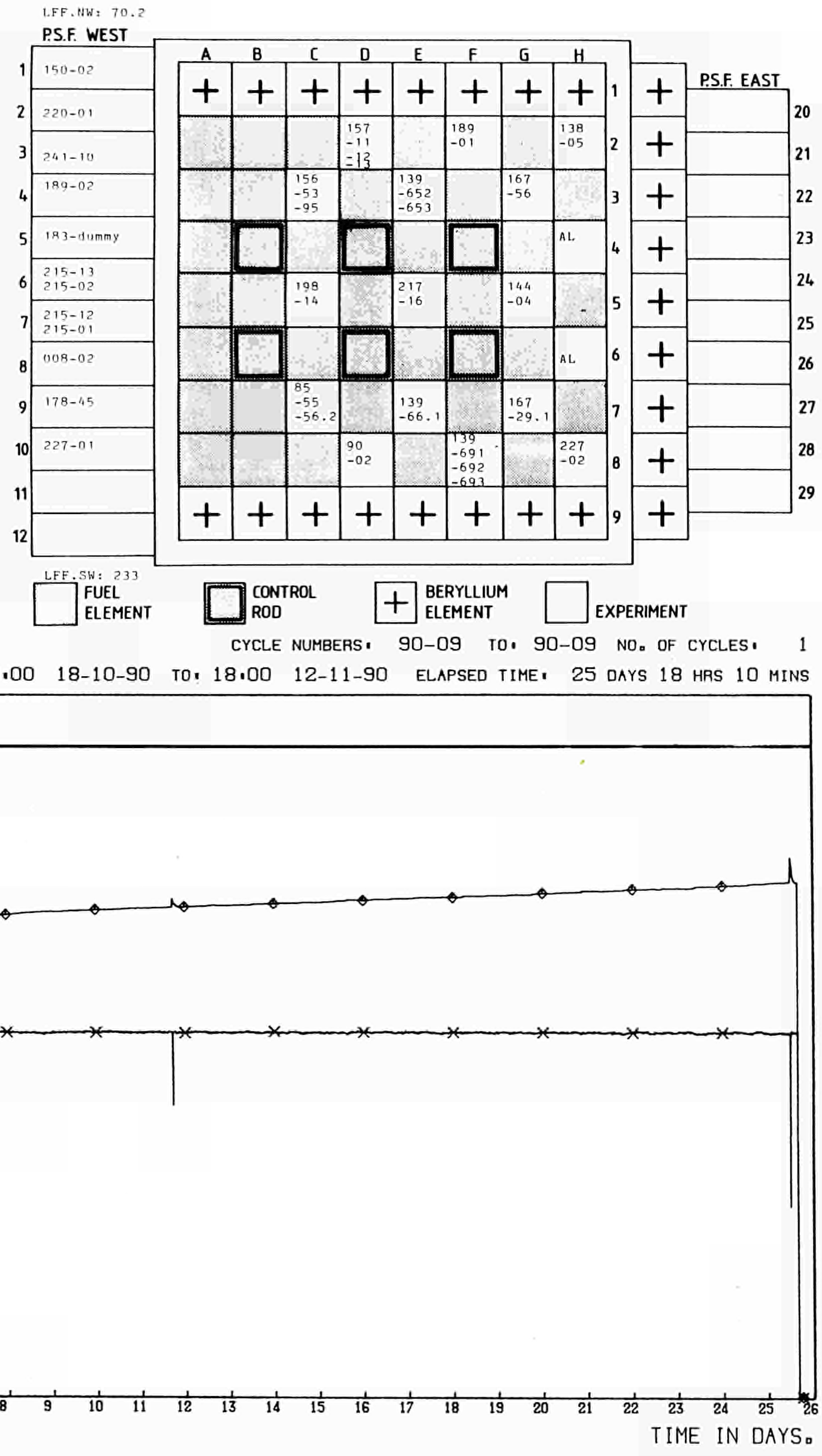
2.2. FUEL CYCLE

2.2.1. Fuel Supply

The USA authorities granted an export licence for 38 kg of HEU which was delivered in October 1990. This supply, together with existing stock will assure HFR operation until autumn 1992.

Fig. 1

HFR cycle 90.09. Experiment loading, reactor power pattern and control rod movement. Experiment codes used are explained in table 3.



2.2.2. Fuel Management

During 1990 new fuel elements and new control rods were delivered on schedule by the manufacturer.
Transfer of depleted fuel elements to the reprocessing facility at Savannah River (USA) has been delayed. For temporary accommodation of spent fuel additional storage racks have been installed in the pool of the HFR.

2.2.3. Testing of LEU Fuel Elements

In-core testing of three test elements has been completed at the end of 1990 at an average burn-up of about 70%. The testing programme comprised neutron flux measurements, cooling gap thickness measurements and reactivity measurements.
The fourth element, which was damaged during handling after a burn-up of 20%, has been in storage until now. Post irradiation examination of one element will be performed in the Hot Cell Laboratories of ECN. The status of the irradiated test elements has been reported at the RERTR meeting, held in Newport, Rhode Island (USA), September 1990.

2.3. SAFETY AND QUALITY MANAGEMENT

2.3.1. Fire Audit

In June the Dutch Licensing Authority (KFD), reinforced by national, provincial and communal fire prevention and fire fighting experts, carried out an extensive audit on all fire prevention and fire fighting measures in the HFR complex. The report of their findings has not yet been received.

2.3.2. Renewal of Technical Safety Documentation

In the context of a future renewal of the HFR Operating Licence, some technical safety documents, such as the Technical Description, the Safety and Accident Analysis and the Technical Safety Specifications were updated. The first document is operational whereas internal review of the other two draft documents is in full progress.
On the basis of these technical documents the new public Facility Description and Safety Report should be completed.

2.3.3. Quality Assurance

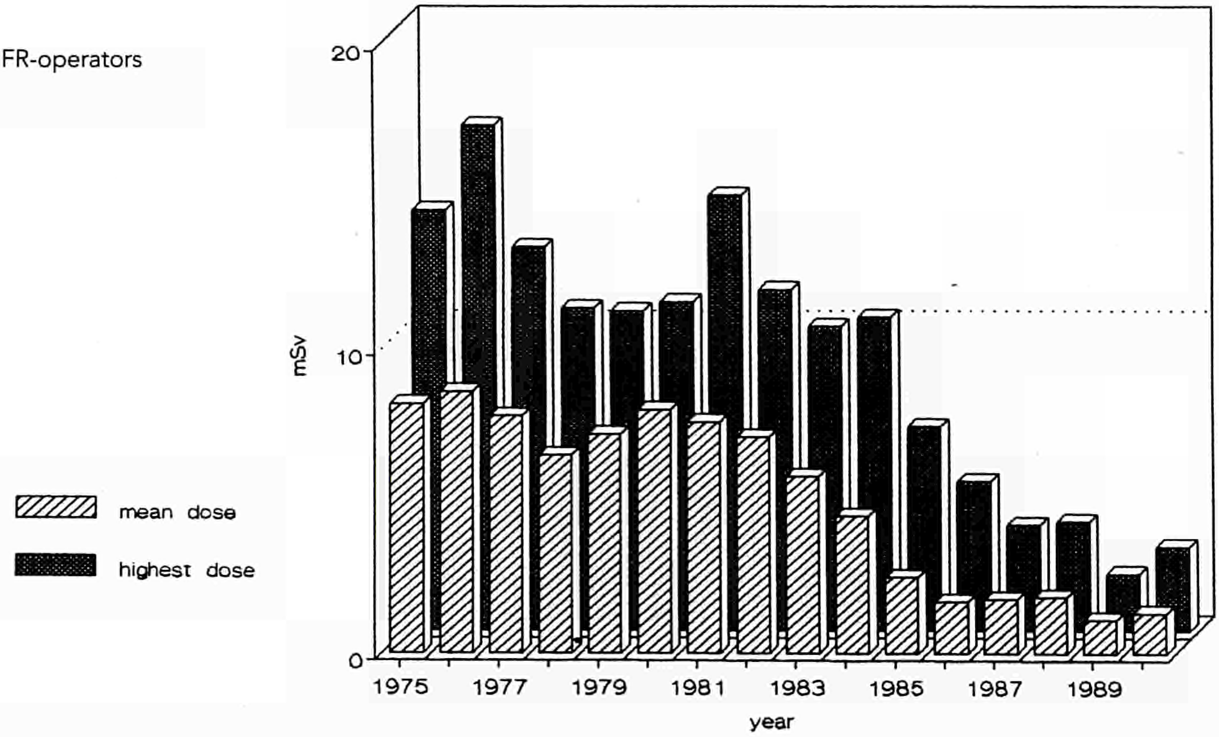
A number of existing procedures has been adapted and reissued. A procedure has been issued for the judgement of the quality of suppliers and contractors.
The Work and Action Plan, resulting from the 1988 audit of the Dutch Licensing Authority (KFD) was updated.
The quality system, as implemented for the HFR operation, will be improved by internal auditing. This internal audit will be carried out by means of checklists based on the "Hoofdregel Kwaliteitsborging" and the relevant Safety Guides and Safety Standards. The checklists will be generated by specially developed software for personal computers and are in accordance with those to be used by the Dutch Licensing Authority (KFD).

2.3.4. Personnel Exposure

A survey of the registered annual doses of HFR operating personnel is given in **fig. 2.**
Notwithstanding the strict application of the ALARA-principle in HFR working practices, a small raise in radiation exposure was encountered.

This was mainly due to the strong rise in number of isotope irradiations and associated handling operations.

Fig. 2
Dose-equivalent HFR-operators



2.4. TECHNICAL MAINTENANCE

Inspections, overhaul, repair and replacement of the technical systems and components have been carried out during the planned maintenance periods of the HFR operating programme for 1990: two extended shutdown periods in March and August. Some special items are described below.

2.4.1. Mechanical Installations

- Annual cleaning of the secondary system inlet section has been carried out.
  Leaking pipe connections were repaired by installation of internally applied cuffs, introduced for the first time.
  These cuffs proved to be very efficient both in the time necessary for application and in their effect.
- The secondary system inlet filter automatic cleaning system was completely overhauled and replaced.
- Design work for a complete renovation of the ion-exchanger drain tanks has been ordered at an external firm.
- Technical specification for replacement of the secondary system inlet valves are being drawn up.

2.4.2. Instrumentation Systems and Informatics

- An improved neutron beam detection system was introduced at the HFR beamtubes for operational safety surveillance.
- The bypass plugs for the nuclear start-up and period nuclear channels were replaced by key operated bypass switches on request of the Dutch Nuclear Inspectorate.

- Two "front-end" systems with attached drawing tablets for use by the HFR drawing offices were installed and connected to the JRC drawing system computer.
- Replacement of monitoring equipment of the HFR stack effluents is progressing.
- Development of an automatic gas mixing system for HFR experiment temperature control has been started following a more straightforward alternative.
- The original cladding rupture monitor has been replaced by a more modern system operating in a 2/3 mode thus reducing the risk of spurious scrams.
- To guarantee undisturbed experiment data collection spare parts were ordered for the dataloggers.

2.4.3. Electrical Installations

- The HFR has been connected to the completely renewed and redesigned Petten site emergency electrical power supply.
  This station consists of three 450 kVA dieselgenerators in a threefold redundant configuration with respect to the HFR needs.
  The temporary stand alone dieselgenerators for HFR back-up, used during the renovation has been dismantled.
  Formal Nuclear Inspectorate approval has been obtained.
- Design, manufacturing and pre-operational testing of a new leaktight cable-penetrations sytem for the HFR containment building has been taken up.
- Complete renewal of power distribution and control units for the power manipulator and further equipment of the HFR dismantling cell is progressing.

2.4.4. Buildings and Site

- Renovation of the secondary pump building has been ordered. The actual work has been delayed due to weather conditions and is now expected to start early in 1991.
- The HFR office building has been provided with cabling for a local area network, which is also connected to both JRC and ECN site networks. Software provisions are present to avoid any undesired exchange of information and data.
- The yearly leakage rate test of the HFR containment building at an overpressure of 0.2 bar was carried out during the March maintenance period.
  The result, reported to the Nuclear Inspectorate (0.027%/day), was well within the prescribed limit (0.1% /day).

2.5. TECHNICAL AND EXPERIMENTAL SUPPORT

Reactor Vessel Material Surveillance (SURP-project)

In order to study the irradiation induced changes in the material of the HFR reactor vessel various aluminium samples are being irradiated in the reactor core and in the pool side facility. These irradiations have been continued throughout 1990.

2.6. UPGRADING AND MODIFICATION PROJECTS

2.6.1. Replacement of Beryllium Elements

Objective:
Replacement of the original elements became necessary due to a combination of irradiation induced embrittlement and handling damage during nearly 30 years of use.

Progress:
All core and reflector positions with beryllium elements are now provided with the new type elements. Replacement took place following normal handling procedures for core elements and did not lead to any increased radiation dose for the personnel involved. The change in reactivity was less then 200 pcm.
Formal approval of the Dutch Nuclear Inspectorate was obtained. The project is foreseen to end with a concluding report describing experience gained with the original elements with respect to handling operations, damage caused by handling and the operational effects due to ingrowth of neutron absorbing isotopes.

2.6.2. Improvement of Gridbar Locking System

Objective:
Avoidance of further technical problems with the existing locking devices and improvement of operational ease.

Progress:
The newly designed locking devices have been manufactured. Assessment of the new system has taken place with a positive result and the Nuclear Inspectorate has been fully informed.
Mounting of the new locking devices on the existing gridbar bodies is now foreseen to be carried out during the in-service inspection operations of the vessel in 1991. The new locking devices use again the approved system of alignment and positioning described in the vessel safety report.

2.6.3. Renewal of HFR Main Power Distribution Cabinet

Objective:
Rearrangements of the electrical power installations at the HFR have necessitated adaptation of the main cabinet. Furthermore spare parts of the existing cabinet are unavailable, endangering future reliability.

Progress:
Preparations have started for the replacement, aiming at concentration of functions up to now served by separate subunits.

2.6.4. Renewal of Chlorine Injection System of the Secondary Cooling System

Objective:
To avoid algae growth in the piping and heat exchanger sytem of the HFR, chlorine is injected. On request of Dutch Labour Inspection authorities the use and storage of chlorine is to be avoided, so alternatives have to be investigated.

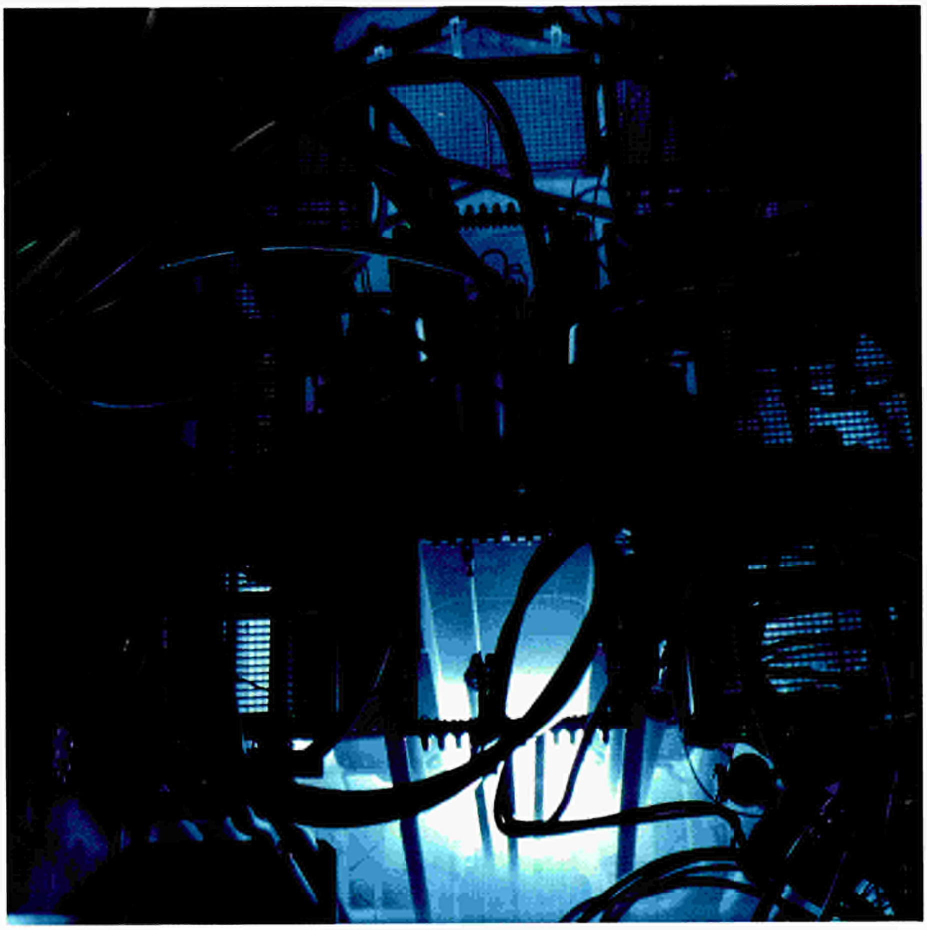


Fig. 3
View into the reactor pool

Progress:
A market research was carried out for alternative chemicals together with economical effects relative to a necessary upgrading of the existing installation to improve safety.
The use of sodium-hypochlorite was found to be more advantageous and to improve environmental safety at the same time.
Technical specifications are being drawn up. Installation of this system is preferably to be combined with the earlier mentioned secondary building renovation.

2.6.5. HFR Control Room Upgrading

Objective:
Reconfiguration and upgrading of HFR control room functions and equipment in order to replace outdated equipment and to introduce modern ergonomic principles in the fields of display of and access to reactor and experiment data.

Progress:
Progress is limited to a further study into requirements, budgetary consequences and timing, by a specialised firm.
During installation reactor operation has to proceed with as little delay as practically possible. Preliminary reports are now available for site discussions and fund raising procedures.

2.6.6. Introduction of a Second Reactor Power Protection System

Objective:
To provide redundancy and diversification for the present power protection system.

Progress:
After a thorough testing period and with consent of the Dutch Nuclear Inspectorate this extra power protection system is now in full operation.

2.6.7. Replacement of the Experiment Data Acquisition Computer

Objective:
Increasing demands by experimenters at the HFR necessitated upgrading of the computer system with respect to scanning speed, storage capacities, graphic display etc.

Progress:
Delivery of a modern computer system with the same operating system and extended storage capabilities (2,5 Gbytes) is expected for the beginning of 1991. The computer can be coupled to the available network systems and has full tape back-up possibilities.

2.7. NUCLEAR SUPPORT

2.7.1. Nuclear Heating Measurements (TRAMP-project)

The design of a Tramp-capsule, fitting in a 72 mm ∅filler element was completed.

2.7.2. Safety Related Calculations

The effects of loading errors of fuel elements and/or experiments on the thermo-hydrolic safety of the HFR were calculated in the framework of the future new Design and Safety Report in two technical reports:
NFA-HFR-TR-90-02 and NFA-HFR-TR-90-03.
The nuclear constants of the new beryllium elements were calculated for use in the Reactor Physics Code HFR-TEDDI.
The results are reported in technical report NFA-HFR-TR-90-01.

2.7.3. Pool Side Facility Neutron Flux Spectrum

The neutron flux spectrum was calculated for the western pool side facility at various distances from the PSF wall. The results are reported in technical report NFA-HFR-90-08.

3. HFR UTILIZATION

In 1990 the average utilization rate of the HFR was 71% of the practical occupation limit. Breakdown of the utilization pattern in terms of the different programme sectors is shown in **figs. 26 and 27.**
A list of irradiation projects is given in **table 3.**
Results are discussed below for each of the programme sectors.

3.1. LIGHT WATER REACTOR (LWR). FUEL AND STRUCTURAL MATERIAL IRRADIATIONS

Although the technology of light water reactors can be regarded as rather mature, there is still sufficient incentive for research reactor programmes with regard to the optimization of fuel cycle cost (testing of advanced fuel concepts and new materials), as well as with regard to plant life extension (ageing processes influenced by radiation, for instance pressure vessel steel embrittlement and irradiation enhanced stress corrosion cracking). For more than 20 years the HFR has provided contributions to R&D on light water reactor fuel with emphasis on non-stationary operating conditions (start-up, operational and over-power transients and power cycling). PWR as well as BWR fuel rods have been tested using UO_2 as well as mixed oxide fuel (U, Pu) O_2. Apart from smaller programmes in the past, structural materials related projects have been taken up only recently with more substantial effort.

a) Fuel Rod Irradiation

Objectives:
Recent projects in the LWR fuel sector address fuel rod behaviour at high burnup mainly. However, also performance testing of new fuel rod concepts with respect to better waterside corrosion resistance, improved economics (e.g. utilization of MOX) and fine tuning of its characteristics are pursued.
Another objective is the investigation of the release and behaviour of fission products after a hypothetical LOCA scenario. In this field a major contribution to the iodine release, its solution and degassing after a LOCA was made through HFR experiments performed at the early 1980's together with the KFA Jülich hot cells /4/. This programme is now being continued with a newly developed irradiation device allowing in-pile LOCA testing of pre-irradiated fuel rods.

The 1990 LWR fuel rod irradiation programmes at the HFR addressed following objectives:
- study of the transient fission gas release,
- investigation of the irradiation behaviour of PHWR fuel and
- study of the iodine release under simulated in-pile LOCA conditions.

Progress:
D125, D176, D178, D201: Power ramp tests of pre-irradiated LWR fuel rods

For the investigation of transient fission gas behaviour in-pile measurement of the fuel rod pressure is employed. A newly, by JRC Petten, developed technique, providing a re-instrumentation capability for irradiated fuel rods /4/ and being performed at the Petten hot cells, was twice successfully applied. First on a fresh BWR fuel rod under simulated hot cell conditions and secondly on a pre-irradiated BWR fuel rod.

LIST OF ACTUAL PROJECTS Situation: 1st August 1990

Exper. Code	Fill. element	Irrad. posit.	Description	Inst.	Person in charge	Irradiation 90	91	92	ECN proj.nr/ JRC account number	Remarks
008	--	P	HF-PIF	JRC	Konrad	X	X	X	--	Operator Nolten ECN
009,011	--	HB1,3	Triple axis spectrometer	ECN	van Dijk	X	X	X	3260	
012,013	--	HB4,5	Neutron diffraction	ECN	van Dijk	X	X	X	3260	
070	--	LFF	PROF	JRC	Tartaglia	X	X	X	--	Operator Nolten ECN
085	72/74/76	C	Intermed. + high temp. graph.	JRC	Tartaglia	X	X	X	7307 AAP2	more nrs.
090	72	C	RIF	JRC	Konrad	X	X	X	--	Operator Nolten ECN
095	--	HB 10	FASY	ECN	Nolten	X	X	X	--	
107	--	HB 9	Single crystal diffraction	ECN	van Dijk	X	X	X	3260	
117	--	P/C	Reactor noise studies	ECN	Turkcan	1)	1)	1)	1417	
121	--	P	Development LWR irrad. dev.	JRC	Markgraf	X	X	X	--	
125	--	P	Power ramp experiments	JRC	Markgraf	X	X	X	7307 APP2	more nrs.
128	--	P	Fuel stack displacement	JRC	Markgraf	X	X	X	7307 BAP2	more nrs.
130	--	HB 11	Mirror system	ECN	Abrahams	X			20261	
136	74	C	FIT	JRC	Konrad	X	X	X	7307 93P2	
138	74	C	BEST	JRC	Conrad	X	X	X	7307 BIP2	more nrs.
139	72	C	SINAS	JRC	Tsotridis	X	X	X	7307 IAP2	more nrs.
144	72	A	HIFI	JRC	Konrad	X	X	X	7307 93P2	
150	--	(P)	Neutrographie kamera	JRC	Markgraf	X	X	X	--	Operat. Leeflang ECN
156	72	C	DISCREET	JRC	Sordon	X	X	X	7307 BQP2	more nrs.
157	72	C	CRISP	JRC	Sordon	X	X	X	7303 14P2	
161	72	C	TRAMP	JRC	Jehenson	X	X	X	--	Operator Nolten ECN
167	72	C	TRIESTE	JRC	Sordon	X	X	X	7303 13P2	
169	--	HB 8	ILONCA	JRC	Markgraf	X	X	X	--	Operat. Leeflang ECN
176	--	P	Power ramp experiments	JRC	Markgraf	X	X	X	--	(see also 125)
178	--	P	Power ramp experiments	JRC	Markgraf	X	X	X	--	(see also 125)
183	--	P	KAKADU	JRC	Moss	X	X	X	7307 FAP2	
184	--	P	POTOM	JRC	Moss	X	X	X	7307 FJP2	
188	--	P	BWFC without fuel	JRC	Markgraf	X	X	X	--	
189	72	C/P	SURP	JRC	Zurita	X	X	X	--	Operator Nolten ECN
192	72	C	OPOST	JRC	Moss	X	X	X	7307 FGP2	more nrs.
195	--	P	Power ramp BWR-Fuel	JRC	Markgraf	X	X	X	--	(see also 125)
197	--	A	COBI	JRC	Konrad	X	X	X	--	Operator Nolten ECN
198	74/76	C	FRUST	JRC	Tartaglia	X	X	X	7303 15P2	
201	--	P	Power PWR-Fuel	JRC	Markgraf	X	X	X	--	
202	--	P	SUPRA	JRC	Tartaglia	X	X		7307 FQP2	more nrs.
203	72	A	CORRI	JRC	Konrad	X	X	X	--	Operator Nolten ECN
206	--	P	ISOLDE	JRC	Markgraf	X	X	X	7307 CAP2	more nrs.
209	--	-	GIF	JRC	Tartaglia	X	X	X	--	Operator Nolten ECN
210	--	-	PR	JRC	Konrad	X	X	X	--	Operator Nolten ECN
211	72	C	NILOC	JRC	Moss	X	X		7303 46P2	
212	74	C	EXOTIC	JRC	Conrad	X	X	X	7307 ISP2	more nrs.
214	72	C	"GA - rods"	JRC	Conrad		X	X	7307 CGP2	
215	72	P	RELIEF	JRC	Moss	X	X	X	7307 GAP2	
217	--	C	CERAM	JRC	Tsotridis	X	X		7307 FWP2	more nrs.
220	--	P	SIP	ECN	J.F.J. Visser	X	X	X	--	
224	74	C	LIBRETTO	JRC	Conrad	X	X	X	7303 12P2	
226	--	P	POMPEI	JRC	Moss	X			7303 46P2	
227	72	C/P	MOKA	JRC	Markgraf	X	X		7307 GGP2	more nrs.
231	--	FE	SIMONE	ECN	Pruimboom	X			0357	
233	--	LFF	SIDO	ECN	J.F.J. Visser	X	X	X	--	
235	--	P	TRAGA	JRC	Moss		X	X	--	
239	--	P	ROSI	JRC	Markgraf	X			--	
240	--	3(5)xP	IRMA	JRC	Sordon	X	X	X	--	
241	--	P	GRIPS	JRC	Tartaglia	X	X		7307 CPP2	
242	--	-	CIEMAT	JRC	Jehenson	X			7307 LBPO	MTR fuel handling
243	72	C	LIMO	JRC	Konrad	X			7307 93P2	
244	--	-	HEISA	ECN	Nolten	X			2252	in 209
245	72	C	NEMESIS	JRC	Tartaglia	X	X		--	
246	--	-	JETI	JRC	Tartaglia	X	X		--	
247	72	C	SiC-ball	JRC	Conrad	X			--	
248	--	HB7/11	BNCT	JRC	Moss	X	X	X	--	
249	--	HB 3	SANS	ECN	van Dijk	X	X	X	--	
250	--	C	SIRENA	JRC	Tartaglia		X	X	--	
252	--	C	BRAIN	JRC	Tartaglia		X	X	--	
253	--	-	GIRAF	ECN	Nolten	X	X	X	1114	
254	--	P	HIP	JRC	Konrad	X	X	X	--	Operator Nolten ECN

1)=Short irr.; A=in core without ext. tube; C=in core irr.; FE=fuel el.; HB=beam tube; LFF=Low Flux Fac.; P=Poolside irr.

