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Commission of the European Communities

Multiannual Programme of the Joint Research Centre 1980-1983

1983 ANNUAL STATUS REPORT

OPERATION OF THE HIGH FLUX REACTOR

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Abstract

The high flux materials testing reactor has been operated in 1983 within a few percent of the pre-set schedule. A major outage period began as planned on 28 November 1983 for the replacement of the present reactor vessel and its peripheral equipment.

During the ten operating cycles before shut-down the reactor utilization reached another record figure in 22 years at 84% of the theoretical full load.

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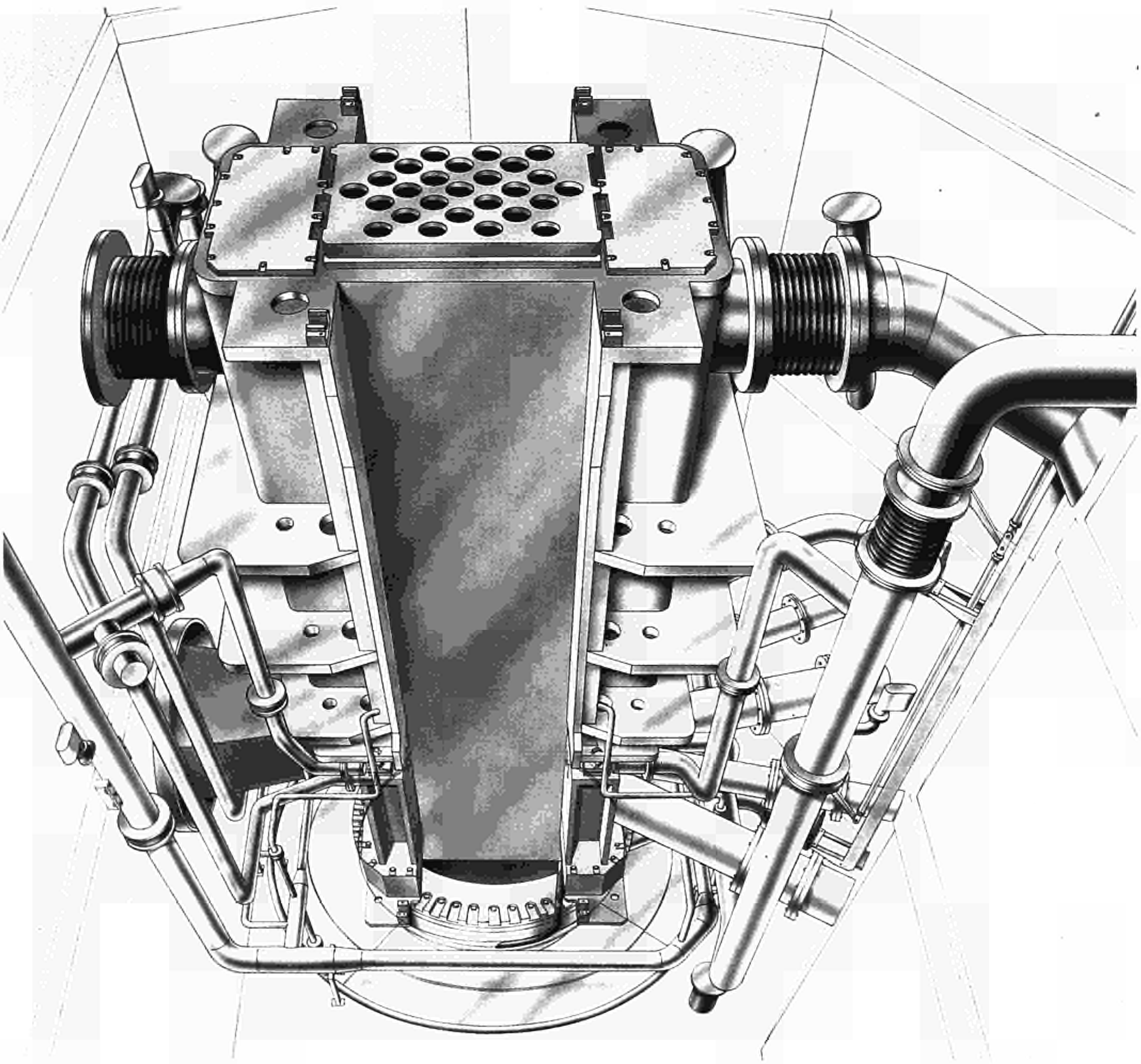
Published by the
COMMISSION OF THE EUROPEAN COMMUNITIES

Directorate-General
Information Market and Innovation

Bâtiment Jean Monnet
LUXEMBOURG

ISBN 92-825-4258-0 [redacted]
Catalogue number: [redacted]



HFR PETTEN
Artist's view of the new reactor vessel with its ancillary systems installed in the pool

Operation of the HFR reactor 1983

Research Staff	**41 persons**
1983 Budget (commitment credits)	
Operation of the HFR, incl. vessel replacement expenses	**14,5 Mio ECU**
Use of HFR by other JRC programmes	**0,9**
Use by commercial clients	**0,1**
Total	**15,5 Mio ECU**

Projects

Unlike most of the other JRC Programmes, "Operation of the High Flux Reactor" is not formally subdivided into individual research projects. For practical reasons, however, four projects have been defined for the 1983 work:

1. **HFR Operation and Maintenance**
2. **Reactor Vessel Replacement**
3. **Reactor Utilization**
4. **General Activities**

On a lower level of subdivision, the term "project" is used for activities under one of the four above headings.