BEST	= Brenn-Element SegmenT	138	JETI	= Joint European Torus Irradiation	246
BNCT	= Boron Neutron Capture Therapy	248	KAKADU	= KAmin KApsel-DUo	183
BRAIN	= BRAzings IrradiatioN	252	LIBRETTO	= LIquid BReeder Exp. w. Tritium Transp. Opt.	224
BWFC	= Boiling Water Fuel Capsule	125	LIMO	= Lamella Irradiation of MOlybdenum	243
CERAM	= net CERAMics	217	MOKA	= Misch Oxyd-brennstäbe	227
CIEMAT	= CIemat Elements MAnipulations for Transport	242	NEMESIS	= NEt MEtalS IrradiationS	245
COBI	= COBalt Isotope production	197	NILOC	= NItride fueL irradiation in (O) Cd screen	211
CORRI	= CObalt ReflectoR Irradiation	203	OPOST	= Over POwer STeady state experiment	192
CRISP	= CReep In Steel sPecimen	157	POMPEI	= Pellets Oxyde Mixte, PEtten Irradiation	226
DISCREET	= DISposable CREEp in Trio	156	POTOM	= POwer TO Melt experiment	184
EXOTIC	= EXtraction Of Tritium In Ceramics	212	PR	= Pneumatic Rabbit in reactor facility	210
FASY	= FAst rabbit SYstem	095	PROF	= Poolside ROtating Facility	070
FIT	= Fissile Isotope Target	136	RIF	= Reloadable Isotope Facility	090
FRUST	= Fusions Reaktor; Untersuchung an STahl	198	ROSI	= ROtative Silicium Irradiation facility	239
GIF	= Gamma Irradiation Facility	209	SANS	= Small Angle Neutron Scattering	249
GIRAF	= Gamma IRrAdiation Facility	253	SIDO	= SIlicon DOping	233
GRIPS	= GRaphite Irradiation in PSf	241	SINAS	= SImplified NASt (NAtrium STeel irradiation)	139
HEISA	= HEated and Instrumented SAlt irradiation	244	SIP	= Silicium Investigation Philips	220
HF-PIF	= High Flux Poolside Isotope Facility	008	SIRENA	= Stainless steel IRradiation for ENeA	250
HIFI	= HIgh FLux facility for Isotopes	144	SUPRA	= irradiation of SUPRA-conducting materials	202
HIP	= Herlaadbare IsotoPen faciliteit	254	SURP	= SURveillance Programme	189
ILONCA	= Installation of a Long Object Neutron CAmera	169	TRAGA	= TRAnsient GAp conductance measurement	235
IRMA	= IRradiation of MinerAls	240	TRAMP	= TRAvelling Measuring Probe	161
ISOLDE	= Iodine SOLubility and Degasing Experiment	206	TRIESTE	= TRIo Irr. Exp. of Steel sampl. und. TEnsion	167

Irradiation of both tests were started during 1990. The fresh BWR fuel rod was only irradiated for a short time in order to check the performance of the new technique. The pre-irradiated fuel rod was at the begin of the irradiation period ramptested and than continued in irradiation for burnup accumulation of additional 15 GWd/t(U). The in pile pressure behaviour has been monitored during the all test periods.

D128: In-pile measurements in LWR fuel

Three D128 experiments have been irradiated at the HFR in the period 1983 to 1989. Every BWR test fuel rod was instrumented with in-pile monitoring of the central fuel rod temperature and fuel rod pressure.
The tests addressed following topics:
(1) investigation of transient fission gas release and fuel restructuring, and
(2) investigation of fuel restructuring at constant temperature level.

The D128 test series has been terminated during the reference period with the completion of the PIE on the last D128 fuel rod at the Petten hot cells and shipment of two of the three fuel rods to KFA Jülich for the destructive PIE.

D227: Irradiation testing of PHWR MOX fuel rods

Two irradiation experiments, each using two short fresh MOX PHWR fuel rods, are being performed at the HFR in order to study the fuel rod power ramping behaviour at approx. 15 GWd/t(M) [e.g. end-of-live (EOL) conditions].

The first test, a simulated EOL test, has been completed in 1986 in the HFR and been sent to the clients hot cells for further PIE.

The second test consisting of a burn-up accumulation phase to 15 GWd/T(M) and a transient test with one fuel rodlet, was continued in irradiation in the HFR core for further burn-up accumulation. At the end of the reference period a burn-up of approx. 8 GWd/t(M) was obtained. A transfer of the experiment from the HFR core to the PSF is scheduled for the the second burn-up accumulation period. The related hardware for this transfer was been prepared during the reference period.

D206: Iodine Solubility and Degassing Experiment (ISOLDE) with pre irradiated PWR fuel rods

The test programme addresses the determination of the rate of iodine release from PWR fuel rods and its solution in steam and water for a LOCA scenario.
Two of the anticipated five in-pile tests with pre-irradiated PWR fuel rods have been successfully performed during 1990. Each test consists of a conditioning period at typical PWR fuel rod power and conditions in order to obtain a typical inventory of shortlived isotopes. The fuel rod is then transferred into the ISOLDE irradiation device. The in-pile section of the ISOLDE capsule is shown in **fig. 4.** This device provides typical PWR system conditions at low power level and after initiation of the LOCA phase typical

◁ **Table 3**
List of actual irradiation projects

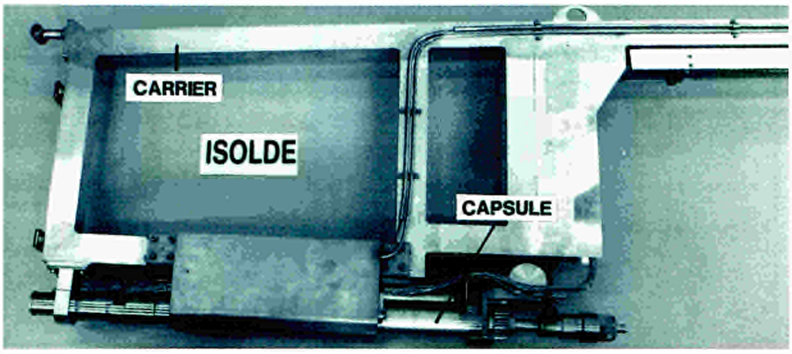


Fig. 4
In-pile section of the ISOLDE irradiation device

LOCA conditions. **Fig. 5** shows the fuel rod temperature and system pres sure versus time for the first ISOLDE test.
In both tests the anticipated fuel rod failure occured. As planned, stean and water samples were collected and made available for PIE at the Pette and Jülich hot cells. The irradiation devices including the fuel rods wer transported to the Jülich hot cells for PIE. In view of the short halflife tim of I-131 all transports were performed shortly after the HFR test. Prior to th transports the fuel rod condition was investigated by neutron radiography

b) Structural Materials Irradiation Testing

Objectives:
The extension of the operational life time of water reactors requires investi gations on the corrosion and mechanical behaviour of the strutural mate rials in the core region and of the pressure vessel. For structural material irradiation testing feasibility studies to the following objectives were pur sued:
- feasibilty study on corrosion testing of Zr-based alloys in the reacto coolant (in both, light and heavy water) and
- conceptional studies on irradiation testing of large CT specimen mad from BWR vessel material.

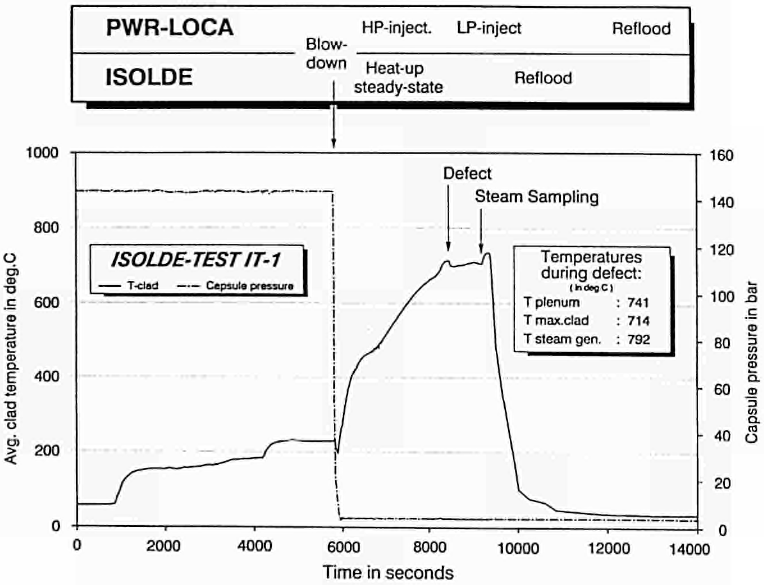


Fig. 5
Temperature and pressure histogram of the first ISOLDE test

Progress:
Feasibilty study on corrosion testing of Zr-based alloys in the reactor coolant (in both, light and heavy water):
A design study for a miniature high pressure loop for irradiation of a sample stack of corrosion samples in a TRIO-type irradiation device was performed and yielded feasibilty for application of both coolant media, light water and heavy water. The irradiation device is reloadable and provides intermediate inspection capabilities of the irradiated samples.

Conceptional studies on irradiation testing of large CT specimen made from BWR vessel material.
The basic lay-out for a new test facility at a HFR beam tube has been elaborated and will be subject to a more extensive feasibility study during the next reference period. The main task of this study is to prove that the HFR is suitable to provide typical BWR gamma- and neutron spectra of commercial BWR's at the inside of their pressure vessel.

References

/1/ J.F.W. Markgraf
HFR irradiation testing of light water reactor (LWR) fuel
EUR 9654 EN, 1984

/2/ H.P. Leeflang, J.F.W. Markgraf, S. McAllister, K.H. van Otterdijk
Zerstörungsfreie Prüfverfahren am HFR Petten zur Inspektion und Untersuchung bestrahlter LWR Brennstäbe KTG- Fachgfruppe Brennelemente, Bonn, Jahrestagung 1990

/3/ M. Gärtner, K. Reichardt
Irradiation testing of SIEMENS/KWU LWR fuel in the HFR Petten
Proceedings of a colloquium on "the HFR Petten, prospects and future utilization", EUR 12522, 1989

/4/ E. Groos, R. Förthmann
Determination of iodine 131 release from defect, irradiated fuel rods under simulated LOCA conditions. International meeting on thermal nuclear reactor safety, Karlsruhe, 1984

3.2. FAST BREEDER REACTOR (FBR). FUEL AND STRUCTURAL MATERIAL IRRADIATIONS

During the late 70s and early 80s, several international R&D programmes were being pursued, each with their own goal of qualifying various FBR fuels and materials under normal and off-normal conditions.
The HFR played an important role in performing many experiments for the German and Dutch programmes. From the mid-80s and onwards, it became apparent that significant measures had to be taken to achieve specific goals including acceptable safety features, within acceptable economic constraints. Consequently, in 1984, a five-nation collaboration to develop a demonstration European Fast Breeder Reactor (EFR) was made. The raison d'être for the FBR remains the same in that at least 60 times more energy can be produced from a given quantity of uranium in an FBR than in a thermal reactor, being equivalent therefore to twice as large as the known world coal resources and 15 times larger than the known oil resources. The objectives of the EFR are: capital and generating costs should be comparable with competing PWR's; availability and reliability should be similar comparable; construction should be assured within a defined time-scale; and there should be a minimum extrapolation to a commercial plant.

All existing and future FBR experimental programmes at the HFR, now fall within the design aims of the EFR. The objectives remain essentially the same.

a) Fuel Irradiations

Objective:
Fast reactor fuel experiments carried out in the HFR Petten currently fall into two categories.

- Transient Tests
The investigation of fast reactor fuel pin behaviour under transient reactor conditions: features investigated include start-up behaviour, power cycling and ramping, fuel melting, transient overpower (TOP) and simulated loss-of-flow (LOF) behaviour. Running experiments and new experiments are being performed with a view to utilizing the information for the design aims of the European Fast Reactor (EFR).

- Advanced Fuel Irradiations
These concern investigations into the operational behaviour of dense (nitride) fast breeder fuels and more fundamental research on fission product kinetics in UO_2 fuel. This group of experiments is part of the JRC Specific Programme on Nuclear Fuels and Actinide Research.

A review of the FBR experiments and their facilities are presented in refs /1/ and /2/, and more recently in ref /3/.

Progress:
Transient Tests

During the reporting period four transient experiments were irradiated over a total of 20 reactor cycles, including 3 specific, short transient tests.

D183 KAKADU

The aim of the KAKADU series of experiments is to demonstrate the behaviour of full size pins (KNK-II) under simulated power ramping up to medium burn-up.
The last KAKADU experiment 27/28 also referred to as OPEQU i.e. Over-Power EQUlibrium completed its scheduled irradiation at the end of 1989. The two fuel pins were transferred to the ECN hot cells, where in March gamma scans were performed. The pins await transport to KfK.

D183 SUPERKAKADU

Preparations are underway for the construction of 4 new capsules for the irradiation of 4 pre-irradiated fuel pins. During the year, 3 pins irradiated in the PHENIX reactor in France, were transported to Petten. The planned irradiation scheme is currently under discussion.

D183 HYPERKAKADU

A new KAKADU series of experiments consisting of extra long pins (>2m),

have necessitated a re-design of the special α-tight EUROS cell, ref./4/. A recent technical investigation, see ref./5/, showed that it is possible to execute the loading and sodium filling of these longer fuel capsules in a modified EUROS cell without too much rebuilding and expenditure.
During the latter half of 1990, the EUROS cell was used again for the first time in 3 years. Three capsules, for the SUPERKAKADU series were loaded. It is currently under discussion whether pre-irradiated fuel pins, originating from the PFR Dounreay, will also be utilized.

D184/D192 POTOM/OPOST

The aim of the POTOM series of experiments is to determine the power at which melting of the fuel first occurs, as a function of material composition (Pu-content), fuel type (homogeneous/heterogeneous) and duration of pre-conditioning. Following 5 POTOM experiments, reported in previous annual reports, the first OPOST experiment was started.
The aim of this series of experiments is to demonstrate fuel behaviour and operability of partially melted fuel pins.
Following a short 3.5 day irradiation of three fuel pins at 550 W/cm, i.e. just at the power-to-melt temperature as determined from the previous series of POTOM experiments, each fuel pin is separately irradiated in position G5 at 550 W/cm. Due to the horizontal flux gradient in this position, only one fuel pin per cycle is irradiated. The 3 fuel pins (27, 28 and 29) are irradiated for 1,2 and 3 cycles respectively.
The first irradiation (27, 1 cycle) was completed in November. The next 2 irradiations will be completed in 1991.

D215 RELIEF

The experiment aims to study, by means of in-pile measurement, the differential and absolute fuel and cladding axial displacements during operational transients. At present two RELIEF experiments are in irradiation. At the end of 1990 RELIEF 12 had completed almost 20 cycles of irradiation at a steady power of 480 W/cm. The attained burn-up is approximately 6.0 at.%. After attaining 5.0 at.% burn-up, the first planned transient was performed. The planned and achieved conditions are shown in **fig. 6.** A second transient is planned for the beginning of 1991 (at 8.0 at.% burn-up). The fourth RELIEF experiment in the present series, RELIEF 13, began irradiation in February 1990. The experiment had attained 2.0 at.% burn-up at the end of 1990. A first transient will be performed in 1991 on achieving 5.0 at.% burn-up.

D235 TRAGA

The development of the TRAGA experiment, which aims to determine by means of noise analysis, the change in the fuel cladding gap heat conductance during simulated transients, is still under consideration.

Advanced Fuel Irradiations

Mixed nitride (U,Pu)N is the reference fuel for a fast reactor cycle with a denser optimised fuel than the currently used mixed oxide.

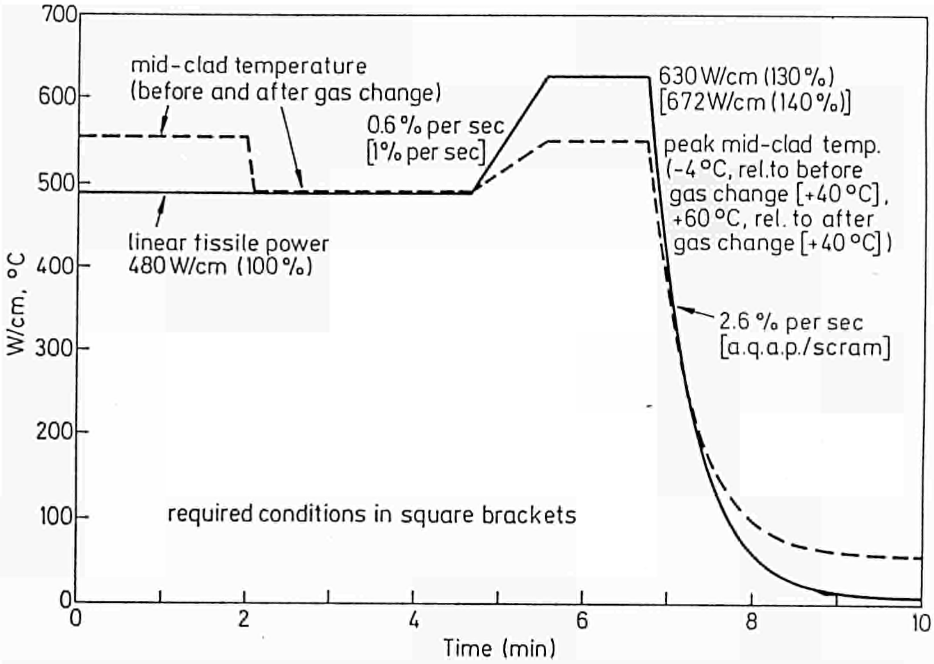


Fig. 6
A comparison of the achieved and required peak linear fissile power and peak cladding temperature changes during the first transient for experiment RELIEF 12

The JRC Karlsruhe programme "Optimisation of Dense Fuels" aims at optimising "pure" mixed nitrides for high burn-up fast reactors. Part of this program involves the irradiation testing of fuel in the HFR.

E211 NILOC

The third and fourth NILOC experiments are now ready for irradiation. The experiment NILOC 3 will irradiate 3 mixed nitride fuel pins simultaneously. NILOC 4 will irradiate 2 nitride pins and 1 mixed oxide pin. The irradiations are planned for the second half of 1991.

E226 POMPEI

Due to a delay in the complex process for manufacturing the special pellets of mixed nitride fuel, the POMPEI experiment will not commence irradiation until the end of 1991.

b) Structural Material Irradiations

The bulk of these HFR experiments presently fall within the scope of fast reactor safety programmes. Irradiations in the HFR Petten are carried out to stringent specifications concerning specimen temperature information of material embrittlement by helium formation and fast neutron displacement.

R 139-57

Objective:
This experiment is part of a fast reactor materials testing programme. The aim of the irradiation experiment is to study the crack propagation characteristics in small CT-block systems of LMFBR materials, SS316 and 304.

Progress:
The R139-57 experiment contains 2 specimen holders with 10 miniature CT-blocks and 8 tensile blocks. Irradiation of leg R139-571 terminated in cycle 90.03. A typical temperature distribution during a reactor cycle is shown in **table 4.**

R 139-58-59

Objective:
This new irradiation programme will provide sufficient specimens for continuous cycling and creep-fatigue post-irradiation testing.
The irradiation and testing conditions will be as close as possible to the conditions of the EFR (European Fast Reactor) above-core structures. The objectives of this work are to provide data on creep fatigue properties of irradiated stainless steel type 316 L(N) for the EFR design data-base, and to verify the creep-fatigue interaction models.

Progress:
The irradiation conditions of this experiment were 823 K at a very low dpa

Table 4
R139-594. Typical statistical analysis of a temperature distribution in a reactor cycle (90.02)

CYCLE NO: 90-02 "D A C O S S Y S T E M" DATE: 09:22:42 6-APR-90

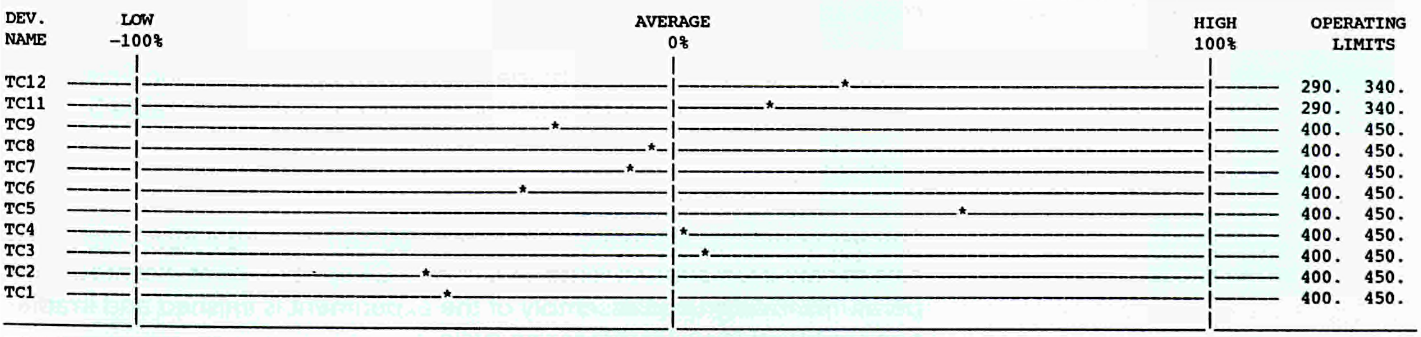
ANALYSIS BY ENGINEERING UNITS FOR PERIOD FROM: 00:00:00 8-FEB-90 TO 17:50:00 5-MAR-90

EXPERIMENT NO. : R139-571
NAME : SINAS
START DATE : 09-02-89
REACTOR LOCATION: D2
GAS PANEL USED : TRIO-F

NOMINAL DEGREES "C": 425.00
SAMPLE :
STRESS MODE :
DATA LOGGER NUMBER : 2
RECORD INTERVAL : 10 MINUTES

CHAN NO.	MEASUR'G POINT NAME	ENG'RING UNIT	ANALYSIS OF MEASURING POINT (BY ENGINEERING UNITS) AVERAGE	MINIMUM	MAXIMUM	STANDARD DEVIATION	ERROR	TOTAL RECORD	ANALYSIS OF DATA RECORDS (BY PERCENTAGE) REACTOR < 43.MW	NO DATA	< LOW LIMIT	> HIGH LIMIT	WITHIN LIMITS
662	TC12	Deg. C	323.15	287.54	332.15	3.619	0.060	3708	0.86	0.00	0.03	0.00	99.11
661	TC11	Deg. C	319.45	280.07	327.77	3.385	0.056	3708	0.86	0.00	0.03	0.00	99.11
659	TC9	Deg. C	419.46	341.87	427.22	3.395	0.056	3708	0.86	0.00	0.19	0.00	98.95
658	TC8	Deg. C	424.22	348.54	428.57	2.325	0.038	3708	0.86	0.00	0.11	0.00	99.03
657	TC7	Deg. C	422.94	347.61	426.85	2.289	0.038	3708	0.86	0.00	0.11	0.00	99.03
656	TC6	Deg. C	417.77	344.38	420.64	2.033	0.034	3708	0.86	0.00	0.13	0.00	99.00
655	TC5	Deg. C	438.26	359.94	441.22	2.113	0.035	3708	0.86	0.00	0.03	0.00	99.11
654	TC4	Deg. C	425.26	345.84	428.87	3.054	0.050	3708	0.86	0.00	0.13	0.00	99.00
653	TC3	Deg. C	426.41	347.39	429.96	3.153	0.052	3708	0.86	0.00	0.13	0.00	99.00
652	TC2	Deg. C	413.46	332.01	417.91	3.632	0.060	3708	0.86	0.00	1.29	0.00	97.84
651	TC1	Deg. C	414.61	333.26	419.33	3.673	0.061	3708	0.86	0.00	1.16	0.00	97.98

RELATIVE POSITIONAL GRAPHIC REPRESENTATION OF ABOVE ENGINEERING UNITS.



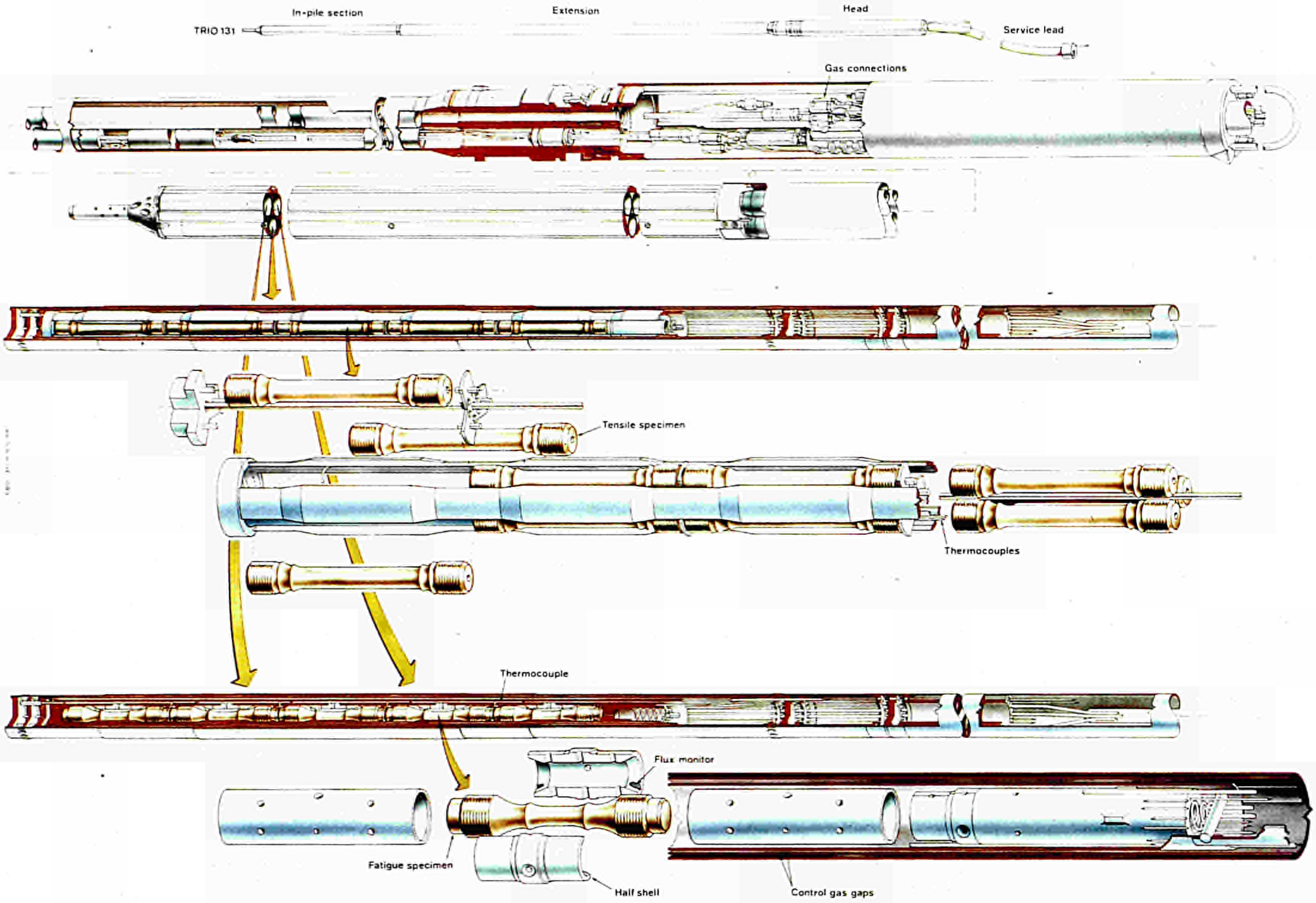


Fig. 7
TRIO-131 containing fatigue and tensile specimens in a double containment

(one reactor cycle in the H8 position) and the irradiation took place in a TRIO-131 with a double container. This was required in order to obtain the temperature of 823 K at a peripherical reactor position.
Two legs of the TRIO contained fatigue specimens and the third leg tensile-creep specimens, shown in **fig. 7.**

Irradiation of the 12 sample holders started in cycle 90.03 and finished in cycle 90.06. The performance of this experiment is shown in **table 5.**

R139-416

The experiment is a continuation of the 400-series using a REFA type capsule for the irradiation of large or half-size CT specimens at elevated temperatures. Design and assembly of the experiment is finished and irradiation started at cycle 90.02 for one cycle.

CYCLE NO: 90-06 "D A C O S S Y S T E M" DATE: 16:05:04 1-AUG-90

ANALYSIS BY ENGINEERING UNITS FOR PERIOD FROM: 03:00:00 21-JUN-90 TO 04:50:00 17-JUL-90

EXPERIMENT NO. : R139-594
NAME : SINAS
START DATE : 25-04-90
REACTOR LOCATION: H8
GAS PANEL USED : TRIO-C

NOMINAL DEGREES "C": 550.00
SAMPLE :
STRESS MODE :
DATA LOGGER NUMBER : 1
RECORD INTERVAL : 10 MINUTES

CHAN NO.	MEASUR'G POINT NAME	ENG'RING UNIT	ANALYSIS OF MEASURING POINT (BY ENGINEERING UNITS) AVERAGE	MINIMUM	MAXIMUM	STANDARD DEVIATION	ERROR	TOTAL RECORD	ANALYSIS OF DATA RECORDS (BY PERCENTAGE) REACTOR < 43.MW	NO DATA	< LOW LIMIT	> HIGH LIMIT	WITHIN LIMITS
144	TC16	Deg. C	516.22	298.56	548.66	17.913	0.306	3756	8.81	0.00	1.17	0.00	90.02
143	TC15	Deg. C	547.67	303.81	570.99	20.172	0.345	3756	8.81	0.00	1.94	0.05	89.19
142	TC14	Deg. C	550.59	305.81	573.34	20.234	0.346	3756	8.81	0.00	1.92	0.08	89.19
141	TC13	Deg. C	551.80	298.17	575.75	21.582	0.369	3756	8.81	0.00	1.92	0.05	89.22
140	TC12	Deg. C	547.99	293.43	573.75	22.469	0.384	3756	8.81	0.00	1.92	0.05	89.22
139	TC11	Deg. C	551.55	297.93	576.63	22.372	0.382	3756	8.81	0.00	1.89	0.05	89.24
138	TC10	Deg. C	545.29	291.19	571.71	22.966	0.392	3756	8.81	0.00	1.89	0.05	89.24
137	TC9	Deg. C	550.88	292.36	576.86	23.722	0.405	3756	8.81	0.00	1.89	0.16	89.14
136	TC8	Deg. C	555.51	297.51	581.00	23.658	0.404	3756	8.81	0.00	1.89	0.53	88.76
135	TC7	Deg. C	543.85	284.74	569.91	24.194	0.413	3756	8.81	0.00	1.94	0.00	89.24
134	TC6	Deg. C	552.04	287.01	580.11	24.933	0.426	3756	8.81	0.00	1.92	0.61	88.66
133	TC5	Deg. C	552.11	288.49	580.11	24.854	0.425	3756	8.81	0.00	1.92	0.61	88.66
132	TC4	Deg. C	548.48	280.49	580.20	25.381	0.434	3756	8.81	0.00	1.97	0.56	88.66
131	TC3	Deg. C	548.07	275.42	582.23	25.836	0.441	3756	8.81	0.00	2.00	0.59	88.60
130	TC2	Deg. C	549.91	277.79	584.48	25.761	0.440	3756	8.81	0.00	1.97	0.59	88.63

RELATIVE POSITIONAL GRAPHIC REPRESENTATION OF ABOVE ENGINEERING UNITS.

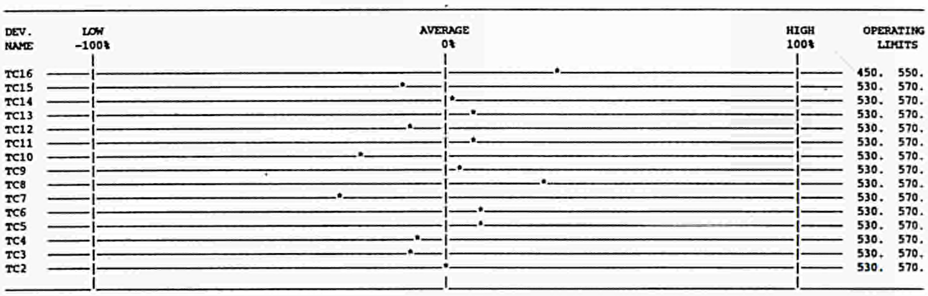


Table 5
R139-594. Typical statistical analysis of a temperature distribution in a reactor cycle (90.06)

References

/1/ Moss, R.L., Tsotridis, G. and Beers, M.
"Fast Breeder Reactor Fuel Pin Experiments in the High Flux Reactor, Petten"
IAEA International Symposium on the Utilization of Multi-Purpose Research Reactors and Related International Co-operation, Grenoble, October 1987

/2/ Moss, R.L., Beers, M., Korko, A.R. and Tsotridis, G.
"Fast Breeder Reactor Fuel Pin Experiments in the High Flux Reactor, Petten: Specialist Design and Instrumentation, and Ancillary Activities"
EWGIT, Mol, September 1988

/3/ Moss, R.L., Beers, M., Debarberis, L. and Tsotridis, G.
"FBR Fuel Pin Testing at the High Flux Reactor, Petten - Summary of Current Programme and Future Trends", J.Eur. Nuclear Society, No. 7/8, 1990

/4/ Konrad, J. and Pithan, D.
"EUROS European Remote Encapsulation Operating System"
Atomkernenergie-Kerntechniek, nr. 2, 1984

/5/ Hale, R.G.
"Technical Investigation into Possible Modifications of the Existing EUROS cell"
HFR/89/2968, Petten

3.3. HIGH TEMPERATURE REACTOR (HTR). FUEL AND GRAPHITE IRRADIATIONS

Because of its potential for high thermal efficiency and production of high temperature process heat the High Temperature Gas-Cooled Reactor concept is still actively pursued in Germany and in several other countries, amongst them USA, USSR and Japan. In Germany research and development for the HTR is concentrated in "Forschungszentrum Jülich", whereas the industrial activities are concentrated within the HTR GmbH, a subsidiary of ABB and Siemens. Under the terms of their joint venture, ABB and Siemens pursue three types of HTR power plants for different market segments:

- the HTR-500, the power plant for electrical utilities (550 MWe),
- the HTR-Module, based on the established technology of the AVR reactor for heat and power for industry and public supplies (200 MWth),
- the GHR for decentralized district heating for homes and industry (10-20 MWth).

In support of the German HTR programme, test irradiations are being performed in the HFR Petten on materials which are typical for the HTR /1,2/:

- spherical fuel elements with low-enriched uranium (UO_2) TRISO coated particles, and
- graphite as a predominant core structural and fuel element matrix material.

Irradiation testing of fuel elements and graphite materials for the US-HTGR is as well being performed at the HFR Petten under the 'Umbrella Agreement' between Germany and USA.

a) Fuel Element Irradiations

Spherical fuel elements for the German HTR Programme

High Temperature Reactor (HTR) fuel testing is being performed at the HFR Petten on reference coated particle systems and production fuel elements for the German UO_2 low-enriched uranium (LEU) fuel cycle. The fuel elements are the reference 60 mm diameter spheres with LEU-TRISO coated particles, as developed by NUKEM/HOBEG in the framework of the 'High Temperature Fuel Cycle'- Project HBK for all future HTR applications in Germany /3,4/.
The irradiation testing of HTR reference fuel elements is performed in two phases. In Phase I, which is meanwhile completed, irradiation experiments were performed for different objectives such as particle failure, fission product transport, fuel element integrity etc. at target and extreme operating conditions. Not a single coated particle became defective in the sense of irreversibly increased fission gas release.
In phase II, 'near-to-production' fuel elements are being tested at the HFR Petten under conditions as close as reasonably achievable to different HTR power plant characteristics, including simulation of fuel reloading systems. The main objectives of the irradiation tests are the confirmation of low coated particle failure rates due to temperature, temperature transients /cycling, burnup and fast neutron fluence and the confirmation of low 'free heavy metal' (Uranium and Thorium) contamination of the fuel element matrix material by natural impurities and/or by particle failure, affected by manufacture.

Legend:

1 Design & calculation
2 Manufacture and commissioning
3 Irradiation
4 Dismantling & PIE
5 Upgrading

Table 6
HTR fuel irradiation experiments.
Survey of present and future activities

YEAR	1990	1991	1992	1993
1. Fuel Elements:				
D 138.05	2 3		4	
D 138.06	2	3		4
D 138.07	2	3		4
D 214.01	4			
2. Graphite spheres	1 2		3 4	
D 247.01				
3. Out-of-pile facilities	5			

Therefore, the irradiation capsules are operated with specially developed SWEEP-LOOPS for on-line measurements of the release of volatile fission products under a wide range ($10^{-10} < R/B < 10^{-1}$), as well as for on-line gas chromatographical analysis of the downstream carrier gas.
A survey of these activities at the HFR Petten is given in **table 6** /5/.

D 138.05/06, Reference tests for the HTR-MODULE:

Objectives:
These reference tests shall confirm the design fission product release data set for 'near-to-production' fuel elements under conditions which simulate realistic power reactor operating and multiple-pass fuel loading conditions of the HTR-MODULE /2/. The irradiation experiment D 138.05 is the first test in phase II on LEU TRISO reference HTR fuel element for the HTR-Module. Project coordinator is KFA Jülich and HBK/HTA-Project. Interatom GmbH is responsible for the test specifications.

Progress:
D 138.05

The irradiation of the first reference test for the HTR-Module with three independently controlled capsules (BEST-rig design /6/) started with cycle 90.06 for a planned irradiation duration of 23 HFR cycles.
The required irradiation conditions were achieved. On-line fission gas release measurements are performed daily. The initial fractional fission gas release of two capsules is in the range of 10^{-10} to 10^{-9}, which corresponds to the heavy metal contamination of the graphite matrix material.
The fractional fission gas release of one capsule (C) is in the range of 10^{-7} to 10^{-6}. This higher fractional fission gas release indicates manufacture caused coated particle failure. The fractional fission gas release (R/B) and the fuel temperature history versus irradiation time is shown for the irradiation cycles in 1990 **(fig.8).** Irradiation progress reports for the six cycles in 1990 were issued /7/. The irradiation is planned to continue until mid 1992.

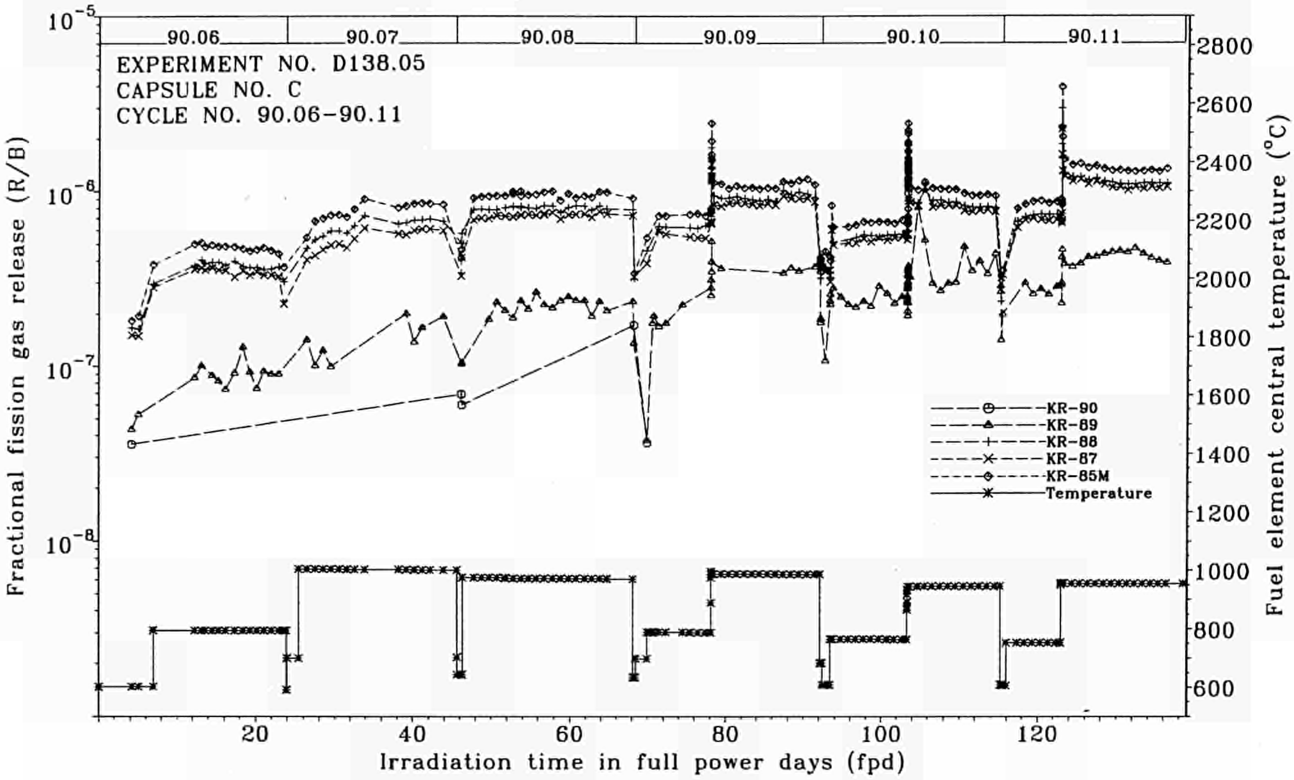


Fig. 8
Fractional fission gas release (R/B) and fuel temperature vs. time

D 138.06

The assembly and commissioning of the rig for the second reference reference test for the HTR-Module was completed in 1990. Preparations were terminated to start the in-pile irradiation with the first HFR cycle in 1991. The planned irradiation duration is 23 HFR cycles.

D 138.07, Reference test for the HTR-500:

Objectives:
This reference test shall confirm the design fission product release data set of the HTR-500 'near-to-production' fuel elements under irradiation conditions, which simulate as close as possibly achievable the realistic fuel element operating history concerning fission power, burn-up/ fast neutron fluence correlation and temperature (including temperature transients/ rampings) due to the 'once-through-then-out' (OTTO) fuel element loading conditions /4/.

Progress:
The manufacture of the rig parts was terminated in 1990. Irradiation start-up is planned for the second half of 1991.

D 247.01, Irradiation of SiC-coated graphite spheres:

Objectives:
SiC coating on the surface of spherical fuel elements has been proposed by KFA for a corrosion resistant spherical HTR fuel element. The irradiation behaviour of SiC-coated graphite spheres (without coated fuel particles) of 60 mm diameter will be examined by in-pile testing.
The test specimens shall be irradiated between 873-1273 K up to a fast neutron fluence (E >0.1 MeV) of $2.6\times10^{25} m^{-2}$ /9/.

Progress:
The design was completed in 1990. Problems, encountered in the preparation of the SiC coating of the graphite spheres delay the irradiation start to the end of 1991.

Irradiation of fuel rods for the US-HTGR

D 214.01, Irradiation of GA fuel rods in segments of the bloc-type fuel element.

Objectives:
This experiment is a joint effort involving General Atomics (GA) Technologies (USA), KFA-HBK Project and IAM Petten under the auspices of the US/FRG 'Umbrella Agreement'for co-operation in High Temperature Gas-Cooled Reactor developments for the TRISO-LEU fissile / TRISO-ThO_2 fertile US-HTGR reference fuel system. The overall objective of this irradiation test with three independent capsules is to obtain in a configuration and time frame, simulating expected HTGR operating conditions, experimental data on metallic fission product transport in and from matrix graphite and on the effects of temperature cycling (1000 - 1500 K) and water vapour injections (10^2-10^4 ppm) on fission gas release during the irradiation campaign /5/.

Progress:
The draft version of the final irradiation report and the quality assurance report were compiled /10,11/. The capsules were transported from Petten to KFA Jülich in November 1990 for fine-dismantling and PIE. The results of the gammaspectrometry activities at Petten were compiled in /12/.
The final irradiation report will be issued after results of neutron metrology, gamma-scanning and metrology of specimens are available.

b) Graphite Irradiations

In the frame of a graphite development and qualification programme a large number of graphite samples have been irradiated during more than 20 years in the HFR at Petten. The HFR graphite irradiation programme supplies the necessary design base for the German High Temperature Reactor Programme.
The irradiation capsules contain unstressed samples (fundamental properties) or creep specimens under tensile or compressive stress.
They are irradiated in three to four fluence steps, with intermediate measurement of their physical properties.
For the range between 573 and 1423 K, the neutron fluences have reached 2×10^{26} m^{-2} (EDN)*

Unstressed Graphite Experiments

Fundamental Properties Graphite Programme

Objectives:
Characterization of reflector and matrix graphites covering all relevant material properties:
- reflector material, aiming at very high neutron fluences, in the order of 2×10^{26} m^{-2} (EDN), at relatively low temperatures between 573 and 873 K.
- matrix material, for lower neutron fluences, in the order of 4×10^{25} m^{-2} (EDN) at higher temperatures, ranging from 773 to 1473 K.

* traditional graphite exposure unit ("Equivalent DIDO Nickel")

Progress:
Three experiments ended the irradiation in 1990. Post-irradiation measurements are presently on-going at KFA Jülich.
In detail:
- Experiment D 85-54, 573 K, follow-up of D 85-47 (reflector graphite) started irradiation in cycle 88.07 and ended in cycle 90.04 in reactor position C7, accumulating the neutron fluence 8 x $10^{25}m^{-2}$ (EDN) /13/.
  It is foreseen to continue the irradiation of the samples in the experiment D 85-64.
- Experiment D 85-55, 873K, follow up of D 85-57 (reflector graphite) started irradiation in cycle 90.03 and ended in cycle 90.10 in position C7, accumulating the neutron fluence 3.5 x $10^{25}m^{-2}$ (EDN) /14/.
- Experiment D85-58, 1023K started the irradiation in cycle 89.09 and ended in cycle 90.08 in reactor position C3. Samples of matrix material were irradiated up to 5 x 10^{25} m^{-2} (EDN) /15/.
- Experiment D85-56II, 723K foresees the irradiation of reflector material samples. The irradiation started in cycle 90.03 in position C7.
  It will continue until the samples will have reached a total neutron fluence of 12 x $10^{25}m^{-2}$ (EDN).

Graphite Creep Experiments D 156 DISCREET

Objective:
The graphite used for structural components of a High Temperature Reactor is subject to thermal and neutron flux gradients which generate stress. Irradiation creep, which relieves stress, is thus an important parameter in the design of these structures.
Various grades of graphite are being irradiated under stress in the HFR up to very high fluences and over the temperature range 570K to 1170K.
Creep measurements are taken out-of-pile at intervals of irradiation.

Progress:
The following activities have taken place in 1990.
D 156-90 Series ASR-1RS, 770K, 5MPa tensile stress.
This series was chosen for a temperature change experiment. The samples irradiated in the sample holder 156-93 at 770K up to fluence of about 15 x $10^{25}m^{-2}$ (EDN) have been re-encapsulated in a new sample holder (156-94) for an irradiation step at 1170K.

Irradiation, started in cycle 89.09, finished in cycle 90.02. Due to the extreme dimensional changes of the samples the foreseen second irradiation step at 1170K will not be performed.
A second temperature change experiment is ongoing.
Unirradiated samples encapsulated in a new sample holder (156-95), started irradiation at 1170K in cycle 90.09. Their irradiation will finish in cycle 91.06.

D156-50 Series ASR-1RG, 770K, 5MPa tensile stress.
Sample holder 156-53 continued irradiation uneventfully until the scheduled end of irradiation in cycle 90.05.

D156-70 Series 770K, 5MPa tensile stress. This is a stress mode change experiment in which samples are first irradiated under compression in the HFIR reactor and then under tension in the HFR. This pattern is representative of service conditions. Due to problems at the HFIR the experiment in the HFR has been delayed until the summer of 1992.

References:

/1/ J. Ahlf, R. Conrad, M. Cundy, H. Scheurer
"Irradiation Experiments on High Temperature Gas-Cooled Reactor Fuels and Graphite at the HFR Petten"
Journal of Nuclear Materials 171 (1990), 31-36

/2/ N. Kirch, H.U. Brinkmann, H. Nabielek
"Bestrahlungserprobung von HTR-Komponenten. Stand und zukünftige Anforderungen"
Proceedings of a Colloquium held in Petten, EUR 12522 (1989)

/3/ A.W. Mehner, W. Heit, K. Röllig, H. Ragoss and H. Müller
"Spherical Fuel Elements for Advanced HTR. Manufacture and Qualification by Irradiation Testing"
Journal of Nuclear Materials 171 (1990), 9-18

/4/ H. Nabielek, W. Kühnlein, W. Schenk
"Development of Advanced HTR Fuel Elements"
Nuclear Engineering and Design, 121 (1990), 199-210

/5/ J. Ahlf, A. Gevers, editors
"Annual Report 1989. Operation of the High Flux Reactor Petten"
EUR 12881 EN (1990)

/6/ R. Conrad
"Design and Safety Report D 138.05",
Technical Note P/F1/90/11, 1990

/7/ R. Conrad, J. Thiel, Th. Timke, Zhu Junguo
"Irradiation Progress Reports no.1 - 6"
Technical Memoranda HFR/90/3103, -3122, -3133, -3141, -3154, 3164

/8/ G.H. Lohnert, H. Ragoss
"The Properties of Spherical Fuel Elements and its Behaviour in the modular HTR"
Presented at the Specialist's Meeting on 'Gas-Cooled Reactor Development and Spent Fuel Treatment', Moscow, USSR, October 1983

/9/ R. Conrad
"Irradiation Proposal D 247.01"
Technical Memorandum HFR/89/2957"

/10/ R. Conrad, D. Burnette
"Irradiation of GA HTGR Fuel Rods at Real Time Simulating"
Operating Conditions in the HFR Petten"
Technical Memorandum HFR/90/3082, 1990

/11/ R. Conrad, D. Burnette
"Quality Assurance Report for the Irradiation of GA HTGR Fuel Rods in the HFR Petten"
Technical Memorandum HFR/90/3084, 1990

/12/ G. Dassel, H.A. Buurveld
"Gammaspectrometry of experiment D 214.01"
ECN-CX-90-044, August, 1990

/13/ P. Fraipont, G.P. Tartaglia
"D85-54 Abschlussbericht"
Technical Note P/F1/90/18
/14/ P. Fraipont, G.P. Tartaglia
"D85-55 Abschlussbericht"
Technical Note - to be printed
/15/ P. Fraipont, G.P. Tartaglia
"D85-58 Abschlussbericht"
Technical Note - to be printed
/16/ M. Cundy, G. Sordon
"Irradiation Induced Creep in Graphite. HFR Experiment D 156 DISCREET Experimental Results"
Technical Note - to be printed

3.4. FUSION REACTOR MATERIAL IRRADIATIONS

Fusion is regarded as one of the promising long term energy options. Important efforts are ongoing wordwide to promote this option. Whereas the larger share of the resources is still spent on programmes to demonstrate the physical feasibility, it is meanwhile fully realized that it is essential to expand the effort on technology. The HFR plays since a long time a major role as test bed for fusion materials irradiations.
The different fusion related projects are incorporated into the European Fusion Technology Programme and form part of the R & D work towards the NET design and towards future demonstration plants. Some of the experiments now under preparation also fall into a test matrix set up in August 1981 under the "IEA implementing agreement for a programme of research and development on radiation damage in fusion materials" (Paris, 1980). The present generation of irradiation experiments mainly concerns creep, fatigue and crack growth in austenitic stainless steel together with research on vanadium alloys, as well as on breeding and structural ceremics and on liquid breeder material.

Unstressed Austenitic Stainless Steel (incl. AMCR) Irradiations.

R 139 Series

Objectives:
ECN participates in the frame of the Commission's cost shared action in the European Fusion Reactor Materials Programme.
A number of candidate materials' properties are determined and presented as a comparison between irradiated and non-irradiated specimens with identical heat treatment. Crack propagation and fracture toughness are obviously the main areas of interest. In order to save irradiation space and limit the temperature gradients in the specimens caused by gamma heating, most specimens are of the compact tension type.

Progress:

R 139-65

This is an irradiation for martensitic steel at three different irradiation temperatures, 500K, 600K and 700K, at different fluence levels.

CYCLE NO: 90-02 "D A C O S S Y S T E M" DATE: 09:27:09 6-APR-90

ANALYSIS BY ENGINEERING UNITS FOR PERIOD FROM: 00:00:00 8-FEB-90 TO 17:50:00 5-MAR-90

EXPERIMENT NO. : R139-654
NAME : SINAS
START DATE : 09-02-89
REACTOR LOCATION: D2
GAS PANEL USED : TRIO-F

NOMINAL DEGREES "C": 270.00
SAMPLE :
STRESS MODE :
DATA LOGGER NUMBER : 2
RECORD INTERVAL : 10 MINUTES

CHAN NO.	MEASUR'G POINT NAME	ENG'RING UNIT	ANALYSIS OF MEASURING POINT (BY ENGINEERING UNITS) AVERAGE	MINIMUM	MAXIMUM	STANDARD DEVIATION	STANDARD ERROR	TOTAL RECORD	ANALYSIS OF DATA RECORDS (BY PERCENTAGE) REACTOR < 43.MW	NO DATA	< LOW LIMIT	> HIGH LIMIT	WITHIN LIMITS
634	TC12	Deg. C	269.51	212.33	279.27	4.361	0.072	3708	0.86	0.00	0.03	0.00	99.11
633	TC11	Deg. C	266.64	210.06	276.15	4.409	0.073	3708	0.86	0.00	0.03	0.00	99.11
632	TC10	Deg. C	259.42	206.30	264.98	3.003	0.050	3708	0.86	0.00	0.03	0.00	99.11
631	TC9	Deg. C	259.20	205.89	264.73	3.034	0.050	3708	0.86	0.00	0.03	0.00	99.11
630	TC8	Deg. C	261.63	210.14	264.60	1.762	0.029	3708	0.86	0.00	0.03	0.00	99.11
629	TC7	Deg. C	258.74	208.11	261.71	1.765	0.029	3708	0.86	0.00	0.03	0.00	99.11
628	TC6	Deg. C	239.88	194.66	242.83	1.569	0.026	3708	0.86	0.00	0.19	0.00	98.95
627	TC5	Deg. C	255.18	205.73	258.18	1.554	0.026	3708	0.86	0.00	0.03	0.00	99.11
626	TC4	Deg. C	251.37	202.54	255.81	2.090	0.034	3708	0.86	0.00	0.05	0.00	99.08
625	TC3	Deg. C	248.14	200.64	252.35	2.162	0.036	3708	0.86	0.00	0.11	0.00	99.03
624	TC2	Deg. C	250.09	200.59	255.27	2.775	0.046	3708	0.86	0.00	0.11	0.00	99.03
623	TC1	Deg. C	245.45	197.96	251.04	3.040	0.050	3708	0.86	0.00	1.27	0.00	97.87

RELATIVE POSITIONAL GRAPHIC REPRESENTATION OF ABOVE ENGINEERING UNITS.