Programme Manager:
P. von der HARDT

1. Introduction

As one of the most powerful materials testing reactors in Europe, the High Flux Reactor at Petten supports research and development in a number of areas, e.g.

- irradiation behaviour studies of potential materials to be used in controlled thermonuclear fusion devices
- the development of nuclear fission energy, especially under safety aspects
- fundamental research with neutron beams, in particular solid state and nuclear structure physics
- the production of radioisotopes for medical, industrial, and agricultural purposes
- neutron activation analysis for geological and environmental studies.

The reactor, its experimental facilities, and the ancillary services have been continuously upgraded with the goal of maintaining a high degree of reliability and of responding to the permanently changing requirements of scientific/technical research.

The replacement of the reactor vessel by a redesigned model has to be seen against the background of this policy. As a result, plant and equipment have demonstrated a consistent availability, near to 100% of scheduled operating time. Simultaneously, the reactor occupation has been on a very high level, i.e. an average of

71 % in 1980
78 % in 1981
81 % in 1982*)
84 % in 1983

confirming that reactor, facilities, and services are in a position to handle a large experimental work volume on schedule.

*) The 1982 occupation, calculated with low enrichment test fuel elements as irradiation experiments, actually exceeded 90%

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2. Objectives

The programme objectives are
1. to operate the reactor in a safe predictable, and reliable way
2. to cooperate with different research teams for the scientific, technical, and administrative definition of reactor utilization projects
3. to direct and manage such projects
4. to develop new methods and equipment for future tasks
5. to maintain international contacts and coordination through meetings, symposia and publications.

HFR Petten

Upgrading and development 1966-1983

- **Power increases 20 to 30, 30 to 45 MW**
- **Introduction of burnable poison fuel**
- **Several core configuration changes**
- **Complete replacement of reactor and general purpose experimental instrumentation**
- **New in-tank experiment penetrations**
- **Several improvements on major plant systems**
- **In-house computer code developments**
- **New reactor and experiment data loggers**
- **New dismantling cell transfer system**
- **Second (beam tube) neutron radiography facility**
- **Modification of the reactor building entrance/exit area**
- **Enlarged computing facilities**

Present major upgrading

- **Replacement of the reactor vessel and of its peripheral installations**

Future developments

- **Development of redundant shut-down systems**
- **Replacement of primary heat exchangers**
- **Medium activity laboratory**
- **Neutron beam quality improvements**
- **New pool neutron radiography camera, image analyser**
- **Studies on complete reactor instrumentation and control room replacement**
- **Studies for a power increase to 60 MW and for a core conversion to reduced enrichment fuel**

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3. Results

3.1. Facilities and Services

3.1.1. Reactor

Reactor operation continued in 1983 at 45 MW during 10 cycles. The plant was shut down on November 28 for the beginning of the vessel replacement period.

Operation during the 10 cycles has been smooth and uneventful. Routine maintenance and inspection confirmed that there were no technical obstacles against continued operation with the existing vessel.

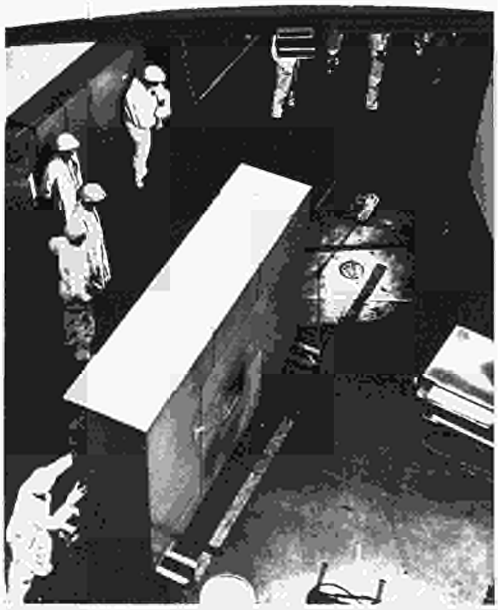
Highlights of vessel replacement preparations in 1983 have been:

- manufacture of all tools and jigs for disassembly of the present vessel, full-scale underwater tests,
- start of manufacture of all components surrounding the new vessel in the pool,
- continuation of manufacture of the new vessel,
- compilation and assessment of detailed scenarios for the three main phases (dismantling, installation, pre-start up commissioning),
- revision of the reactor Design and Safety report.