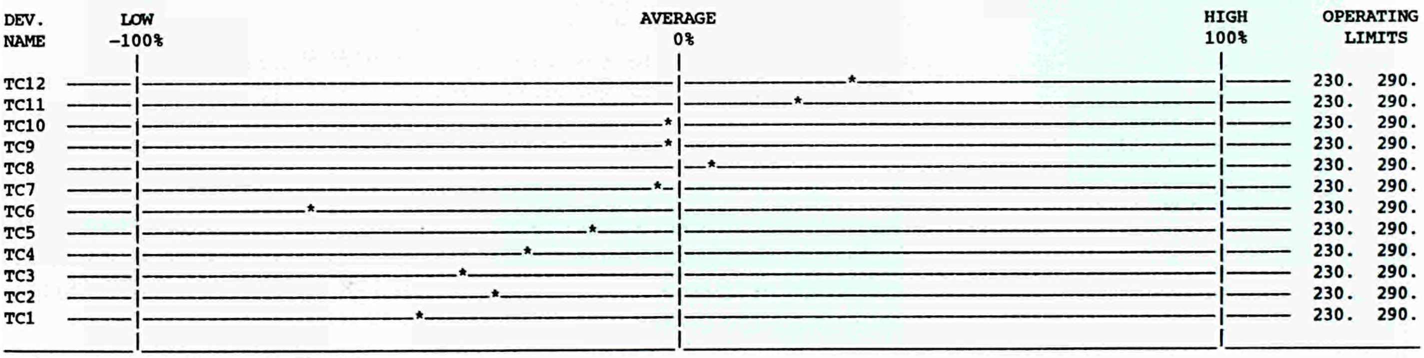


Table 7
R139-654. Typical statistical analysis of a temperature distribution in a reactor cycle (90.02)

The specimens are designed to be irradiated in TRIO 129 legs. The 600K and 700K are planned for 10 dpa and occupy two legs of a TRIO 129 in E3 position, whereas there are three different legs to be irradiated at 500K: the first one at 0.5 dpa, the second at 2.5 dpa and the third at 7 dpa. Irradiation of the first leg (500K and 0.5 dpa) started in 88.02 and terminated in 88.03 in E3. Irradiation of the remaining two legs (500K, 2.5 and 7 dpa) started in 88.06 in D2 position and finished in 90.02.
A typical statistical analysis of the temperature distribution during a reactor cycle is presented in **table 7.**

R 139-66

This irradiation will accommodate NET construction material. 40 CT specimens, 10 tensile and 20 fatigue will be irradiated in core position E7 at low temperature. The damage required is about 5 dpa.
The specimens will be in contact with the reactor coolant in a REFA 170.

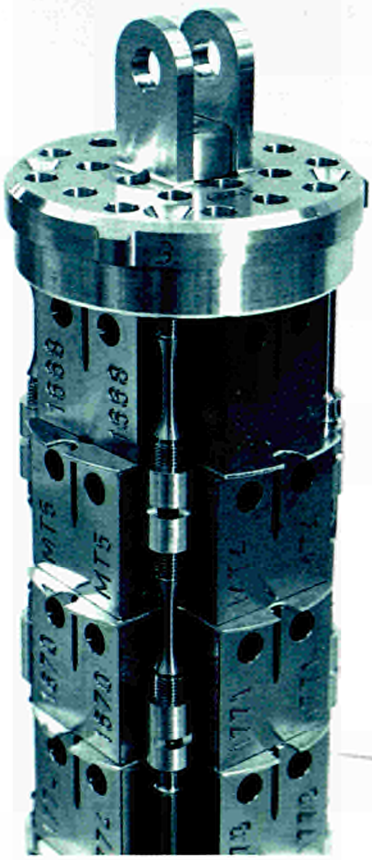


Fig. 9
Loading arrangement of experiment 139-66

Irradiation started in cycle 90.06. The loading arrangement of the experiment is shown in **fig. 9.**

R 139-69

This experiment consists of 6 sample holders with 10 CT specimens in each holder. Three sample holders are planned for 0.3 dpa at 525K and three for 5 dpa at 525K. Irradiation started in cycle 90.07. A typical temperature distrubution is presented in **table 8.**

E 198-14,15,16, R 139-68 in SIENA

Objective:
In the year 1985, the NET Team stressed the need for a very high dose irradiation of first wall candidate materials. For this purpose a special irradiation facility was developed, fulfilling the following requirements:
- Irradiation temperatures: in the range 423K - 773K for stainless steel.
- Helium/dpa ratio as close as possible to 13 for austenitic steel (NET operating conditions) which can only be obtained in a special capsule, calculated and designed for "spectrum tailoring".

The design was given the name SIENA, standing for Steel Irradiation in Enhanced Neutron Arrangement.
The parties involved in the irradiation are:

JRC-IAM, Ispra	: tensile samples (316L, AMCR, Cu and Cu-Cr-Zr)
KfK-IMF, Karlsruhe	: tensile and charpy samples (DIN 1.4914)
ECN, Petten	: tensile and fatigue samples of 316L and vanadium alloys

The duration of the irradiation (experiment E198-14) was initially fixed to 35 dpa in stainless steel. The targets of NET changed and the experiment was concluded at 15 dpa. Other experiments (E198-15, E198-16, R139-68) presently share the device.

Table 8
R139-694. Typical statistical analysis of a temperature distribution in a reactor cycle (90.11)

CYCLE NO: 90-11 "D A C O S S Y S T E M" DATE: 12:15:23 10-JAN-91

ANALYSIS BY ENGINEERING UNITS FOR PERIOD FROM: 16:00:00 13-DEC-90 TO 07:30:00 7-JAN-91

EXPERIMENT NO. : R139-694
NAME : SINAS
START DATE : 14-12-90
REACTOR LOCATION: F8
GAS PANEL USED : TRIO-D

NOMINAL DEGREES "C": 250.00
SAMPLE :
STRESS MODE :
DATA LOGGER NUMBER : 1
RECORD INTERVAL : 10 MINUTES

CHAN NO.	MEASUR'G POINT NAME	ENG'RING UNIT	ANALYSIS OF MEASURING POINT (BY ENGINEERING UNITS) AVERAGE	MINIMUM	MAXIMUM	STANDARD DEVIATION	STANDARD ERROR	TOTAL RECORD	ANALYSIS OF DATA RECORDS (BY PERCENTAGE) REACTOR < 43.MW	NO DATA	< LOW LIMIT	> HIGH LIMIT	WITHIN LIMITS
138	TC10	Deg. C	251.57	163.70	257.03	9.109	0.158	3550	6.87	0.00	2.90	0.00	90.23
137	TC9	Deg. C	251.74	163.60	257.16	9.144	0.159	3550	6.87	0.00	2.90	0.00	90.23
136	TC8	Deg. C	250.53	174.77	254.23	7.378	0.128	3550	6.87	0.00	2.90	0.00	90.23
135	TC7	Deg. C	248.60	173.37	252.02	7.338	0.128	3550	6.87	0.00	2.90	0.00	90.23
134	TC6	Deg. C	256.23	193.23	259.32	5.576	0.097	3550	6.87	0.00	0.11	0.00	93.01
133	TC5	Deg. C	256.16	192.74	259.33	5.620	0.098	3550	6.87	0.00	0.17	0.00	92.96
132	TC4	Deg. C	254.96	201.36	257.78	4.212	0.073	3550	6.87	0.00	0.08	0.00	93.04
131	TC3	Deg. C	254.83	201.65	257.81	4.281	0.074	3550	6.87	0.00	0.08	0.00	93.04
130	TC2	Deg. C	249.79	201.91	252.99	3.868	0.067	3550	6.87	0.00	0.11	0.00	93.01
129	TC1	Deg. C	249.61	201.70	253.02	3.873	0.067	3550	6.87	0.00	0.11	0.00	93.01

RELATIVE POSITIONAL GRAPHIC REPRESENTATION OF ABOVE ENGINEERING UNITS.

DEV. NAME	LOW -100%	AVERAGE 0%	HIGH 100%	OPERATING LIMITS	
TC10				225.	275.
TC9				225.	275.
TC8				225.	275.
TC7				225.	275.
TC6				225.	275.
TC5				225.	275.
TC4				225.	275.
TC3				225.	275.
TC2				225.	275.
TC1				225.	275.

Progress:
The irradiation of the SIENA capsule continued, as scheduled, in HFR position C5.

All the sample holders belonging to the experiment E198-14 (sponsors: JRC-IAM-MPAR and KfK-IMF) ended the irradiation having reached the scheduled damage (5, 10 or 15 dpa).
An overview of the sample holders unloaded is given in **table 11.**
Post irradiation experiments (tensile, creep, charpy) are presently ongoing on the samples.
Details about irradiations can be found in the reports /3,4,5/.

Two new experiments, E198-15, E198-16, sponsored by JRC-IAM-MPAR, are under irradiation in the capsule. The goal of the irradiation is to establish the irradiation effects on low activation materials.
As illustrated in **table 9,** they are austenitic stainless steel in which nickel is replaced by manganese (AMCR steels).

They offer the advantage of lower long term activation, compared to Cr-Ni steels. Moreover, because of the absence of Ni, the amount of helium produced during irradiation will be much less and the material will suffer less from helium induced embrittlement. These materials have also a better corrosion resistance against helium than the traditional Cr-Ni steels.

Table 9
Chemical composition of optimized Cr-Mn stainless steels

	IF-A	IF-B	IF-C	IF-D	IF-E
			(wt%)		
Cr	13.57	12.37	13.14	10.24	17.86
Mn	11.34	10.62	18.00	16.92	11.00
Ni	2.04	0.23	2.14	0.13	2.08
Mo	0.031	0.023	0.037	0.026	0.041
C	0.10	0.31	0.10	0.26	0.08
N	0.047	0.036	0.042	0.080	0.054
Si	0.20	0.17	0.20	0.50	0.30
V	0.63	0.64	0.021	0.032	0.74
W	1.42	1.38	1.92	2.04	2.02
			(ppm)		
S	70	70	50	30	70
P	130	140	130	80	140
Cu	370	290	360	240	370
Al	30	30	30	45	40
Nb	50	50	50	50	50
Ta	50	50	50	50	50
Pb	2	1	2	1	1.5
Co	220	200	210	200	220
B	3	3	3	3	3
Bi	1	1	1	0.5	1
Ag	1	1	1	1	1
Ti	10	10	10	20	10

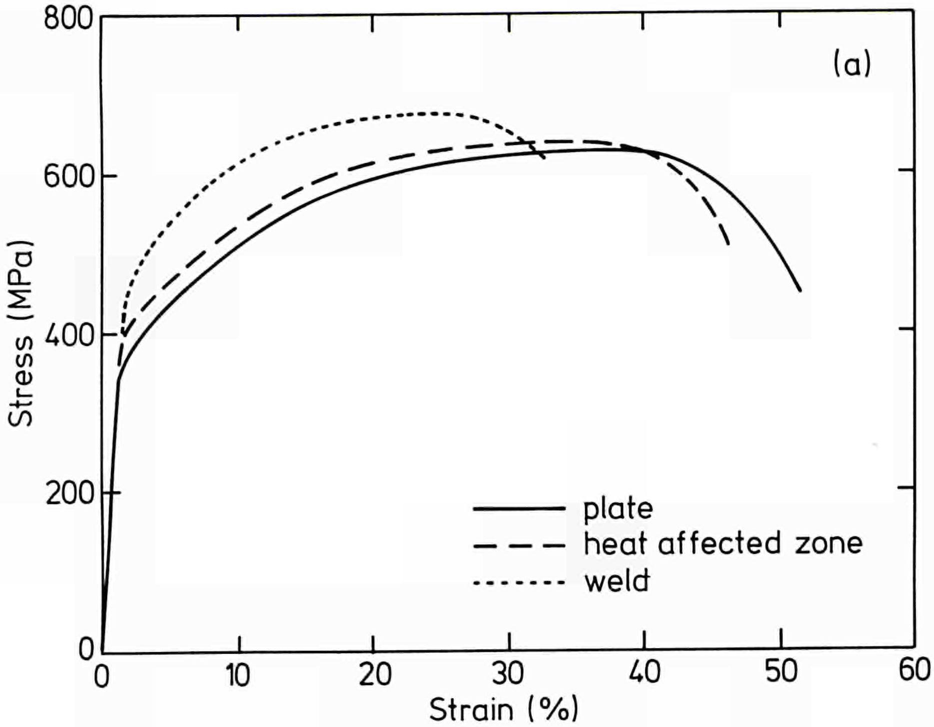


Fig. 10
Selected experimental stress-strain curves (SIENA).
Specimens tested at 20⁰C; strain rate $10^{-3}s^{-1}$; irradiation conditions: 550⁰C, 2.7 dpa

Tensile samples of the various alloys are irradiated at 523K and 723K up to two different damage values (10 and 25 dpa). The various components of the first wall must be assembled using various procedures (welding, brazing etc). It is important to investigate the irradiation behaviour of the joints. In this respect, tensile tests have been performed on samples (316 welded joints) irradiated in the past in the SIENA capsules and in other devices. The evaluation of the test results is being done in collaboration with the IAM-MPAR Division. Comparison studies on the welding areas (parent metal, heat affected zone, welding) have been reported in /1/. An extended study on the parameters of the constitutive equations of the plastic flow of such materials have also been performed /2/. Selected experimental stress-strain curves are shown in **fig. 10.** Three sample holders, containing tensile samples of the experiment R139-68, sponsored by ECN, started irradiation in the capsule during 1990, to reach 5dpa of total damage. Composition of the materials irradiated is given in **table 10.**

Table 10
Chemical composition (wt%) of the European 316L reference heat ERHI and ERHII

	ERHI		ERHII	
	Specified Limits	Measured Values	Specified Limits	Measured Values
C	≤0.03	0.021	≤0.03	0.019
Cr	17/18	17.5	17/18	17.25
Ni	12/12.5	12.3	12/12.5	12.17
Mo	2.3/2.7	2.41	2.3/2.7	2.31
Mn	1.6/2.0	1.79	1.6/2.0	1.75
N	0.06/0.08	0.059	0.06/0.08	0.074
Si	≤0.5	0.43	≤0.5	0.35
Cu	<1.0	0.21	<0.3	0.07
Co	<0.25	0.18	<0.10	0.078
S	<0.025	0.009	<0.01	0.0006
P	<0.035	0.029	<0.035	0.019
Ta	<0.15	0.05	<0.15	0.002
B	<0.0025	0.0023	<0.0015	0.0009

Table 11
Unloaded samples of E 198-14

Legend:
Sample Type: 1 = Tensile Samples;
2 = Charpy Samples
Sample Material: A = AISI 316L;
B = 1.4914 St. Steel;
C = AMCR;
D = Copper;
E = Cu/Zr alloy

Chan nr.	Irrad Temp (^{0}C)	dpa	Client	Sample mat	Sample type	Sample holder	Irrad. start	Irrad. end
1	300	15	JRC/KfK	A+B	1+2	A1	87.11	90.06
2	350	15	JRC/KfK	A+B	1+2	A1	87.11	90.06
4	400	15	JRC/KfK	A+B	1+2	A1	87.11	90.06
5	450	15	JRC/KfK	A+B	1+2	A1	87.11	90.06
6	250	10	JRC	C	1	A1	87.11	89.10
7	300	15	JRC	A	1	A1	87.11	90.06
9	350	15	JRC	A	1	A1	87.11	90.06
10	400	15	JRC	A	1	A1	87.11	90.06
11	475	15	KfK	A	1+2	A1	87.11	90.06
13	450	15	JRC	A	1	A1	87.11	90.06
14	250	15	JRC/KfK	B	1+2	A1	87.11	90.06
18	300	5	KfK	B	1+2	A1	89.09	90.06
19	300	10	KfK	B	1+2	A1	88.10	90.06
20	400	10	KfK	B	1+2	A1	88.10	90.06
21	475	10	KfK	B	1+2	Cu	88.10	90.06

Irradiation history (0.6 dpa) has been reported in /6/.

An overview of the present occupation of the SIENA capsule is given in **table 12.**

Table 12
Present stituation.
Occupation of the SIENA capsule - reactor position C5

Legend:
Sample Type: 1 = Tensile Samples;
2 = Charpy Samples
Sample Material: A = AISI 316L;
B = 1.4914 St. Steel;
C = AMCR;
D = Copper;
E = Cu/Zr alloy

Chan nr.	Irrad Temp (^{0}C)	dpa	Client	Sample mat	Sample type	Sample holder	Irrad. start	Irrad. end
1	250	0.6	ECN	A+B	1	A1	90.06	90.06
2	250	5	ECN	A+B	1	A1	90.06	91.03
4	250	5	ECN	A+b	1	A1	90.06	91.03
5	250	10	JRC	C	1	A1	90.06	92.01
7	250	25	JRC	C	1	Cu	90.06	94.01
10	450	10	JRC	C	1	Cu	90.06	92.01
13	450	25	JRC	C	1	A1	90.06	94.01
15	250	10	JRC	C	1	A1	89.09	91.03
16	250	25	JRC	C	1	A1	89.09	93.03
17	450	10	JRC	C	1	Cu	89.09	91.03
22	450	25	JRC	C	1	Cu	89.09	93.03

Other channels: dummies

Creep Testing of Fusion Materials (Austenic Stainless Steel)

Objective:

Austenitic stainless steels have been considered as candidate structural materials for the First Wall of NET.

Manganese containing steels (AMCR) are developed within the scope of the fusion materials programme of the JRC because the helium production rate of these alloys is smaller, the corrosion resistance against lithium is better, and the neutron activation is lower compared to nickel based austenitic stainless steel alloys.

In order to study the effects of neutron irradiation on the creep behaviour of these materials and on nickel-based steels such as 316-CE reference, US 316 and US PCA steels two irradiation creep facilities were developed for the HFR at Petten (namely TRIESTE and CRISP).

Progress:

E167 TRIESTE
Intermittent Creep Measurement (MAT-5)

The entire experimental TRIESTE programme comprises seven irradiation facilities where each facility is irradiated for eight steps or more and dimensional measurements on the individual tensile samples are performed in hot-cells between the irradiation steps.

The irradiation series E 167-10, E 167-20, E 167-30, E 167-40, E 167-50, E 167-60, E 167-70 and E 167-80 are distinguished by the type of sample material, the irradiation temperature (between 350 and 673 K) and the applied stresses (between 25 and 300 MPa) during the irradiation. Irradiation samples and half-shell pairs are manufactured from nine different materials (AMCR-0033, AMCR-0034, AMCR-0035, AISI 316L, AISI 316, DIN 7758, DIN 7761, DIN 7763, PCA).

The irradiation history of the TRIESTE series is shown in **table 13.**

Table 13
Damage obtained in TRIESTE experiments at the end of 1990

TRIESTE series	Irradiation Start [HFR-cycle]	Damage obtained [dpa]
E 167-10	83.10	6.0
E 167-20	85.03	6.9
E 167-30	85.06	3.9
E 167-40	87.09	4.2
E 167-50	88.04	3.0
E 167-60	88.07	2.1
E 167-70	90.03	0.6

The following activities were pursued during the reporting period:

- Irradiations continued in 1990. Experiments E 167-19, E 167-47, E 167-56 were irradiated for three HFR cycles and the experiment E 167-29 for four cycles.
  In the same period the experiments E 167-55, E 167-65 were irradiated for two cycles and the experiments E 167-71, E 167-72, E 167-48 for one cycle.
- Creep elongations of individual samples of the experiments E 167-19, E167-29, E 167-47, E 167-55, E 167-65, E 167-71 and E 167-72 were measured in hot cells using semi-automatic measuring devices.
- E 167-80 series.
  Irradiation of stainless steel samples at low temperature (about 350K) has been delayed to 1991 due to accidental damage of a component during assembly.

E 157 CRISP
In-Pile Creep Measurement (MAT-5)

In the irradiation device CRISP the creep elongation of three specimens in three different rigs can be measured simultaneously. Strain measurements are taken semi-continuously by comparing the sample lenght with the lenght of an unstressed reference piece of the same material.
All three rigs, combined in one standard TRIO irradiation facility, are independent with respect to the irradiation temperature and the applied stresses.
The experimental programme comprises three irradiation thimbles with a total of nine individual creep rigs.

E 157/11-13
The irradiation of a second set of three sample holders started in cycle 90.07. The irradiation temperature is the same for the three legs (673K). The applied stresses are respectively 100 MPa, 100 MPa and 50 MPa. The material is AISI 316L. Irradiation end is planned in cycle 91.04.
The strain measurement system has not properly worked in two legs for a part of the irradiation.

Irradiation of SuperConducting Materials

D 202 SUPRA

Objective:
In these experiments materials are being irradiated whose changes under irradiation give data on the behaviour of the coil and structure materials in superconducting magnets of fusion reactors.

Progress:
Sponsered by KfK-ITP, various materials like V_3Si, $PbMo_8S_6$ and $TlCa_3Ba_2Cu_3O_7$ have been investigated in the past.
Specimens of $YBa_2Cu_3O_7$ are currently irradiated at 323K and up to 10^{23} n m^{-2} (E > 1MeV).
Irradiations are performed with a Cd screen surrounding the samples to filter thermal neutrons and to minimize activation of the samples which can

be analyzed in the laboratory. Critical current measurements performed after irradiation show an increase of superconducting properties due to neutron effect /9/.

Irradiation of Vanadium Alloys

R 204 VABONA

Objective:
The ECN Project 1.624 foresees the "Radiation Damage Investigation of Vanadium for Fusion Reactors" and, more specifically, the assesment of the viability of boron doping of metals, prior to neutron irradiation, as a means of simulating the effects of fusion reactor irradiation. The irradiation damage of materials in the flux regions of a fusion reactor will be characterized by the high amount of helium produced simultaneously with the atomic displacement. Whereas in fission and fusion reactors the displacement rates are of a comparable order of magnitude, the production rate of helium in a fusion device is much larger because of the higher energy of the neutrons.
As the irradiation of materials with these neutrons is at present possible only on a very limited scale, and as the need for materials data for fusion reactors is growing, simulation of the effects is a necessity.
Relevant simulation requires that helium generation and atom displacement which are considered to be most damaging, are introduced in the material in a realistic ratio, preferably simultaneously.
Doping the candidate materials with a certain amount of boron, prior to irradiation seems to be a way to approach realistic fusion reactor irradiation damage: The boron-10, with its high cross section for fission neutrons, will provide for an increased helium generation, bringing the relation between dpa and helium production close to "realistic" values.

Progress:
Three new experiments R 204-07/08/09 have been launched in 1987. Due to problems concerning the production of new vanadium alloys, the client has not yet delivered the samples. The irradiation start is forseen in 1991. The sample holders will be irradiated at three different temperatures (873, 973, 1073K) up to 5 dpa.

Blanket Breeder Materials Irradiations

Within the European Fusion Technology Programme on Blanket Breeder Technology three experimental programmes are carried out at the HFR Petten, namely EXOTIC, LIBRETTO and ELIMA. The tritium breeding blanket materials are either ceramic lithium compounds or the eutectic alloy Pb-17Li.
The main objectives of these irradiation tests are:
- study of tritium release kinetics by in-situ tritium release measurements,
- irradiation damage studies,
- compatibility studies up to high Li burnup,
- tritium permeation studies through reference cladding materials,
- study of tritium extraction methods,
- study of tritium permeation barriers.

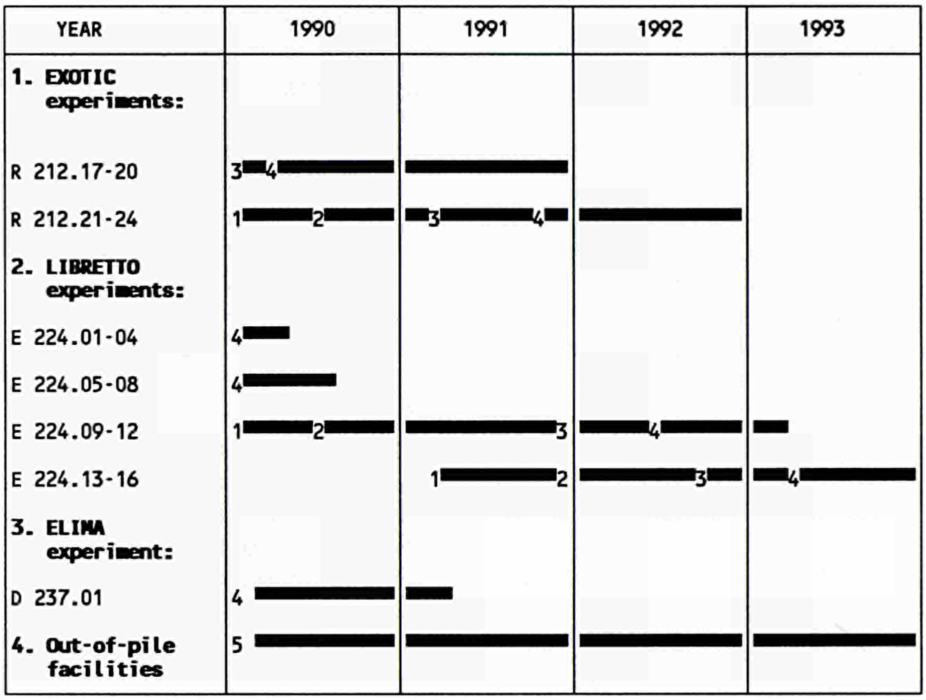


Table 14
Fusion blanket breeder experiments. Survey of present and future activities

Legend:
1 Design & calculation
2 Manufacture and commissioning
3 Irradiation
4 Dismantling & PIE
5 Upgrading

The results of these experiments are relevant for the selection of candidate blanket breeder materials and for the design of blanket concepts for future fusion reactors (e.g. NET, ITER).
The HFR Petten activities on blanket breeder irradiations are summarized in **table 14.**

R 212 EXOTIC Irradiation of ceramic lithium compounds

The experimental programme EXOTIC is being carried out since 1984 as a joint project by ECN Petten, NRL Springfields, SCK/CEN Mol in cooperation with IAM Petten. The Fusion Technology Steering Committee (FTSC) decided to concentrate the European effort within the 1988-1992 European Fusion Technology Programme. Therefore, three other European laboratories, namely CEA Saclay, KfK Karlsruhe and ENEA Casaccia joined the EXOTIC project in 1988. More insight is needed on mechanisms and kinetics of tritium release and on irradiation damage. Three categories of irradiation experiments were defined, namely "short-, medium-, and long-term" irradiations. All candidate ceramic tritium breeding materials should be tested in these tests. The 'medium-term' experiments (EXOTIC-5/6 in the programme period) should be performed at the HFR Petten. 'Medium-term' experiments are defined as those which achieve a Li burnup of ~ 1%.
The EXOTIC programme comprises manufacture, characterization, irradiation and pre- and post-irradiation examination of the Li-compounds $LiAlO_2$, Li_2SiO_3, Li_4SiO_4, Li_2O, Li_2ZrO_3, $Li_6Zr_2O_7$ and Li_8ZrO_6 with a variety of specific characteristics. The present EXOTIC programme consists of six irradiation experiments. Five experiments were performed until 1990 at the HFR Petten /10,11,12/. PIE is presently being performed at the participating laboratories.

EXOTIC-5 R 212.17-20

Objectives:
The objectives of the EXOTIC-5 experiment are:
- Comparison of tritium release characteristics and irradiation behaviour of eight different ceramic materials, in-pile tested in eight independently purged and controlled capsules,
- Determination of tritium release properties as a function of temperature, burnup and purge gas chemistry,
- Selection of final fabrication processes for ceramic materials to be tested in 'long-term' irradiations.

Progress:
The irradiation was terminated in 1990 after 6 HFR cycles, i.e. 135.67 full power days. Approx. 500 temperature transients were performed between 300 and 650 C at different Li burnup steps and with different purge gas chemistry to obtain data on tritium release kinetics. The irradiation data were compiled in /10,13,14/ and published at the 16th SOFT conference in London in 1990 /15/. PIE started in 1990 at the Hot Cell laboratories of ECN.

EXOTIC-6 R 212.21-24

Objectives:
The EXOTIC-6 experiment is the second 'medium-term' experiment within the 1988-1992 Fusion Technology Programme. Two laboratories have withdrawn from the programme, namely SCK/CEN and NRL.
The EXOTIC-6 experiment comprises eight different materials in eight independent capsules. The objectives are almost similar with EXOTIC-5. More emphasis is laid on effects of purge gas chemistry on tritium release /16/. The EXOTIC-6 experiment will be provided with advanced techniques for temperature control and in-situ tritium reduction beds to reduce traces of HTO in HT.

Progress:
Design work for the EXOTIC-6 experiment was completed in 1990 and fabrication and assembly started in 1990. Irradiation during six cycles is planned for 1991.

D 237.01 ELIMA Irradiation of ceramic lithium compounds under a fast neutron spectrum

Objectives:
KfK Karlsruhe has set up a comparative irradiation programme to study the effects of irradiation damage by fast neutrons and by tritium and alpha-recoil particles on a variety of ceramic breeder materials of different laboratories.
Therefore, one experiment was performed in a mixed neutron spectrum at the OSIRIS materials testing reactor at Saclay. Another experiment was performed at the HFR Petten under a quasi-fast neutron spectrum, which was obtained by enclosing the test specimens with a thermal neutron absorber screen (cadmium).

Progress:
The report on gamma-scanning, performed by ECN, was issued /17/. The final irradiation report is under preparation.

E 224 LIBRETTO Irradiation of liquid blanket breeder material, Pb-17Li

Objectives:
The experimental programme LIBRETTO is being carried out as a joint programme between JRC Ispra and CEA Saclay in co-opeartion with IAM Petten. The programme consists of four irradiation experiments. The objectives of the LIBRETTO experiments are the in-pile testing of the eutectic alloy Pb-17Li in a mixed neutron spectrum to assess tritium release kinetics, tritium extraction methods, compatibility studies and tritium permeation through reference stainless steel cladding with and without permeation barriers.The results of the LIBRETTO experiments are relevant for the design of liquid blanket breeder concepts for future thermo-nuclear fusion reactors.

Progress:
The work for the first two experiments was completed in 1990 /18-20/.
The main conclusions are:
Steady state tritium release by sweeping and permeation was observed at temperatures >580 K.
The temperature dependence of the tritium residence times can be described by an Arrhenius law for capsules with different cladding materials; a single activated process is observed in the temperature range 560 - 760 K for all capsules. The tritium residence times are significantly influenced by the cladding material and not by the plenum volume.
The aluminide permeation barrier shows promising and consistent performance under irradiation. The increase in tritium residence times becomes significant at temperatures <570 K.
Gas bubble formation in the alloy of closed capsules can lead to significant alloy volume increase and thus reduce the alloy density.
The retained tritium quantity in the alloy of <0.03 mCi/g confirms the low capability of Pb-17Li to confine tritium.
The calculated and measured tritium production rates are in good agreement. The predicted ^{210}Po generation is in good agreement with the measured data.

LIBRETTO-3 E 224.09-12

Objectives:
The LIBRETTO-3 experiment comprises four independent capsules filled with static Pb-17Li. The capsule wall material is AISI 316L. Three capsules will be coated by a tritium permeation barrier, either on the outside or on the inside of the capsule tube. The main objective of this experiment is to study the tritium release and extraction from the alloy by either bubbling a high-purity purge gas directly through the alloy or by purging the outer surface of the closed capsules and measure the tritium permeation rates. These experiments will be performed in-pile with in-situ tritium release measurements, within a temperature range of 350 to 450^{0}C and with a variation of the purge gas chemistry.

Progress:
The design of the third LIBRETTO experiment /21/ was completed in 1990. The assembly is in progress and will be terminated by the beginning of 1991. The irradiation is planned for five cycles, to start in 1991.

Irradiation of Ceramic First Wall and Insulators Material

D 217 CERAM

In the frame of the European Fusion Reactor Materials Research Programme (MAT6/MAT13), different ceramics are investigated as candidate materials for the first wall protection of NET.
The experiment is part of a joint programme including CEA Saclay and KfK Karlsruhe. Two other experiments are performed in OSIRIS (Saclay) and PHENIX (Marcoule).

In the first wall of a nuclear fusion reactor, non-metallic materials are eligible for use as limiters and liners. These components require high heat resistance - i.e. primarily a very high melting point and good resistance to thermal shocks. As the losses of radiation energy from the plasma rise substantially with the atomic number of plasma impurities, only materials with low atomic weights are admitted.
Graphite and SiC are favoured materials. All the other high melting compounds of light atoms exhibit serious drawbacks: borides because of high (n,α) helium generation under neutron irradiation, nitrides due to $^{14}N(n,p)^{14}C$ reactions and dissociation at elevated temperatures, oxides on account of their low thermal and low electric conductivities, the latter compounds being suspected of promoting arc discharges between the plasma and the wall.

The decision about whether graphite and SiC are actually suited can be made only after the crucial conditions in the fusion reactor and their impacts on the behaviour of the components have been taken into consideration. Primarily thermal loading has to be considered the consequences of which are influenced by neutron irradiation from the fusion plasma too.

Materials are selected on the basis of their stability against neutrons. They must keep their dimensional integrity, mechanical and thermal properties when irradiated with neutrons up to a flux of $\geq 10^{22}$ neutrons/cm^2. It is known that graphite with good behaviour against neutrons should: be isotropic, have a high tensile strength, have a low thermal expansion coefficient, be well graphitized and have a good resistance to thermal shock.
The selected materials are different types of graphite and SiC. Four kinds of fine grain graphites coated or not with SiC and two kinds of sintered SiC are irradiated. The material properties that will be examined in post irradiation tests are Young's modulus, tensile strength, linear expansion coefficient and thermal diffusivity.

Legs 14,15 and 16

Objective:
This experiment is part of a joint CEA Saclay, KfK and KFA programme.

The aim of the experiment is to select materials satisfying the phase 1 requirement of NET.
The irradiation temperature is 1773K and the target dose 3 dpa.
The materials are different types of SiC and carbonite materials.

Progress:
Sample holder 14 has been transported to KfK at the first quarter of 1990.
Sample holder 15 will be tranported to CEA Saclay at the first half of 1991.
Irradiation of 16 was finished in cycle 90.11.
Dismantling of the experiment will start at the first half of 1991.

Legs 17-18-19

Objective:
This experiment is a continuation of the previous series of experiments. Irradiation temperature is 1200^{0}C and the target dose 5 dpa.

Progress:
Manufacturing of the sample holders is finished. Assembly will start at the second quarter of 1991.

Leg 20

Objective:
Within the scope of the European Fusion Technology Programme, KfK/IMFI is investigating various ceramic insulator materials for the construction of millimeter-wave windows in plasma heating systems. The materials under irradiation are Al_2O_3, $MgAl_2O_4$ and MgO. The required fluence is $3 \times 10^{25} n/m^2$ (E > 0.1 MeV) at relatively low irradiation temperatures, 80^{0}C.

Progress:
Irradiation of the experiment started in cycle 90.10 and it will continue up to cycle 92.03.

First Wall Coating Graphite Irradiations

D 241 GRIPS

Objective:
The aim of the experiment (GRIPS stands for Graphite Irradiation in Pool Side Facility) is to investigate the irradiation behaviour, in particular the reduction in thermal conductivity, of several types of nuclear graphite (fine grained, superfine grained, oriented pyrolitic) which are potential candidates for the first wall protection and other applications in NET.
This experiment is part of a research programme carried out by KFA Jülich, in support of and in collaboration with the materials experts of the NET Team at Garching.

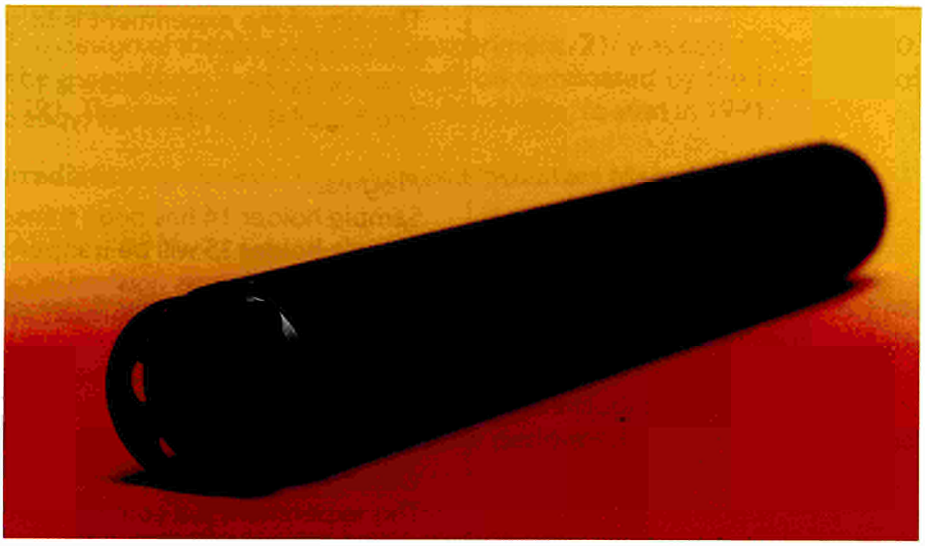


Fig. 11
Graphite drum used to house specimens (GRIPS)

Progress:
The final experiment specifications are as follows:
- two irradiation temperatures: 673K and 873K
- five irradiations per temperatures with neutron fluences (E> 0.1 MeV) in the range 10^{20} - 10^{24} m^{-2}.
- a total of 32 cylindrical samples to be irradiated in each experiment (dimensions: ∅ 6, l=32 or ∅ 6, l=25 mm)

Fig. 11 shows a graphite drum which houses the samples.

The first irradiation series (673K) was completed in 1990. One sample holder of the second series (873K) has also been irradiated (fluence reached: $10^{24}m^{-2}$). Post irradiation experiments are presently performed on the samples.

Divertor Materials Irradiations

D 245 NEMESIS

The divertor has two functions:
- extraction of impurities and thermal energy from the plasma to keep the contamination at low level.
- protection of the first wall against heat and particle flux during plasma burning phases.

The body of the divertor has the function to transfer the thermal energy to the coolant, while the surface must withstand the high ionic flux without too much degradation.
Materials with high atomic number are candidates for this last utilization. In this respect KFA Jülich is investigating the irradiation of Molybdenum and Molybdenum alloys.
The experiment NEMESIS consists of two irradiation series (0.2, 1 dpa) of the materials listed in **table 15** at three temperatures (~ 353K, 673K, 973K).

Table 15
Composition of the 4 divertor materials to be irradiated

Material	Mo	Ti	Zr	Re	C	Cr
Mo	100	-	-	-	-	-
TZM	99.39	0.5	0.09	-	0.02	-
MoRe20	75.24	-	-	24.76	-	-
Z6	>99	-	0.2	-	-	24ppm

Characteristics of the specimens are the following.

Specimen type	Dimensions (mm)	Number of specimens (per material)
3 points load	2x2x50	25
Charpy	6x6x44	16

In each irradiation 100 three-points specimens (25 per material) and 64 Charpy samples (16 per material) will be subjected to neutron damage.

Progress:
In 1990 the sample holders were manufactured as follows:
two similars, "dry", in which different filler materials have been used (Al for 673K irradiation, Mo for 973K irradiation), one "wet" in which the samples are in contact with the primary coolant of the reactor (water) which keeps the temperature of the samples down at 80^{0}C.
Fig. 12 shows one "wet" sample holder during assembly.
The irradiation campaign (first series: 0.2 dpa) started in cycle 90.11/23,24/.

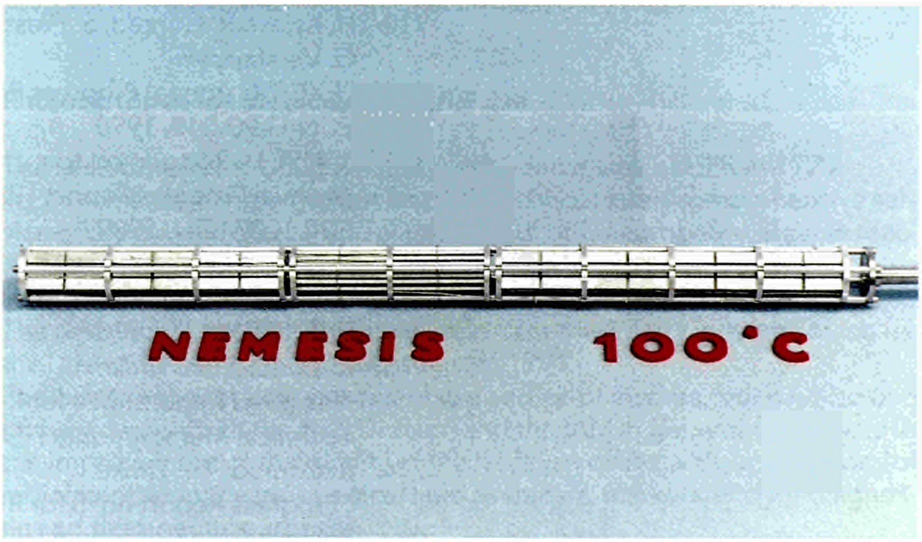


Fig. 12
Partial view of a NEMESIS "wet" sample holder during assembly

References:

/1/ G.P. Tartaglia, G. Piatti, H. Schreuer, W. van Witzenburg
"Irradiation effects on mechanical properties of 316 welded joints"
16th Symposium on Fusion Technology - September 1990

/2/ G.P. Tartaglia, G. Piatti
"Constitutive equations for plastic flow in irradiated 316 welded joints"
To be published

/3/ G.P. Tartaglia, P. Fraipont
"E192-14 SIENA experiment - 15 dpa irradiation"
Technical Note P/F1/90/21

/4/ P. Fraipont, G.P. Tartaglia
"E198-14 SIENA experiment - 10 dpa irradiation"
Technical Note P/F1/90/22

/5/ P. Fraipont, G.P. Tartaglia
"E198-15 SIENA experiment - 5 dpa irradiation"
Technical Note to be printed

/6/ P. Fraipont, G.P. Tartaglia
"R139-68 SINAS experiment - 0,6 dpa irradiation"
Technical Note P/F1/90/20

/7/ H. Hausen, W. Schüle, M.R. Cundy
"Irradiation Creep Experiment on Fusion Reactor Candidate Structural Materials"
All Union Conference on Structural Materials for Fusion Reactors, Leningrad, September 1990

/8/ H. Hausen, W. Schüle, M.R. Cundy
"Irradiation Creep Experiments on Fusion Reactor Candidate Structural Materials"
EUR 13193 EN, 1990

/9/ H. Kupfer, C. Keller, C. Meier-Hirmer, K. Salama, V. Selvamanickam, G.P. Tartaglia
"Critical Current and Relaxation of Oriented Grained $YBa_2Cu_3O_7$ after Fast Neutron Irradiation"
Applied Superconductivity Conference, September 1990 USA

/10/ H. Kwast, R. Conrad, S. Preston, N. Roux, H. Werle, S. Casadio, G. Verstappen
"EXOTIC Annual Progress Report 1989"
ECN-C-90-042, 1990

/11/ J. Ahlf, H. Röttger, editors
"Annual Progress Report 1988. Operation of the HFR Petten"
EUR 12271 EN, 1989

/12/ J. Ahlf, A. Gevers, editors
"Annual Report 1989. Operation of the High Flux Reactor Petten"
EUR 12881 EN, 1990

/13/ R. Conrad, Th. Timke
"Progress Report no. 4 for R 212.17-20"
Technical Memorandum HFR/90/2984, 1990

/14/ R. Conrad, Th. Timke
"Progress Report no. 5 for R 212.17-20"
Technical Memorandum HFR/90/3053, 1990

/15/ H. Kwast, R. Conrad, S.D. Preston, G. Verstappen, N. Roux, S. Casadio, H. Werle, J.D. Elen
"Comparison of the tritium residence times of various ceramic breeder materials irradiated in EXOTIC experiments 4 and 5"
16th Symposium on Fusion Technology, 3 - 7 September, 1990, London, UK

/16/ R. Conrad
Irradiation Proposal for EXOTIC-6 R 212.21-24
"Technical Memorandum HFR/89/2956, 1989"

/17/ G. Dassel, H.A. Buurveld
"Gammaspectrometry of ELIMA experiment"
ECN-CX-90-034

/18/ R. Conrad
"Irradiation Experiments on Liquid Tritium Breeding Material Pb 17Li in the HFR Petten".
Fusion Engineering and Design, 1990, to be published

/19/ R. Conrad, L. Debarberis
"Irradiation of Liquid Breeder Material Pb-17Li with in-situ Tritium Release Measurements in the LIBRETTO-2 Experiment".
Journal of Nuclear Materials, 1990, to be published

/20/ G. Dassel, H.A. Buurveld
"Gammaspectrometry of LIBRETTO-2 experiment"
ECN-CX-90-033

/21/ R. Conrad
"Irradiation Proposal LIBRETTO-3"
Technical Memorandum HFR/89/2953

/22/ P. Fraipont, H. Scheurer, C. Sciolla, G.P. Tartaglia
"GRIPS: Graphite Irradiation in the Pool Site Facility experiment D 241"
Technical Note P/F1/90/20

/23/ G.P. Tartaglia
"NEMESIS : Net Metals Irradiations - experiment D 245"
Technical Memorandum HFR/89/2493

/24/ P. Fraipont, G.P. Tartaglia
"Experiment D245 - NEMESIS - Net Metals Irradiation"
Design and Safety Report - Technical Note P/F1/90/19

3.5. RADIONUCLIDE PRODUCTION

Radioisotopes for Medical/Industrial use

The radioisotopes production has notably increased at HFR in 1990. Improvements in the organization of the service, more comprehensive service offered to the clients, and shut-down of other european research reactors have led to a 13% increase in production compared to 1989.

The activity has become the most important third party income source for the IAM. A further growth is foreseen for 1991.
Radioisotopes production is not only a source of income, but it is also one of the ways in which the HFR Division and the IAM in general, contribute to the improvement of the quality of life because of the wide applications of radioisotopes in the bio-medical field as tracers, markers, and for diagnostic and therapeutic purposes.

About 68% of the radionuclide production concerns applications in the medical field.

Production of Ir^{192}, P^{32}, Y^{90}, Sr^{89}, Pd^{103}, Xe^{133} takes place in the devices HIFI (144), HFPIF (008), RIF (90) suitable for general production. More than 50 capsules/cycle have been irradiated in 1990.

A list of medical applications of these nuclides is given below.

Ir^{192}: general radiographic use (in form of discs),
treatment of superficial cancers,
destruction of malignant tumours by interstitial or
intracavitary radiotherapy (inform of needles or wires)

Y^{90}: treatment of rheumatic disease,
treatment of liver cancer (in form of microspheres)

Pd^{103}: treatment of prostate cancer and other localized tumours

P^{32}: diagnosis of superficial tumours,
treatment of leukemia and tumours of lymphatic system,
destruction of skin angiomas

Sr^{89}: studies of bone pathologies,
pain-killer for secondary bone cancer

Xe^{133}: pulmonary perfusion,
measurement of local blood flow

Industrial uses of Ir^{192}:
check of weldings,
radiography in space rockets/aircrafts
density gauge for sintering materials,
tracers, markers

A new irradiation facility HIP (254) has been designed as replacement for the older RIF and HFPIF, offering better use of available space and improved handling. Manufacture of this facility has been started.

ER136 In Core-FIT. Irradiation of Fissile Targets

Objective:
The objective of this irradiation is the recovery of Mo-99 from the irradiated fissile targets for the manufacture of Tc-99m generators with high specific activities, and the production of Xe-133 and I-131.
Tc^{99m} is widely used in medical applications: tumour scintigraphy, brain/renal imaging, bone imaging, angiocardiography,liver, spleen, medullary imaging, visualization of blood pools and blood flow, scintigraphy of salivary glands and gastric areas.
I^{131} is used for study of pulmonary or cerebral edema, thyroid therapy/investigation, study of renal functions, lung scintigraphy, study of the vascular systeem.

Progress:
In 1990 the production continued successfully. Irradiated targets are sent to the reprocessing plant. A modified device is under development, to reach higher fluence rate values.
A new device (MOIRA) has been built to allow irradiation of the targets in the PSF.

ER197 COBI/ER203 CORRI. Irradiation of Cobalt

Objective:
Irradiation of cobalt for use in a sterilization plant. Two COBI facilities with 120 cobalt strips each, and two CORRI facilities with 48 cobalt strips each are available for this type of irradiation.
Requested specific cobalt activity is normally 1500-3000 GBq per gram. This specific activity is not suitable for medical applications (~ 9000 GBq per gram). Investigations are ongoing to look for technical solutions which will allow the production of cobalt for such use.

Progress:
In 1990 the production of cobalt continued for a total activity produced around 6 PBq. After unloading the activated strips are sent to the customer for the fabrication of the sources. The design of new devices is ongoing to irradiate cobalt in form of needles.
The production of radionuclides for industrial use represented 26% of the total production.

Activation Analysis

Objective:
Devices used for general radioisotope production are also used to irradiate various kinds of material used for scientific applications.
Activation analysis is used in the archeologic field, in geology (rare earth, sedimentary studies), in forensic applications and in environmental studies (atmosphere particles, aerosols, toxicology).

Progress:
In 1990 irradiation for the British Universities continued (age determination of rocks, mineral composition etc.).
A series of irradiations, carried out for the JRC Ispra, was concerned with the examination of human and animal tissues, and other biological materials.

Activation analysis of small samples of stainless steel, thulium, silicon etc. took also place in the standard radioisotope devices (HIFI, RIF, HFPIF).

Activities performed in the scientific field represented about 6% of the total radionuclide production.

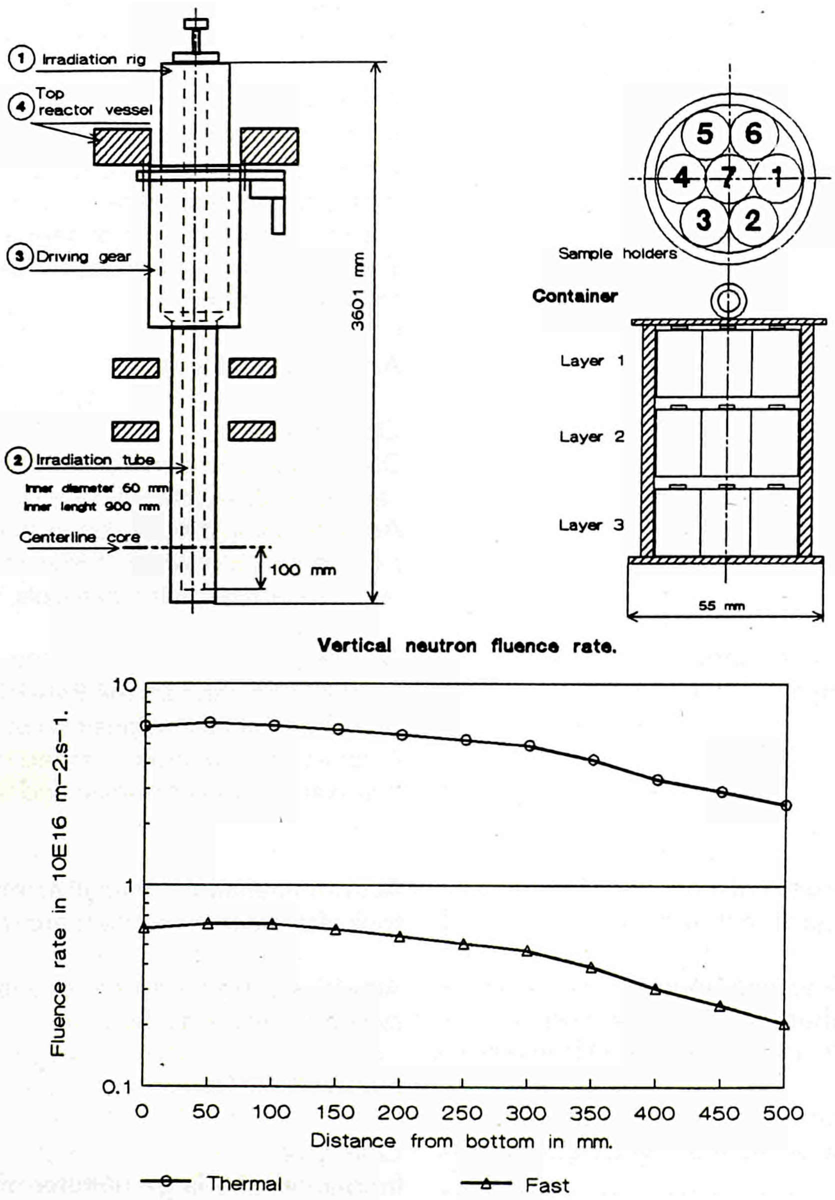
ER70 PROF

Objective:
Irradiation of a large number of samples for neutron activation analysis.

The Poolside Rotating Facility (PROF) consists of an irradiation rig and a driving gear **(fig. 13).** It is installed near the reactor core in the vertical irradiation position NW. For flattening of the radial neutron fluence rate the rig is rotating around the vertical axis at a speed of one revolution per minute. The rig can be placed or removed at any moment during reactor operation. The irradiation tube has an internal diameter of 60 mm and a length of 900 mm. Irradiations targets will be placed in sample holders fitted into a polyethene container with an outer diameter of 55 mm. A total of 21 sample holders each with a volume of 1 cm^3 can be loaded.

Progress:
The rig has been operated without problems for isotope production. A total of 47 irradiations were carried out.

Fig. 13
Pool side rotating facility (PROF)



3.6. SOLID STATE PHYSICS AND MATERIALS SCIENCE

The Solid State Physics Group of the Service Unit Materials of ECN operates 6 neutron spectrometers for carrying out both fundamental and applied research in Solid State Physics, Chemistry and Materials Science. It comprises the determination of crystallographic and magnetic structures of both powdered and mono-crystalline specimens, the study of atomic and magnetic short-range correlations, dynamic studies using inelastic neutron scattering.

In the field of applied research Small-Angle Neutron Scattering (SANS) was used for a large variety of materials investigating micro structural properties. The interest and demand for investigations with SANS is steadily increasing. Subjects have been growth of precipitates in irradiated steel, pore stuctures in ceramics, colloidal dispersions, behaviour of polymer chains in solution, etc.

Conventional diffraction was used for determination of texture in model systems of ß-brass, in rolled steel plates, but also in exotic samples as meteorites.

The possibilities for the determination of residual stresses in materials by means of neutron diffraction have largely been increased by completing a new diffractometer solely dedicated to stress analysis **(see fig. 14).**

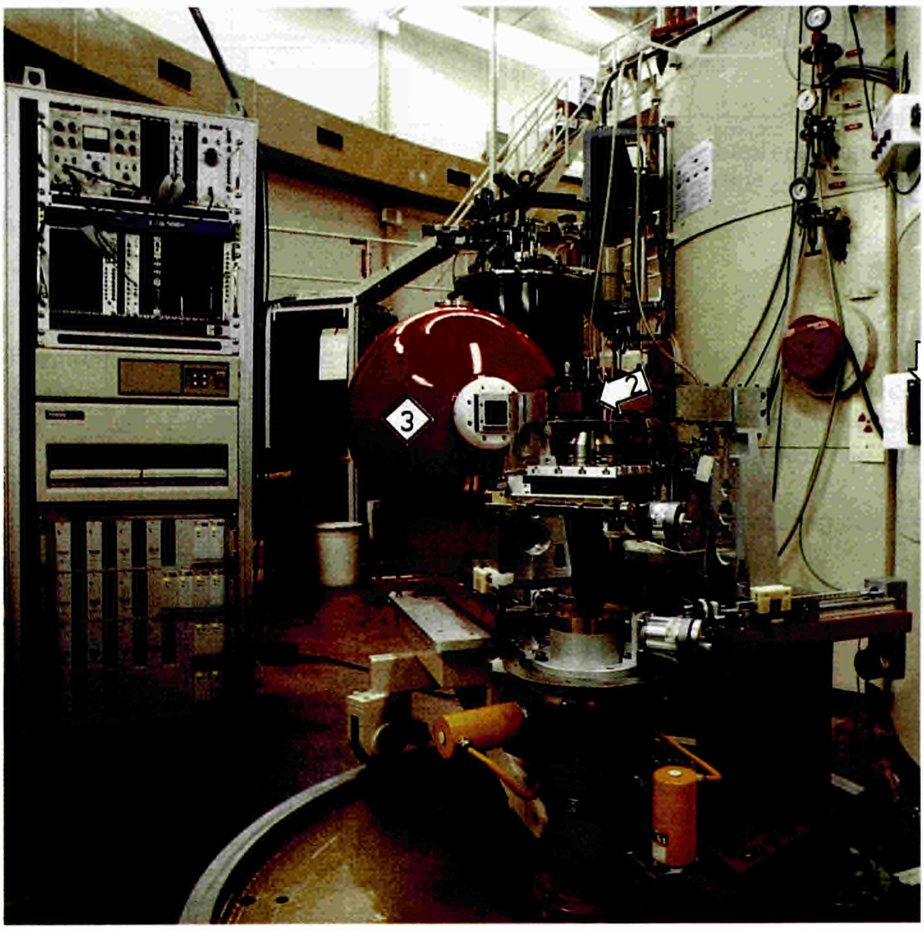


Fig. 14

Diffractometer for stress measurements. Photograph of the new diffractometer at beamhole HB4 of the HFR. This apparatus is fully dedicated to non destructive investigations of residual stresses in materials by means of neutron diffraction. A monochromatic beam, selected by a double-crystal monochromator (variable between $\lambda = 1.5$ Å and 6.5 Å) leaves the concrete shielding at 1. in the direction of the sample (2), where it subsequently is reflected in the direction of the neutron detector resided in the spherical shielding (3). Accurately positioning of the sample and adjustable slits enable to select carefully small volumes (few mm^3), which will be examined for the presence of residual stresses.

Stress introduces strain, which on its turn results in a change of the reflection angle. Accurate determination of reflection angle provides the information needed for obtaining the stress state in a particular volume of the sample.

3.7. MISCELLANEOUS

ER 220 SIP. Irradiation Facility for Silicon Characterization

Objective:
The SIP facility **(fig. 15)** has been designed for the activation and subsequent analysis of industrial silicon samples with regard to impurities. The facility allows the irradiation of 5 to 30 stacked silicon discs (4" or 6" diameter, 0.5 mm thick) packed into a quartz glass container. This container is placed in a reloadable irradiation canister which rotates during irradiation in order to provide maximum neutron fluence rate flattening.
The irradiation is carried out in the PSF.

Progress:
During the period under review 32 containers have been irradiated.
Since the installation of this facility 152 irradiations have been carried out, corresponding to a total irradiation time of 10.705 hrs.

R 233 SIDO

Objective:
Development, design, manufacture and characterization of a prototype facility for the "doping" of industrial silicon crystals.

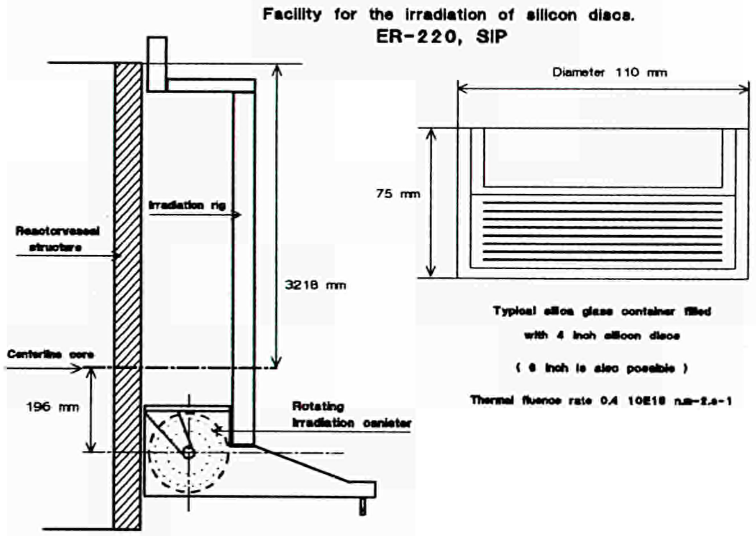
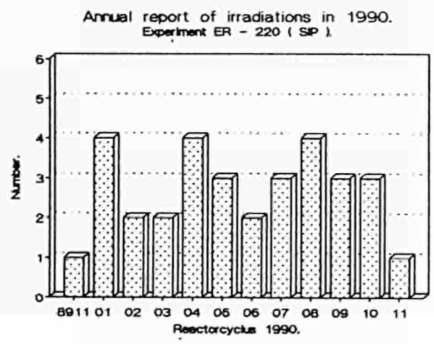
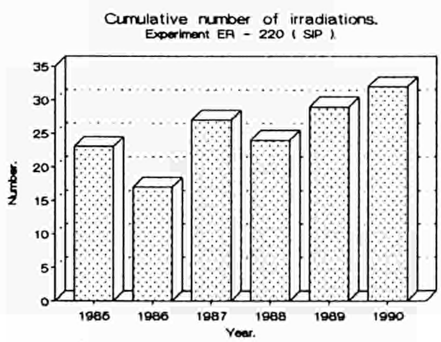


Fig. 15
Facility for the irradiation of silicon discs (SIP)





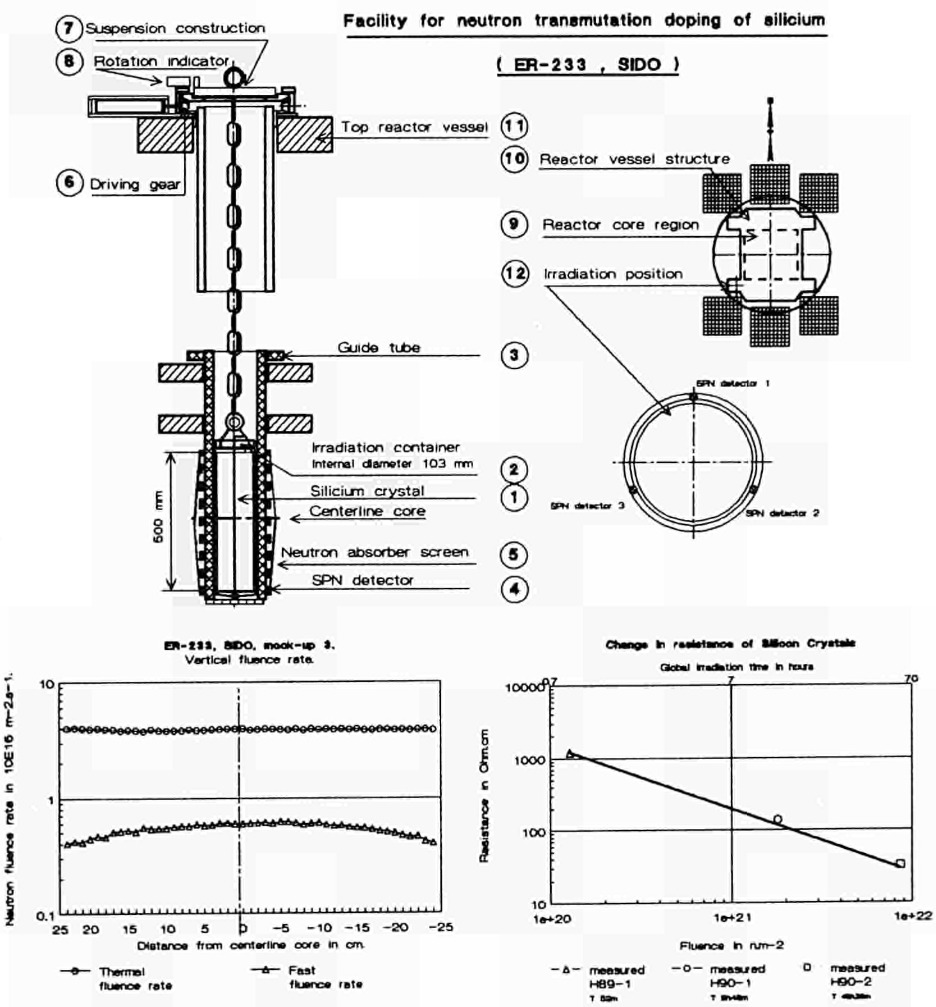


Fig. 16
Facility for neutron transmutation doping of silicon (SIDO)

The facility **(fig. 16)** consists of a driving unit with a sample holder rotating inside an insert tube. The crystal, in a reloadable container, will be placed in the insert-tube by means of a chain which is connected to the removable part of the driving gear. The dimensions of the crystal to be irradiated are limited to a diameter of 103 mm and a length of 500 mm.
The vertical fluence rate distribution will be flattened by a neutron absorber screen positioned outside the insert-tube.
To enable fluence monitoring three collectrons (self-powered neutron detectors are fitted. The facility is installed in the south-west Low Flux Facility.

Progress:
Three test irradiations have been performed of silicon crystals with a diameter of 4" and a length of 450 mm, on behalf of a manufacturer. The neutron dose varied from 0.17 until 8.6 x 10^{21}n m^{-2}, corresponding to a resistance of 1000-30 Ohm.cm. Two of the irradiations were entirely successful, but during the irradiation of one crystal a malfunction occurred in the rotating unit. A new unit has been designed and installed. The crystals will be irradiated in reloadable containers.

Fig. 17
Measurement at the dummy reactor vessel

For standard irradiation parameters, i.e. crystal target resistivity of about 70 Ohm.cm, the irradiation capacity of this facility is limited to about 1000 kg/year, provided that sufficient contaioners are available.
Upscaling of the doping activities to yearly quantities of 10 to 20 tonnes has been subject to technical and commercial feasibility studies by ECN and JRC. The prospectives were sufficiently encouraging to continue with a more detailed analyses as a joint activity of ECN and JRC.

Minerals Irradiations

Objective:
The purpose of the irradiation is to induce physical property changes in the material without activation.

Progress:
For the experiment 240, irradiation parameters have been established to the extent that specified results can be achieved.

Two small rigs have been built and are available for routine production.
A big rig (four times the size of the small one) has been designed and the construction is in a very advanced state.
The rig will be completed on customer's request.

R 244 HEISA. Heated Instrumented Salt Irradiation

Objective:
The study of the behaviour of salt in a gamma radiation field, as part of the project on the storage of nuclear waste in salt domes.
Gamma radiation causes a desintegration of NaC1 which produces $C1_2$ and H_2 gas with the release of some energy. Salt samples are irradiated under high pressure (~ 200 bar) in the gamma irradiation facility (GIF) in the storage pool.

Progress:
Two HEISA capsules have been designed, one for operation at atmospheric pressure, the other for operation at about 200 bars. Both became operational in the autumn of 1990.

ER 209 GIF and R 253 GIRAF

Objective:
Irradiation facilities for gamma irradiation of various samples, using spent HFR fuel elements as gamma source.

Progress:
Two new GIF sample holders were constructed, which are longer than the earlier ones. In this way the O-ring seal of the lid of the holder is further away from the gamma source, improving its lifetime.

GIRAF is constructed for gamma irradiation of large samples. It occupies 4 fuel element positions in a modified fuel element storage rack. A cadmium shield suppresses neutrons. The sample holder is an aluminium tube, internal dimensions ∅ 155 mm x 1070 mm.

4. GENERAL AND DEVELOPMENT ACTIVITIES

This chapter concerns either services supporting a number of projects or investments and work intended to keep equipment and competence at the required level. The general and development activities within the HFR programme include:

- operation and maintenance of ancillary services and laboratories
- design studies and development of new irradiation devices
- technical support to the running irradiation programme.

4.1. ASSEMBLY LABORATORY

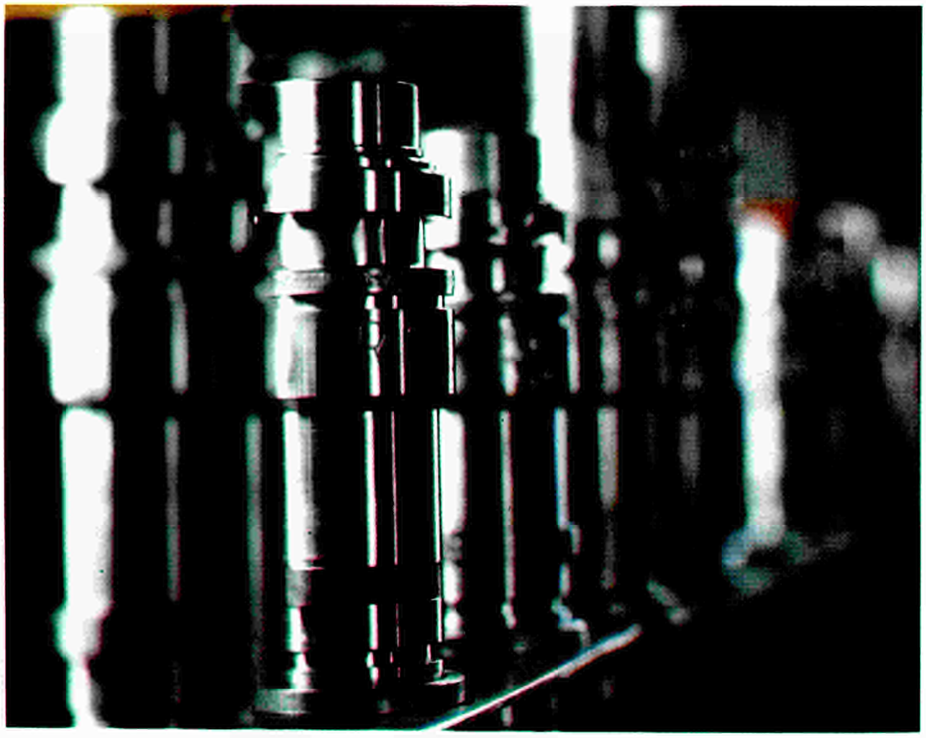
In 1990 the assembly staff was extended to four members.
59 irradiation experiments were assembled and carried out under contract to external suppliers. A portable gas test panel equiped with pressure control transducers and the possibility to operation under vacuum is available. A glove box for loading U/Pu fuel pins under safe precautions is under construction. These are required for loading fresh FBR fuel pins in sample holders for the transient experiments OPOST, POTOM, KAKADU and NILOC. The new assembly room will be finished in the middle of 1991.

4.2. STANDARD IRRADIATION DEVICES

During the reporting period the following orders and fabrications of standard devices were carried out internally or by external firms.

- 4 TRIESTE rigs incl. carrier
- 1 REFA 170 rig (modified)
- 1 TRIO 131 rig (modified)
- 1 PSF capsule holder
- 2 TRIO instrumentation heads
- 1 LIBRETTO instrumentation head
- 1 EXOTIC instrumentation head

Fig. 18
Top of a TRIO capsule



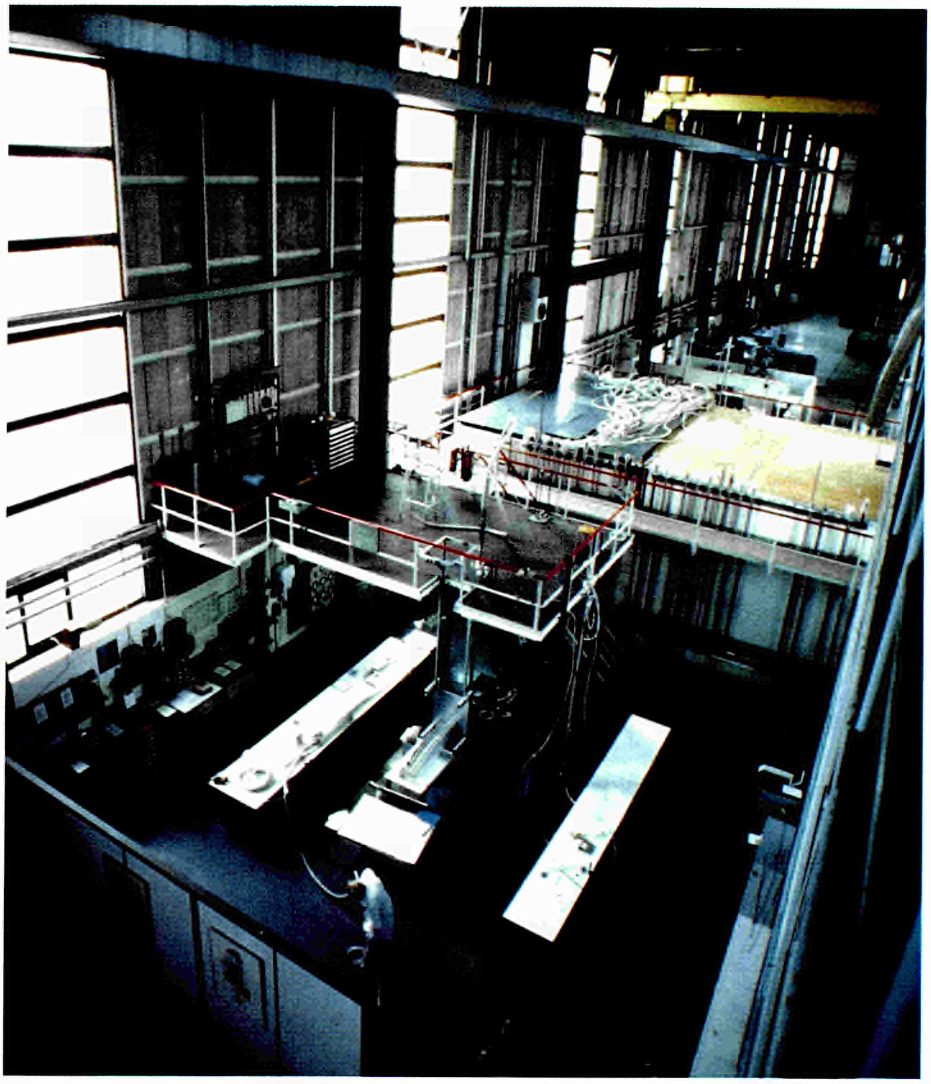


Fig. 19
View of the Technology Hall
with Quality Control Laboratory

4.3. QUALITY CONTROL

- During the reporting period the Quality Control and Assurance group has sent off 109 reports with the following items:
  - 42 Sample holders
  - 18 In-core capsules
  - 16 Instrumentation heads
  - 20 P.S.F.-carriers
  - 27 P.S.F.-capsules

  e.o.
- To control leaktightness and to follow the highest norm in this field a new computerised Helium-Leak test machine has been taken into operation.
- The store facilities of Standard Irradiation Capsules have been extended by 23 positions and the PSF store facility has been rearranged.
- The stock of HFR-project materials has been fully updated.

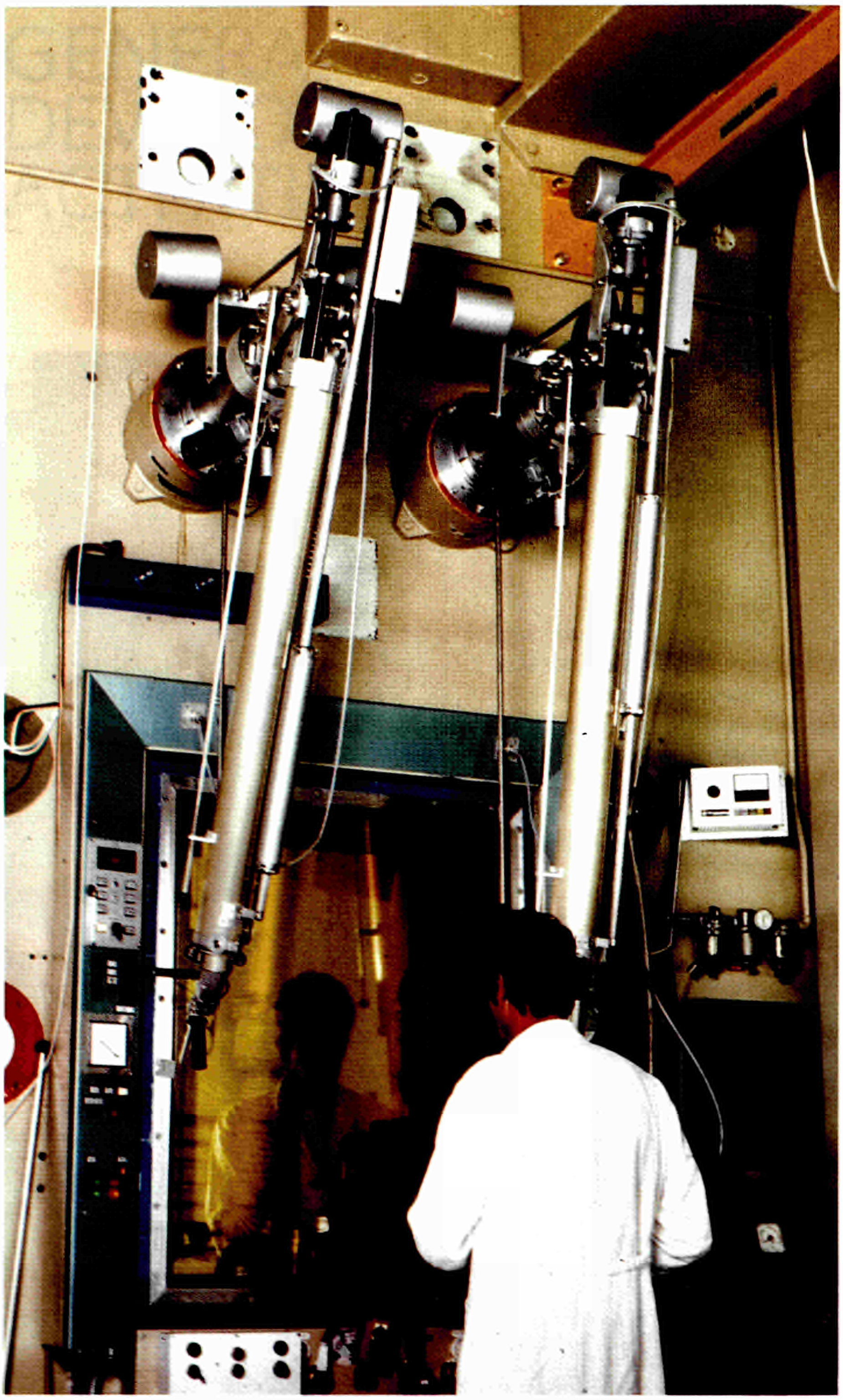


Fig. 20
Dismantling cell at the HFR

- The total reserve of the BWFC-carriers and capsules has been tested and reported.
- X-ray film interpretation room has been improved to the DIN norm prüfklasse B and filmklasse G1, using a densitymeter, Image Quality Indicators, reference radiographs of welds.
- A new High Pressure Test facility is in operation.
- Liquid Metal Filling Station:
  - o A Turbo-Molecular-Vacuumpump, Low-Pressure Measuring Devices and a full Stainless Steel Circuit have been installed.
  - o This installation will be used for Sodium-filling or for NaK filling.
  - o The Heater-powersupply will be replaced by an Electronic Process Controller.

4.4. EXPERIMENT OPERATION

Despite of increasing technical complexity of the experiments the team provided on schedule their services to a succesful operation of the irradiations. During the 11 cycles of 1990 they loaded 10 TRIESTE sample carriers, 2 REFA and 31 TRIO sample holders into the respective reloadable irradiation devices, for in-core irradiation. They unloaded, and prepared for dismanteling, 6 TRIESTE sample carriers, 1 REFA and 26 TRIO/QUATTRO sample holders. Over the concerning period they did more than 38 loadings of 240, this means 114 interventions on delicate samples.
Concerning the PSF-irradiation devices, they installed succesfully an irradiation device for 215-type fuel pins, an irradiation device for 241-graphite type sample holders, and they developed new out of pile intrumentation to increase the number of type 240 mineral irradiations.
The device for locking sample holders into the instrumented head has been upgraded, to avoid unlocking during reactor operation.

4.5. HOT CELLS AND POST-IRRADIATION WORK

The cell team provided the following services:

Dismantling cell

- Dismantling and assembly of 85 irradiated experiments
- 26 external and internal transports of irradiated experiments and samples
- 18 waste transports
- 11 neutron radiography images have been taken of irradiated fuel pins and other irradiated material.
- New experiment (D241, GRIPS):
  This new experiment was installed and already 6 times reloaded in the DM-cell.
- After a general cleaning action and inspection of the total equipment of the DM-cell a new window was installed.
  This renewal led to an enormous improvement in viewing during handling special capsules and visual control of reactor components.
- A new underwater saw was ordered in 1989 and is meanwhile used to dispose fuel elements and control rods of the HFR.
- For internal transports between the reactor cell and our cells in the LSO (ECN) a new "Syntacs-container" was installed. The main reason for this purchase was to improve the technical and safety aspects for transportation of high active materials.

G5/G6 cells (LSO)

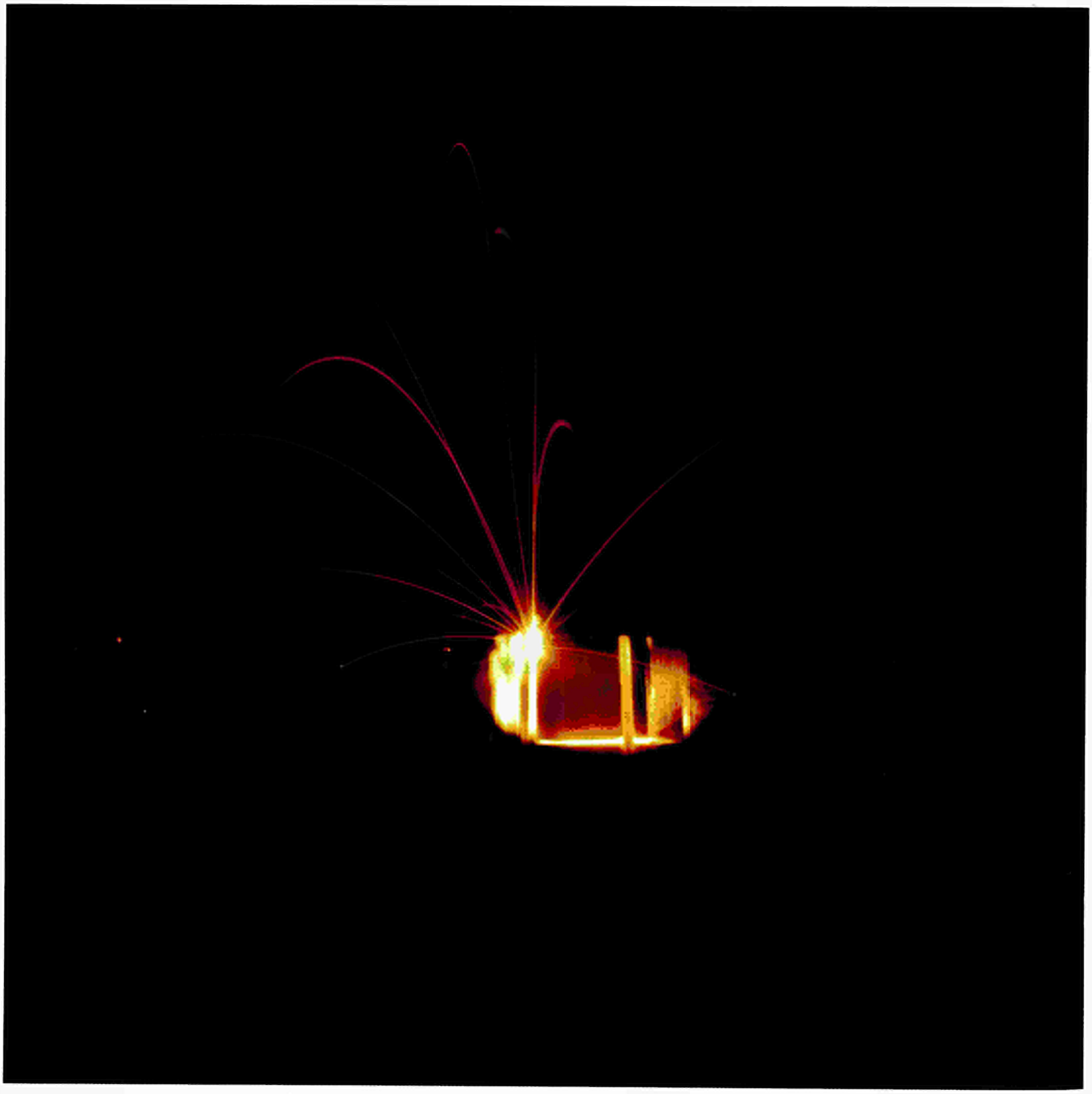
- Experiments D85.55; 56/2
  New sample holders have been loaded with the above mentioned series of samples.
- Experiments D156.94; 95
  Dismantling and dimension measurements have been executed.
- "Poussix fuel pins"
  Three pre-irradiated fuel pins have been transported from Cadarache to Petten.
- Experiments E167 (TRIESTE)
  Visual inspection and measurements on several sample carriers were executed.

4.6. JOINING TECHNIQUES

The electron Beam Welding (EBW) and High Temperature Brazing group provided the following services:

- routine weldings for sample holder assembly
- welding of 55 tensile samples for materials department
- specific weldings for irradiation devices fabricated at outside delivery firms
- heat treatment of minerals.

Fig.21
Electron beam welding



4.7. NEUTRON RADIOGRAPHY

Objectives:

Neutron radiography is a non-destructive inspection and testing technique capable of producing images of components, assemblies and materials, on film or real time devices. In comparison to X- and gamma-rays, neutrons penetrate heavy metals like steel, lead and uranium much more easily, whilst at the same time having the unique capability to image light materials such as hydrogen bearing materials. The joint ECN & JRC service called the "Petten Neutron Radiography Services" serves with an HFR underwater camera, the HFR HB-8 beam tube based neutron radiography system with filtered neutrons and the LFR based thermal neutron radiography system, with its real time imaging system at the HFR HB8 facility and its image analysis devices the following tasks:

- Promotion and provision of neutron radiography services and support of EC research and industry /1/ and
- support of HFR irradiation projects with non-destructive inspection capability.

Progress:

HB-8 beam tube NR facility

- A research contract on the application of neutron radiography to space components technology was concluded and research in this field started with comparative tests using X-ray and neutron radiography.
- Several inspections were performed as a service to industry and research, including proof testing for new potential clients. These inspections related to the following areas:
  - o high-tec ceramics
  - o turbine blades for jet engines
  - o composite structures from aircraft industry
  - o pyrotechnique devices from space craft and satellites
  - o aircraft fuselage
- The capabilities of neutron radiography were displayed at the 1990 Hannover Industrial Fair. In promotional actions potential clients were invited to provide test samples for trial testing.
- At the first international topical meeting on neutron radiography system design and characterization in Pembroke/Canada recent work and studies on an upgrading of the HFR HB8 neutron radiography facility for commercial application /2/ and experiences in radiographic unsharpness determination by means of a knife edge object /3/ were presented.
- First trials with a lowlight TV system for dynamic neutron radiography were successfully performed. **Fig. 22** shows schematically the lay-out of this system.

HFR underwater NR camera

- Neutron radiographic inspections as a service to irradiation experiments have been performed.
- A large adapter, providing a large chamber above the imaging chamber of the underwater camera for insertion of the entire ISOLDE irradiation capsule was commissioned and successfully applied with the first two ISOLDE tests.

PETTEN NEUTRON RADIOGRAPHY SERVICES, PNRS,
CHARACTERISTICS OF FACILITIES

REAL TIME NEUTRON RADIOGRAPHY

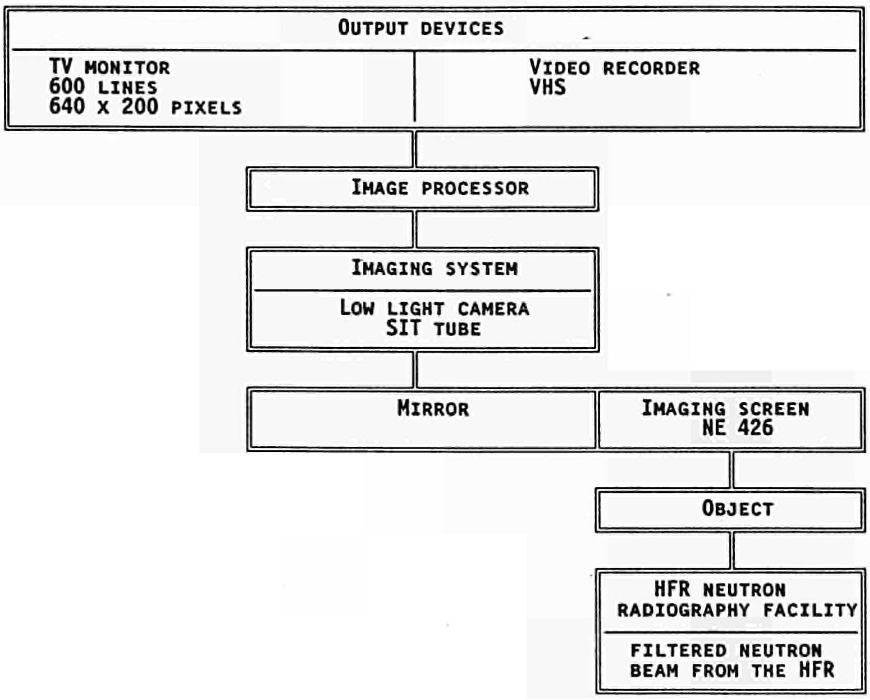


Fig. 22
Real time neutron radiography system at the HFR Petten

Neutron Radiography Working Group (NRWG)

- The 12th Plenary Meeting of the NRWG was prepared.
  This meeting took place in Paris on 13th November, 1990
- Assistance was provided in publication of the proceedings of the 3rd World Conference on Neutron Radiography held in 1989 in Osaka, Japan /4/.

References:

/1/ J.F.W. Markgraf (editor)
Neutron radiography at the HFR Petten
Compilation of the HFR Petten contributions to the Third World Conference on Neutron Radiography and the SITEF symposium 1989
EUR 12727 EN, 1990

/2/ H.P. Leeflang, J.F.W. Markgraf, K.H. van Otterdijk
A proposed upgrading of the HFR HB-8 neutron radiography facility for commercial application
First International Topical Meeting on Neutron Radiography System. Design and Characterization, Canada, 1990

/3/ H.P. Leeflang, J.F.W. Markgraf, K.H. van Otterdijk
Experiences in radiographic unsharpness determination by means of a knife edge object. First International Topical Meeting on Neutron Radiography System. Design and Characterization, Canada, 1990

/4/ J. Barton, S. Fujine, K. Kanda, G. Matsumoto (editors)
Proceedings of the Third World Conference on Neutron Radiography
ISBN 0-7923-0832-8, EUR 12876, 1990

4.8. DEVELOPMENT OF LWR FUEL TESTING DEVICES

Objectives:

The objectives of R&D for LWR fuel testing devices were related to:

- the development of a "low power fuel testing capsule" providing characteristic PWR fuel rod surface temperatures from approx. 150 W/cm linear heat generation rate onwards and suited for power cycling tests and investigation of the fuel rod behaviour at extended burn-up,
- the modernization of the non-destructive HFR pool facilities for eddy current and diameter measurement of irradiated fuel rods and
- the development of an in-pile profilometry rig.

Progress:

- The development work on the "low power" BWFC capsule /1/ was continued. The design of a "low power" BWFC capsule with an electrical heater was completed. This device will be utilized in the anticipated irradiation test with high burn-up LWR fuel.
- The out-of-pile testing of two ISOLDE capsules was continued in order to characterize their thermal behaviour prior to the in-pile tests.
- The proof testing of the recently introduced re-instrumentation technique was successfully completed.
- Set-up and out-of-pile testing of a new HFR pool inspection system for fuel rod inspection by eddy current and diameter measurement /2/.

References:

/1/ T.D.A. Kennedy, J.F.W. Markgraf, S. McAllister, I. Ruyter
Development of a two dimensional computer code for the prediction of two-phase heat transfer in an experimental LWR irradiation capsule.
The Journal of the British Nuclear Society, publication pending

/2/ A. Carey, S. McAllister
Development of an improved, automated NDE facility for LWR fuel rod testing
10th international conference on NDE in the nuclear and pressure vessel industries, Glasgow, 1990

4.9. DEVELOPMENT OF A CONTROL SYSTEM FOR SWEPT HTR FUEL EXPERIMENTS SWEEP-LOOPS

The main activities in the development of the SWEEP-LOOPS in 1990 were concentrated on the preparation and calibration of the system for the operation of the D 138 experiments with six independent control circuits. The gas sampling station and the multi-channel analyser were prepared to measure low activities (<10^4Bq). Manuals for the operation of the reference tests D 138.05/06 were issued /1-3/.

References:

/1/ Th. Timke, R. Conrad
Manual SWEEP-LOOPS
Technical Memorandum HFR/90/3016, April 1990

/2/ R. Conrad, Th. Timke
Manual D 138.05
Technical Memorandum HFR/90/3019, April 1990

/3/ R. Conrad, Th. Timke
Manual D 138.06
Technical Memorandum HFR/90/3145, December, 1990

4.10. DEVELOPMENT OF IRRADIATION FACILITIES FOR FUSION BLANKET MATERIALS

The up-grading of the Tritium Measuring Station for the LIBRETTO-3 and the EXOTIC-6 experiments continued in 1990 /1/. This concerned mainly the extension of the gas supply system with a variety of high-purity purge gasses and the extension of the instrumentation with a control system for electrical in-pile heaters.

Reference:

/1/ R. Conrad, L. Debarberis
"Irradiation Facilities for Testing Solid and Liquid Blanket Breeder Materials with in-situ Tritium Release Measurements in the HFR Petten"
Journal of Nuclear Materials, 1990, to be published

4.11. BORON NEUTRON CAPTURE THERAPY (BNCT)

During 1990, important steps were achieved in creating a filtered neutron beam at HB11 for BNCT applications. As reported previously, BNCT is the utilization within a cancer cell of the energy produced by the instantaneous nuclear fission of the boron-10 nucleus into an alpha particle and a lithium ion, after the capture of a slow (thermal) neutron, i.e. $^{10}B(n,\alpha)^7Li$. The emitted irradiation destroys those cancer cells in which the boron capture event takes place. To achieve this phenomenon, one needs a suitable, preferentially tumour-seaking boron compound and a high flux of thermal neutrons at the tumour site. For this latter reason and others, the beam tube HB11 was designated a suitable facility for developing a neutron beam with the appropriate characteristics.

Following initial studies in 1989, the final design of a facility was agreed upon at the beginning of 1990. A filter configuration of Aluminium, Titanium, Cadmium, Sulphur and Liquid Argon was found to give the optimum beam, see **Fig. 23.**

In addition, a new main beam shutter was designed, which can shut down the beam within 15 seconds, thus enabling many treatments per day to be performed but also allowing for medical intervention to the patient in case of emergency.

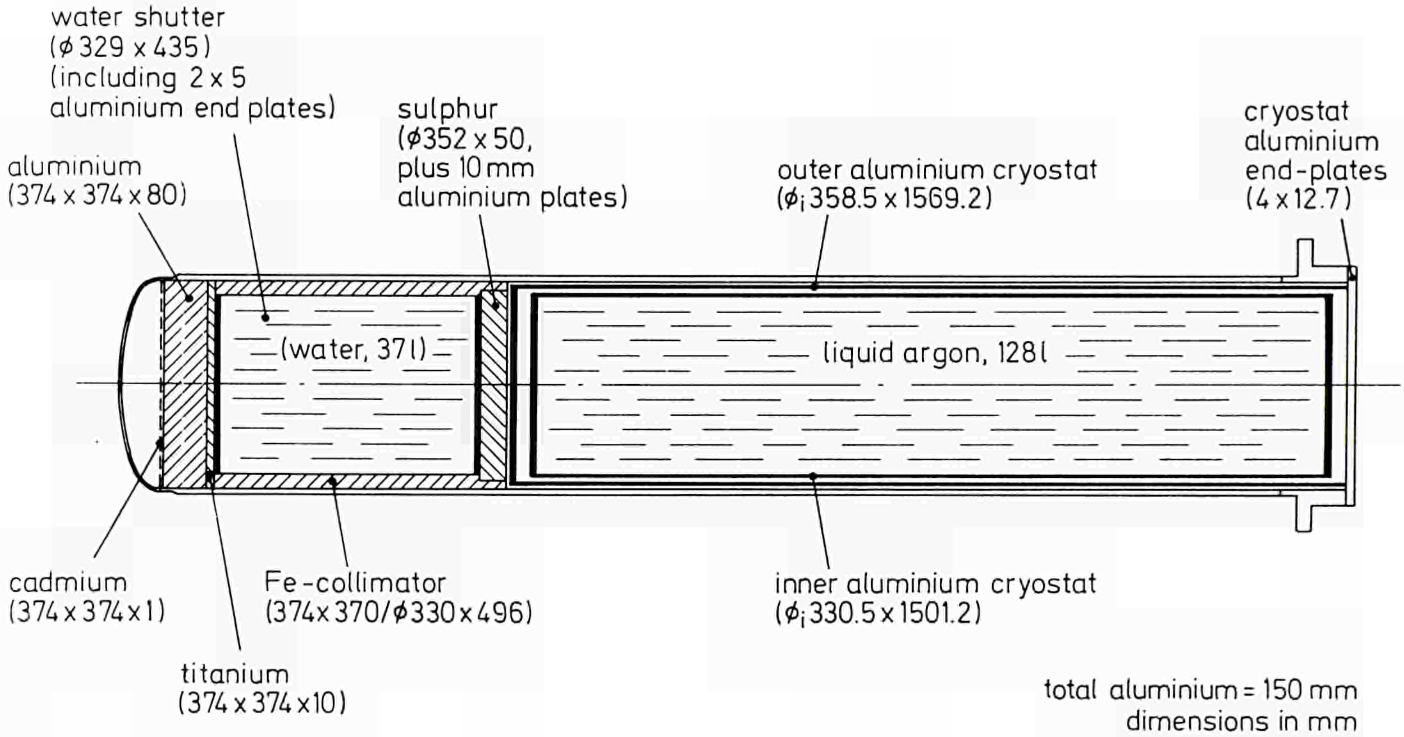


Fig. 23
Filter configuration for the HB11 BNCT neutron beam

The filter components and beam shutter, including newly modelled shielding blocks, were manufactured and delivered to the reactor during July and August. Due to a very sustained effect on behalf of staff from JRC and ECN, it was possible during the six weeks reactor shut down period, to dis-assemble the old HB11 configuration, including the removal of the highly activated mirror system, and install all the new components.
Only one day of planned reactor operation was lost.

Following the installation, the system is presently undergoing a commissioning phase. In particular, the workings of the liquid argon system are being fully checked. The constraints of operating with a liquid gas, are such that at the operating pressure of 2 bar, the gas (argon) is only liquid over a 10K range. Hence, control systems such as pumps, cryo-coolers, compressors and safety valves have all been designed with built-in redundancy, see **fig. 24.**

In mid-October the beam was opened at a special 500 kW run of the reactor to release its first epithermal neutrons. Numerous nuclear measurements were taken to characterize the beam and to compare with calculations. The first results indicated that the fast neutron and gamma ray components in the mixed beam are possibly higher than anticipated. Later measurements, with the cryo-coolers and pumps in operation, showed that the liquid argon filter (cryostat chamber) must have been partially gaseous, hence allowing a streaming of high energy neutrons and gamma rays through the chamber.
The new results now agree with calculation and are within the design goals of the beam.

The latest planning schedules full power operation for April 1991.
The experimental programme will then procede with cell culture and phantom irradiation experiments. Prior to the first clinical trials on cancer patients, now planned for the end of 1992, healthy tissue tolerance studies will be performed using healthy and brain-tumour bearing dogs. This is a mandatory step to satisfy the medical ethics committees.

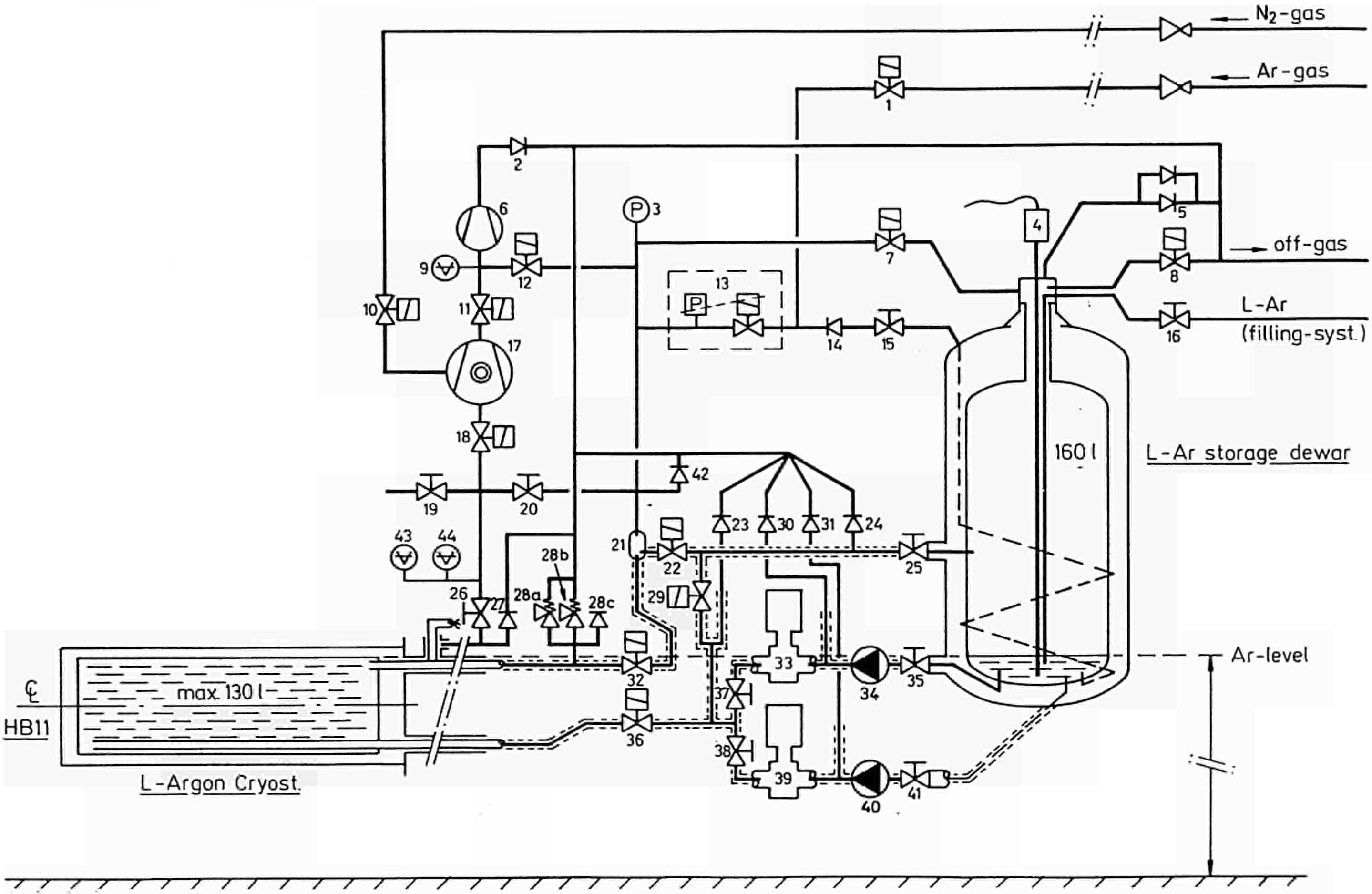


Fig. 24
The flow scheme for the liquid argon component of the BNCT filter configuration

The progress of the project depends strongly on collaboration with European partners belonging to the Concerted Action on BCNT, ref /1/, and on obtaining additional funding from appropriate research sources.
At the recent 4th International Symposium on Neutron Capture Therapy for Cancer, in Sydney, 13 papers were presented by the Petten group.
In comparison with similar projects worldwide, the Petten BNCT facility, see **fig. 25,** will be the first such facility in Europe and remains as the first such facility in the world that could treat cancer patients with epithermal neutrons.

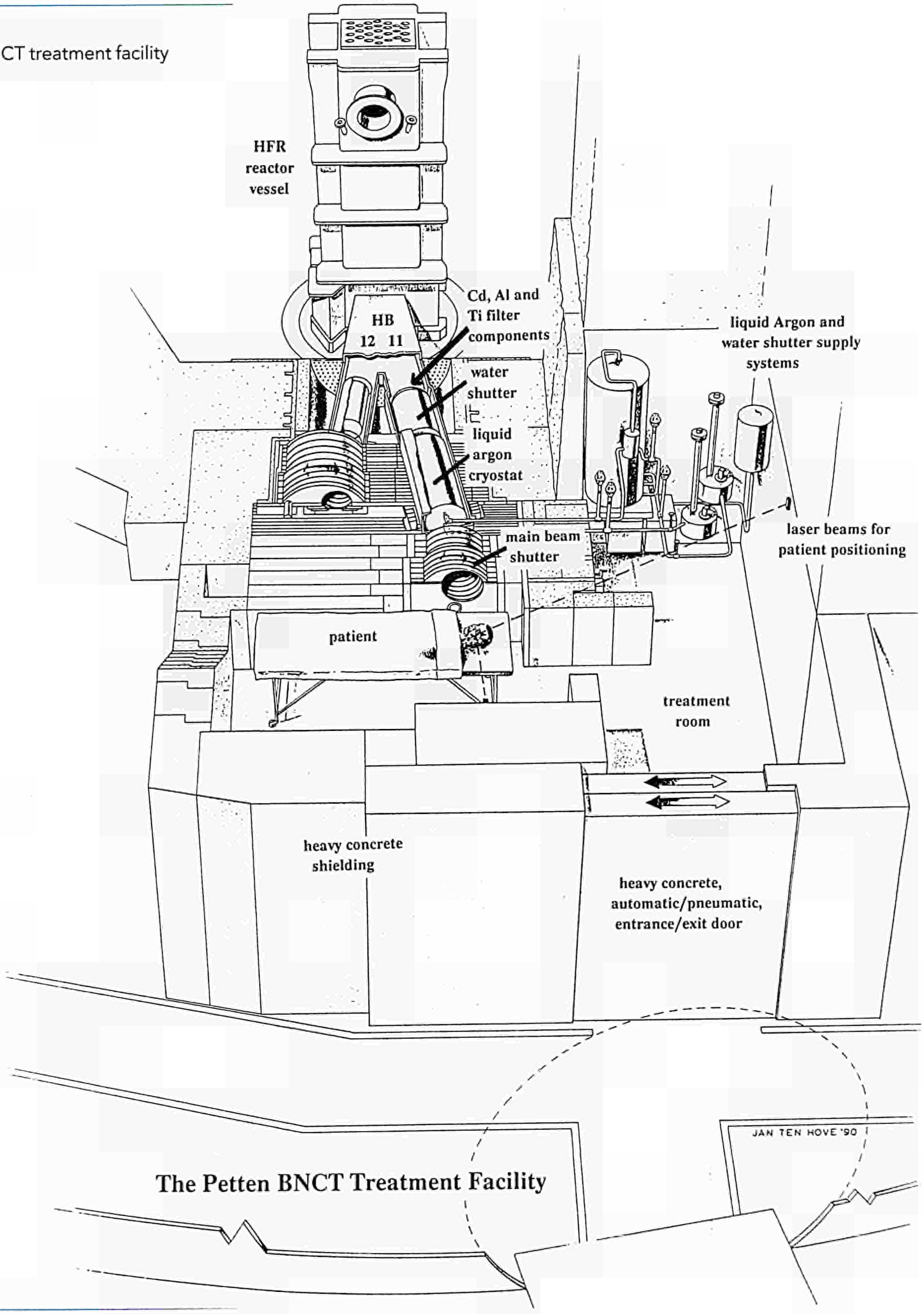
References:

/1/ D.Gabel
Approach to Boron Neutron Capture Therapy in Europe:
Goals of a European Collaboration on Boron Neutron Capture Therapy, EPAC 80, 2nd.European Particle Accelerator Conference, Edition Frontières, Gif-sur-Yvette, Vol. 1, 283-285

/2/ L. Dewit, R.L. Moss and D. Gabel
New developments in Neutron Capture Therapy
EUR. J. Cancer, October 1990

/3/ R.L. Moss, F. Stecher-Rasmussen, R. Huiskamp, L. Dewit and B. Mijnheer
The Petten BNCT Project
4th International Symposium on Neutron Capture Therapy for Cancer, Sydney, Australia, 4-7th December, 1990

Fig. 25
The Petten BNCT treatment facility



4.12. NEUTRON TRANSMUTATION DOPING OF SILICON CRYSTALS

Thermal neutrons are used for transmutation doping of Silicon crystals in order to provide them with the semiconductor characteristics. About 20% of the Silicon used for semiconductors/chips needs to be treated with neutrons due to the high requirements of uniformity in doping required for their future use in high power electronics.

Most research reactors provide doping services to industry. In view of demands from the international market following actions were undertaken:

- Investigation of the HFR characteristics with regard to the provision of a service to industry for NTD of Silicon crystals.
- Market assessment.

R & D and operation of SIDO:

- Test irradiations of Silicon crystals have been performed in the SIDO facility. Details are reported in chapter 3, para 3.7.

Feasibility of HFR for NTD services:

- Technically, HFR could provide NTD services for Silicon crystals ranging between 3 and 6 inch outer diameter. A production system with an annual throughput of approx. 20 t based on 4 inch crystals and a final resistance of 60 Ohm/cm could be accommodated.

Market situation:

- A market study yielded that the world market for NTD Silicon is not yet saturated and that a new NTD facility would have good chances to be successful. Further contacts with European and international industry will be established in order to explore needs and to get commitments for future utilization of NTD services from HFR.

4.13. PROGRAMME MANAGEMENT AND MISCELLANEOUS

Planning

During the reporting period the HFR Planning Meeting was held three times and three editions of the loading chart were issued (HFR/27 to HFR/29).

ACPM

The Advisory Committee on Programme Management met in Petten on June 22 and December 7, 1990.

It reviewed the status and progress of the HFR Programme on the basis of documents prepared by JRC-IAM Petten.

EWGIT (European Working Group on Irradiation Technology)

The EWGIT Select Committee met on February 6, 1990 at Petten to discuss the preparation of an International Conference on Irradiation Technology. The conference is now scheduled for 1992.

NRWG (Neutron Radiography Working Group)

The 12th Plenary NRWG Meeting and the 6th subgroup meeting on "Practical Neutron Radiography" took place at CEA, Paris, on November 13/14, 1990.

The NRWG reviewed the status and progress of its programme of work. The preparations for the intended publication of the "Handbook on Practical Neutron Radiography" were continued by the subgroup.

EWGRD (Euratom Working Group on Reactor Dosimetry)
The EWGRD Programme Committee organized the 7th ASTM-EURATOM Symposium on Reactor Dosimetry. The Symposium took place in Strasbourg, France, 27-31 August, 1990 and 110 participants attended the various sessions.
The theme of the Symposium was dosimetry necessary for the assessment of irradiated reactor materials, featuring irradiation metrology techniques, data bases and standardization. The proceedings of the Symposium will be published in the second half of 1991.

The 55th Meeting of the EWGRD was held August 27, 1990 in Strasbourg. The main topic of the meeting was organizational aspects of the Symposium.

Seminars organized by the HFR Division

Zhu, Junguo, Tsinghua University, Beijing, China
"R & D on HTGR in China"
6th February 1990

S. McAllister, JRC-IAM Petten
"Design & Development of Low-Power BWFC"
16th February 1990

J. Markgraf, JRC-IAM Petten
"Neutron-Radiography in Europe"
22nd February 1990

D. de Zaaijer, ECN Petten
"Quality Assurance at the HFR Petten"
27th March 1990

R.D. Burnette, GA-Technologies, San Diego, USA
"Preliminary results of the D 214 experiment"
19th April 1990

J. Thiel, HRB, Mannheim, Germany
"Fission product release from HTR Fuel Elements"
19th April 1990

Prof. O. Aiozawa, Musashi Inst. of Technology, Japan
"Neutron Beam Design for BNCT and experience of treatment at the Musashi Reactor"
1st May 1990

Dr. M.T. Hutchings, AEA Harwell, UK
"Application of Neutron Scattering Techniques to Material Sciences"
8th June 1990

Dr. K. Ishimoto, JAERI, Japan
"PIE of FBR and LWR fuel rods used in Reactor Safety Programmes"
15th June 1990

S. McAllister, JRC-IAM, Petten
"Multi axial creep testing & modelling of alloy 800H"
3rd July 1990

Prof. R.F. Bath, Ohio State Univerity, USA
"Boron Neutron Capture Therapy of Cancer - Progress and Problems"
10th August 1990

W.P. Voorbraak, ECN Petten
"Neutron dosimetry"
4th September 1990

R.W. Sanderse, ECN Petten
"Health physics at the HFR Petten"
3rd October 1990

J.B.M. de Haas, ECN Petten
"Nuclear computational support at the HFR Petten"
29th November 1990

A. Zurita, JRC-IAM Petten
"The characteristics of the Nuclear Sector in Spain. An example of a medium nuclear developed country"
4th December 1990

A.G. Lee, AECL, Canada
"The characteristics of the MAPLE X10 Research Reactor"
6th December 1990

5. SUMMARY

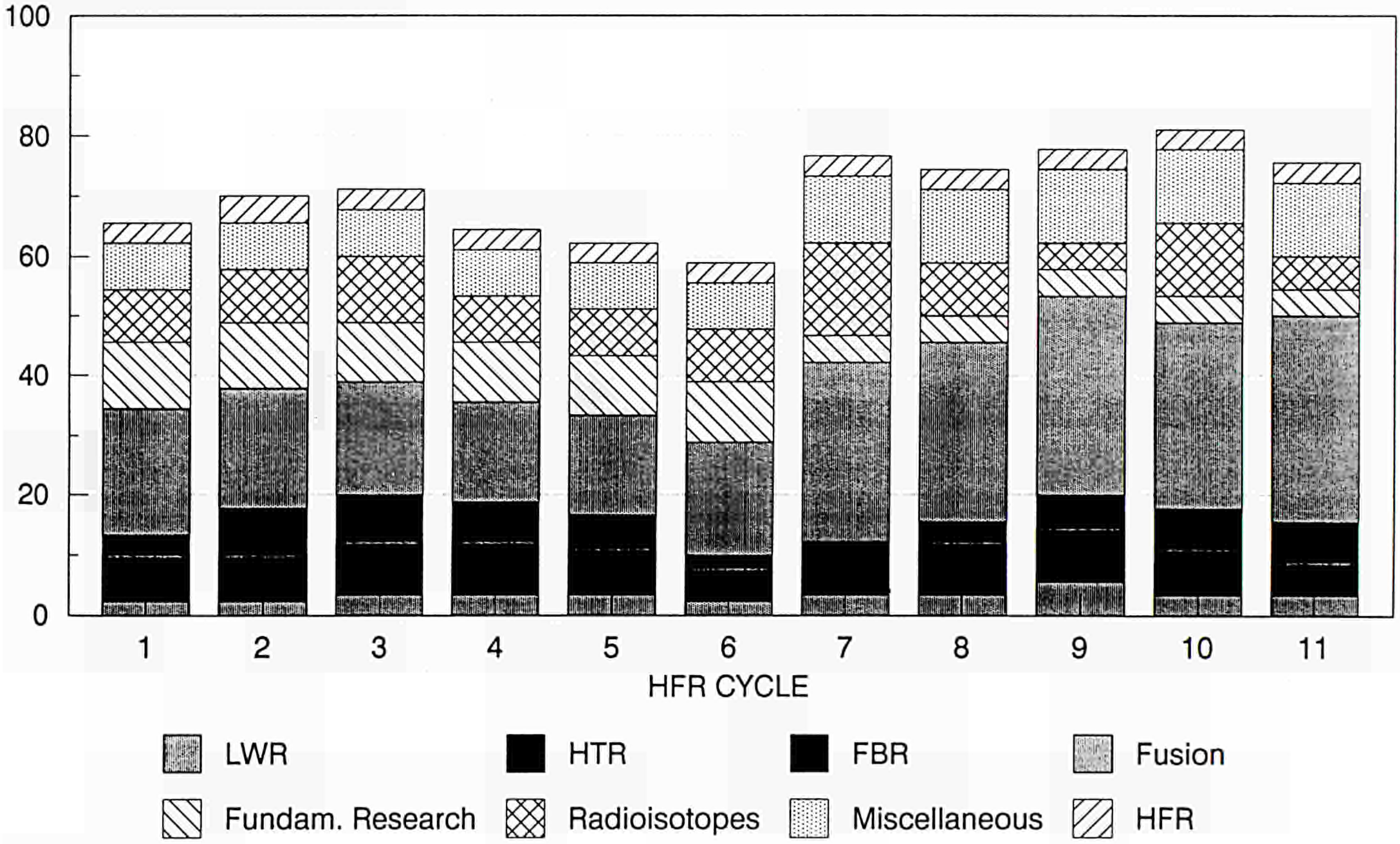
5.1. HFR OPERATION, MAINTENANCE, DEVELOPMENT AND SUPPORT

In 1990 HFR operation was carried out as planned.
The total availability of the reactor was 96% of its scheduled operating time, i.e. 262 out of 273 days.
Routine maintenance and modification activities were carried out in the main stop periods in March and July/August, 1990.
Good progress was made in the scheduled upgrading projects.

5.2 HFR UTILIZATION

In 1990 the average utilization of the HFR was 71% of the practical occupation limit.
Breakdown of the utilization pattern in terms of the different programme sectors is shown in **figs. 26 and 27.**
Programmes related to nuclear energy had again the largest share, the contribution of fusion research being substantially larger than that of fission related research.
Fundamental research at the beam tubes retained its relatively high share.
The utilization of the reactor for radioisotope production increased remarkably.

Fig. 26
HFR utilization in 1990 per cycle in % of the practical occupation limit



Average total: 71%

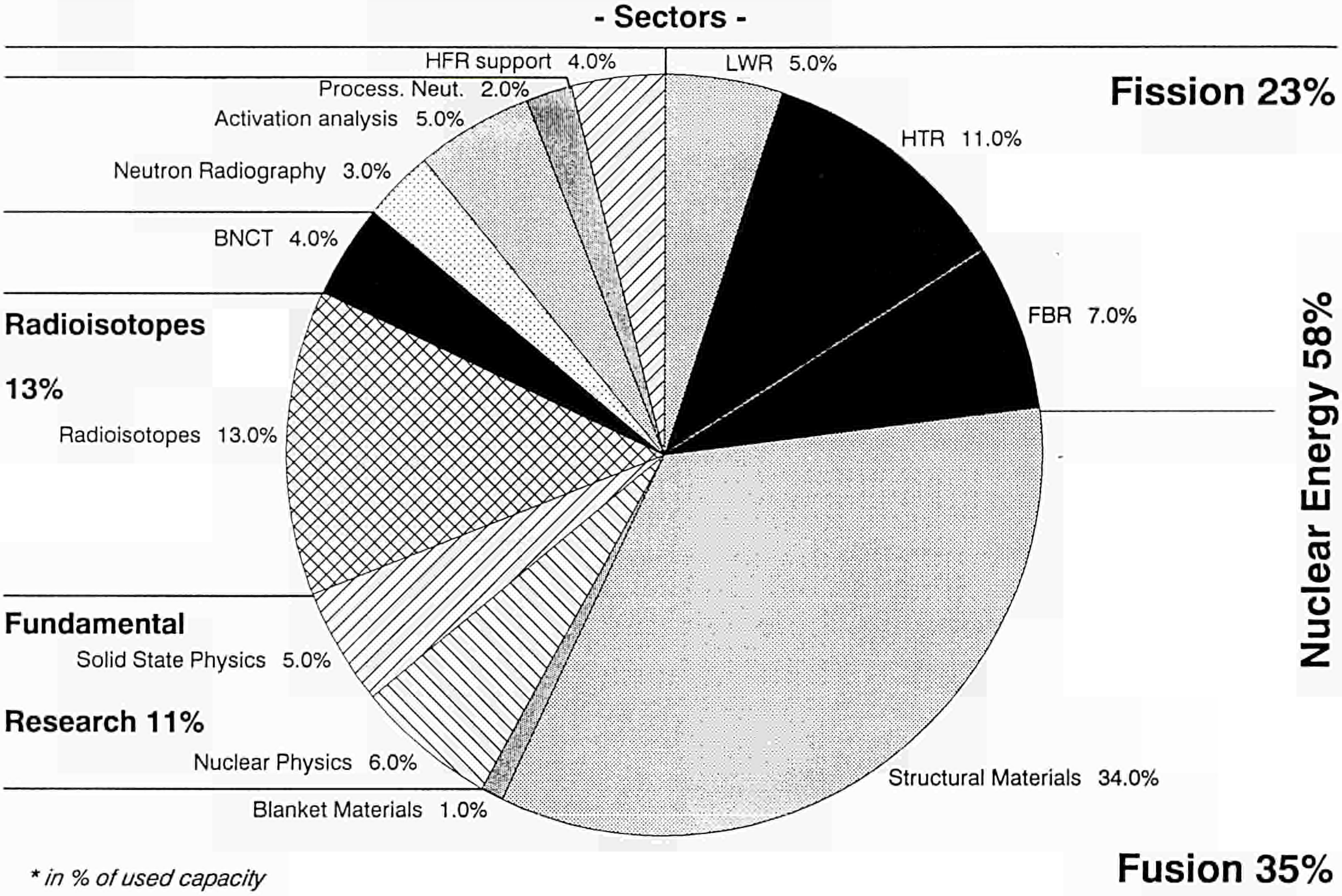


Fig. 27
HFR utilization in 1990 in % of used capacity

5.3. GENERAL AND DEVELOPMENT ACTIVITIES

Work in support of the irradiation programmes, such as assembly of rigs, quality control, experiment operation and PIE and hot cell work, continued as normal.
Development activities addressed upgrading of irradiation devices, neutron radiography and neutron capture therapy.

6. HFR PUBLICATIONS

Topical Reports

J. Ahlf, A. Gevers (editors)
Annual Report 1989
Operation of the High Flux Reactor
EUR 12881 EN, 1990

J.F.W. Markgraf (editor)
Neutron Radiography at the HFR Petten
Compilation of the HFR Petten contributions to the Third World Conference on Neutron Radiography and the SITEF symposium 1989
EUR 12727 EN, March 1990

J. Barton, S. Fujine, K. Kanda, G. Matsumoto (editors)
Proceedings of the Third World Conference on Neutron Radiography
ISBN 0-7923-0832-8, EUR 12876, July 1990

H. Kwast, R. Conrad, S. Preston, N. Roux, H. Werle, S. Casadio, G. Verstappen
EXOTIC Annual Progress Report 1989
ECN-C-90-042, 1990

H. Hausen, W. Schüle, M.R. Cundy
Irradiation creep experiments on fusion reactors candidate structural materials
EUR 13193 EN, 1990

Contributions to Conferences

J. Ahlf
The High Flux Reactor Petten,
Present Status and Prospects
Proceedings of the First Meeting of the International Group on Research Reactors, CONF-9002100, p 45-57

J. Ahlf, J. Schinkel
Upgrading and Modernization of the High Flux Reactor Petten
Proceedings of the Jahrestagung Kerntechnik 1990, p 625-628

A. Carey, S. McAllister
Development of an improved, automated NDE facility for LWR fuel rod testing
10th International Conference on NDE in the Nuclear and Pressure Vessel Industries, London, 11 - 14 June 1990

H.P. Leeflang, J.F.W. Markgraf, K.H. van Otterdijk
A proposed upgrading of the HFR HB-8 neutron radiography facility for commercial application
First International Topical Meeting on Neutron Radiography System Design and Characterization, Pembroke/Canada, 28 - 30 August 1990

H.P. Leeflang, J.F.W. Markgraf, K.H. van Otterdijk
Experiences in radiographic unsharpness determination by means of a knife edge object
First International Topical Meeting on Neutron Radiography System Design and Characterization, Pembroke/Canada, 28 - 30 August 1990

H.P. Leeflang, J.F.W. Markgraf, S. McAllister, K.H. van Otterdijk
Non-destructive testing methods at the HFR Petten for inspection and examination of LWR fuel rods
KTG-Fachgruppe Brennelemente,
Fachtag 1990, Bonn, 19 - 20 November 1990

R.L. Moss, F. Stecher-Rasmussen, R. Huiskamp, L. Dewit and B. Mijnheer
The Petten BNCT Project
4th International Symposium on Neutron Capture Therapy for Cancer, Sydney, Australia, 4 - 7th December, 1990

F. Stecher-Rasmussen, J.B.M. de Haas, W. Freudenreich, W. Voorbraak, B. Mijnheer, R.L. Moss and M. Konijnenberg
Dose Distribution Studies for BNCT Optimisation and Treatment Planning
4th International Symposium on Neutron Capture Therapy for Cancer, Sydney, Australia, 4 - 7th December, 1990

F. Stecher-Rasmussen, R. Huiskamp, M. Konijnenberg, V.G.A. Gregoire, B. Mijnheer, A.C. Begg, R.L. Moss and L. Dewit
Boron detection for the Petten BNCT project: prompt-gamma, ICP-AES track etch and ESI
4th International Symposium on Neutron Capture Therapy for Cancer, Sydney, Australia, 4 - 7th December, 1990

R. Huiskamp, A.C. Begg, V.G.A. Gregoire, D. Gabel, A. Siefert and R.L. Moss
Radiobiology Studies at Petten: status on cell culture, mice and dog exp.
4th International Symposium on Neutron Capture Therapy for Cancer, Sydney, Australia, 4 - 7th December, 1990

L. Dewit, B. Mijnheer, R.L. Moss and D. Gabel
A proposal for clinical pilot studies for BNCT
4th International Symposium on Neutron Capture Therapy for Cancer, Sydney, Australia, 4 - 7th December, 1990

H. Kwast, R. Conrad, S.D. Preston, G. Verstappen, N. Roux, S. Casadio, H. Werle, J.D. Elen
Comparison of the tritium residence times of various ceramic breeder materials irradiated in EXOTIC experiments 4 and 5
16th Symposium on Fusion Technology, London, 3 - 7 September 1990

H. Küpfer, C. Keller, C. Meier, K. Salama, V. Selvamanickam, G.P. Tartaglia
Critical Current and Relaxation of Oriented Grained $YBa_2Cu_3O_7$ after Fast Neutron Irradiation
Applied Superconductivity Conference, United States, September 1990

G.P. Tartaglia, G. Piatti, H. Scheurer, W. Van Witzenburg
Irradiation Effects on Mechanical Properties of 316 Welded Joints
16th SOFT Conference, September 1990

G.P. Tartaglia, G. Sordon
Irraggiamento di materiali per reattori a fusione nel reattore HFR
ORA 35880 - Conferenza su "Tecnologia dei Reattori a Fusione" Frascati, December 1990

H. Hausen, W. Schüle, M.R. Cundy
Irradiation Creep Experiments on Fusion Reactor Candidate Structural Materials
Conference on Structural Materials for Fusion Reactors
Leningrad, September 1990

H. Pruimboom
Status report on the irradiation testing of four low-enriched fuel elements (U_3Si_2-Al and $U_3Si_{1.6}$-Al) by the Netherlands Energy Research Foundation (ECN).
RERTR meeting
Newport, Rhode Island, USA, September 1990

Scientific or Technical Articles

T.E. Chung, R.C. Hurst, S. McAllister
Modelling the multiaxial creep behaviour of Alloy 800H
To be published in : International Journal of Pressure Vessels and Piping

T.D.A. Kennedy, J.F.W. Markgraf, S. McAllister, I. Ruyter
Development of a two dimensional computer code for the prediction of two-phase heat transfer in an experimental LWR irradiation capsule
To be published in : Journal of the British Nuclear Society

L. Dewit, R.L. Moss and D. Gabel
New developments in Neutron Capture Therapy
EUR. J. Cancer, October 1990

R. Conrad
Irradiation Experiments on Liquid Tritium Breeding Material Pb-17Li in the HFR Petten
Fusion Engineering and Design 13, 1990 (to be published)

R. Conrad, L. Debarberis
Irradiation of Liquid Breeder Material Pb-17Li with in-situ Tritium Release Measurements in the LIBRETTO-2 Experiment
Journal of Nuclear Materials 176, 1990 (to be published)

J. Ahlf, R. Conrad, M. Cundy, H. Schreuer
Irradiation Experiments on High Temperature Gas-Cooled Reactor Fuels and Graphite at the HFR Petten
Journal of Nuclear Materials 171, 1990, 31-36

R. Conrad, L. Debarberis
Irradiation Facilities for Testing Solid and Liquid Blanket Breeder Materials with in-situ Tritium Release Measurements in the HFR Petten
Journal of Nuclear Materials 176, 1990 (to be published)

GLOSSARY

ACPM	Advisory Committee on Programme Management
AMCR	Acier Mangan Chrome (Low activation material)
ASTM	American Society for Testing and Materials
BEST	Brenn Element SegmenT
BNCT	Boron Neutron Capture Therapy
BOL	Beginning Of Life
BU	or bu Burn-up
BWFC	Boiling Water Fuel-element Capsule
BWR	Boiling Water Reactor
CEA	Commissariat à l'Energie Atomique
CEN	Centre d'Etudes Nucléaires
CERAM	net CERAMics
CERCA	Compagnie pour l'Etude et la Réalisation de Combustibles Atomiques
CFC	Carbon Fibre Compound
CIEMAT	Ciemat-Elements Manipulations for Transport
COBI	CObalt Isotope production
CORRI	CObalt Reflector Irradiation
CPM	Critical Path Method
CRISP	Creep in Steel Specimens
CT	Compact Tension (specimen)
DACOS	Data Acquisition and Control On-line System
DAR	Damage to Activation Ratio
DIN	Deutsche Industrie Norm
DISCREET	Disposable CREEP in TRIO
DM	Dismantling Cell
ECN	Energieonderzoek Centrum Nederland
EDN	Equivalent DIDO Nickel fast neutron fluence
EFR	European Fast Reactor
ELIMA	Exp. for Li-materials
ENEA	Ente Nazionale Energie Alternative
EOL	End Of Life
EUROS	European Remote encapsulation Operating System
EWGIT	European Working Group on Irradiation Technology
EWGRD	Euratom Working Group on Reactor Dosimetry
EXOTIC	Extraction of Tritium in Ceramics
FBR	Fast Breeder Reactor
FIT	Fissile Isotope Target
FPD (or f.p.d.)	Full Power Day
GA	Technologies General Atomics
GIF	Gamma Irradiation Facility
GRIPS	Graphite Irradiation in Pool Side Facility
HBK-Projekt	Hochtemperatur reaktor-BrennstoffKreislauf
HEISA	HEated and Instrumented SAlt-irradiation
HEU	Highly Enriched Uranium
HFR	High Flux Reactor
HP-PIF	High Flux Poolside Isotope Facility
HRB	Hochtemperatur ReacktorBau GmbH
HTR(HTGR)	High Temperature Reactor
IAEA	International Atomic Energy Agency
IAM	Institute for Advanced Materials
IEA	International Energy Agency

INSAR	Integrated Safety Assessment of Research Reactors
INZINTA	Isotope Trading Enterprise, Budapest
ISOLDE	Iodine Solubility and Degassing Experiment with pre-irradiated PWR fuel rods
JAERI	Japenese Atomic Energy Research Institute
KAKADU	Kamin Kasel-Duo (Twin capsules for fuel pin irradiation)
KFA	Kernforschungsanlage Jülich
KFD	Kernfysische Dienst
KfK	Kernforschungszentrum Karlsruhe
KNK	Kompakte Natriumgekuhlte Kernreaktoranlage
KWU	Siemens AG, UB KWU
LAN	Local Area Network
LEU	Low-enriched Uranium
LIBRETTO	LIquid BReeder Experiment with Tritium Transport Option
LMFBR	Liquid Metal Fast Breeder Reactor
LOCA	Loss of Cooling Accident
LOF	Loss-Of-Flow
LSO	Laboratorium voor Sterk radioactieve Objekten
LWR	Light Water Reactor
MD	Materials Division
MOX	Mixed Oxide
MTR	Materials Testing Reactor
NAST	Na-steel irradiation
NCT	Neutron Capture Therapy
NEMESIS	NEtMEtalS IrradiationS
NET	Next European Torus
NILOC	NItride fuel, Low in Oxygen and Carbon
NRWG	Neutron Radiography Working Group
OPEQU	Over-Power EQUilibrium
OPOST	Overpower steady/state irradiation
ORNL	Oak Ridge National Laboratory
PCI	Pellet-Cladding Interaction
PDP	Trademark for "Digital Equipment Corporation" computers
PHWR	Pressurized Heavy Water Reactor
PIE	Post-irradiation Examinations
PIF	Pool side Isotope Facility
POMPEI	Pellets Oxyde Mixte, PEtten Irradiation
POTOM	Power to melt irradiation
PROF	Pool Side Rotating Facility
PSF	Pool Side Facility
PWR	Pressurized Water Reactor
QA or Q/A	Quality Assurance
QC	Quality Control
QUATTRO	Four channel reloadable rig (29mm)
R&D	Research and Development
REFA	Reloadable Facility
RELIEF	FBR fuel/cladding, axial displacement measurement experiment
RIF	Reloadable Isotope Facility

SANS	Small Angle Neutron Scattering
SCK	StudieCentrum voor Kernenergie (Mol,B)
SIDO	Silicon Doping Facility
SIENA	Steel Irradiation in Enhanced Neutron Arrangement
SIMONE	Test Irradiation for low enriched Silicide fuel elements
SINAS	Simplified NAST (irradiation capsule)
SIP	Silicium Investigation Philips
SOFT	Symposium on Fusion Technology
SUPRA	Irradiation of Superconducting Alloys
TEDDI	Computer programme to evaluate reactor neutron spectrum
THTR	Thorium High Temperature Reactor
TMI	Three Mile Island
TMS	Tritium Measuring Station
TOP	Transient Overpower
TRAGA	Transient Gap conductance measurement
TRAMP	Travelling Measuring Probe (STICK) Gamma calorimeter
TRIESTE	TRIO Irradiation with Experiment of Steel-Samples under Tension
TRIO	Irradiation Device with three thimbles
TRISO	Coated HTR fuel particle types
UKAEA	United Kingdom Atomic Energy Authority
VABONA	Vanadium Irradiation with Boron doping in Natrium-bonding

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ABSTRACT

In 1990 the operation of the High Flux Reactor was carried out as planned.
The availability was 96% of scheduled operating time.
The average utilization of the reactor was 71% of the practical limit.
The reactor was utilized for research programmes in support of nuclear fission reactors and thermonuclear fusion, for fundamental research with neutrons, for radioisotope production, and for various smaller activities.
General activities in support of running irradiation programmes progressed in the normal way.
Development activities addressed upgrading of irradiation devices, neutron radiography and neutron capture therapy.

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