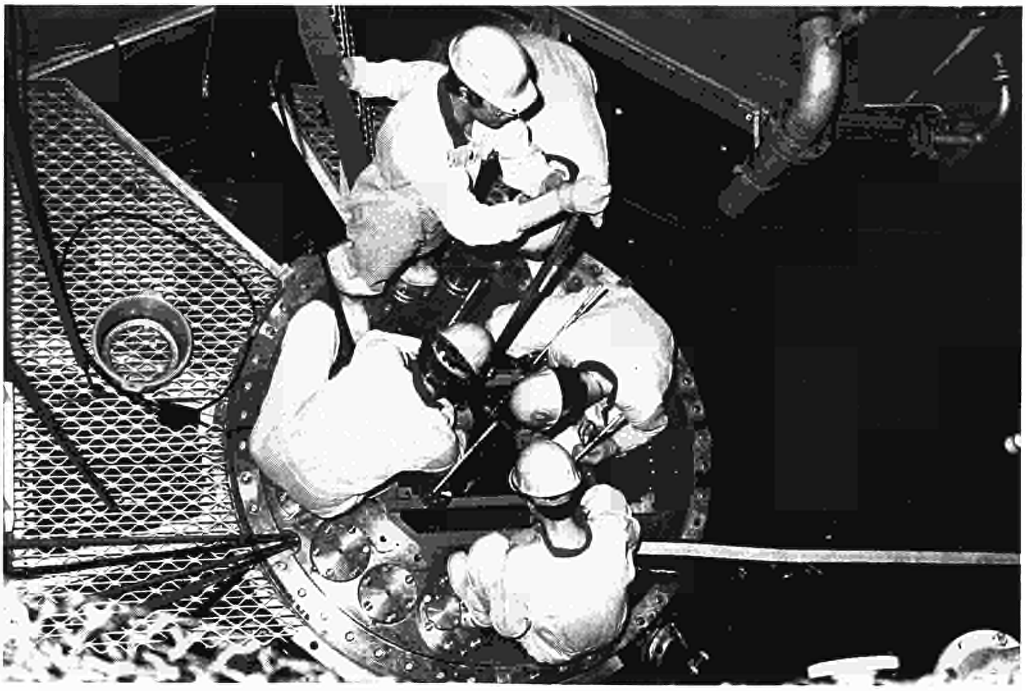
The license for vessel replacement has been issued by the Safety Authorities in August 1983. It is supported by well over 400 technical documents supplied by JRC Petten. Discussions on specific safety questions continued throughout the year.

Disassembly of experimental equipment at the horizontal beam tubes started in November after remaining storage problems had been solved through an agreement with the Dutch Energy Research

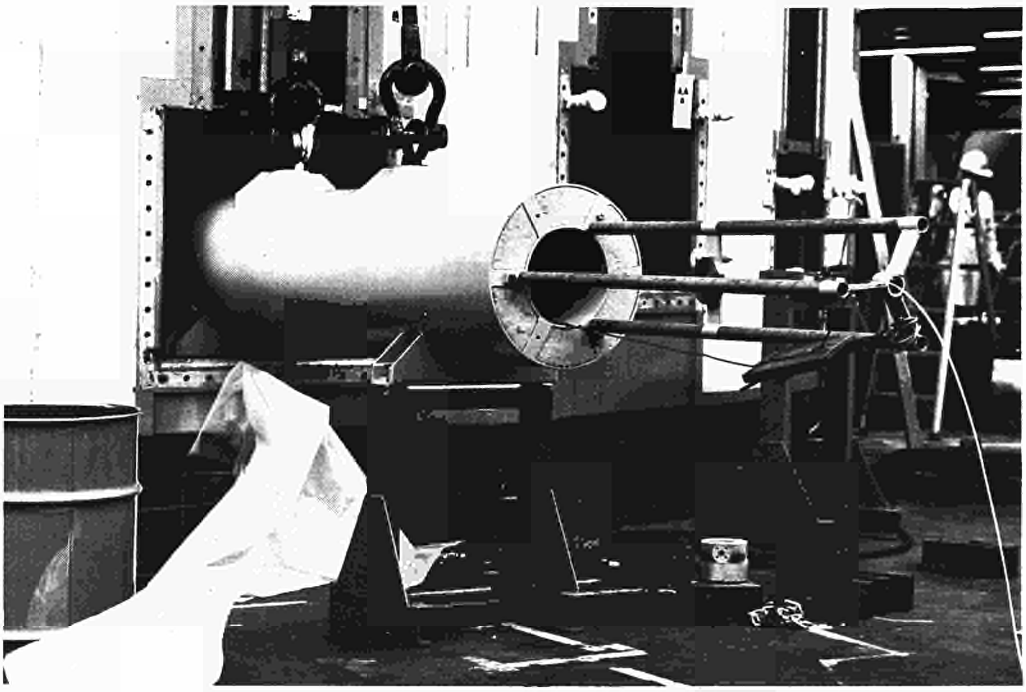
Vessel replacement
Storage of active shielding plugs



Vessel replacement
Removal of thermal column front shield



Vessel replacement
Disassembly of components of the old vessel



Vessel replacement
Removal of beam tube collimator

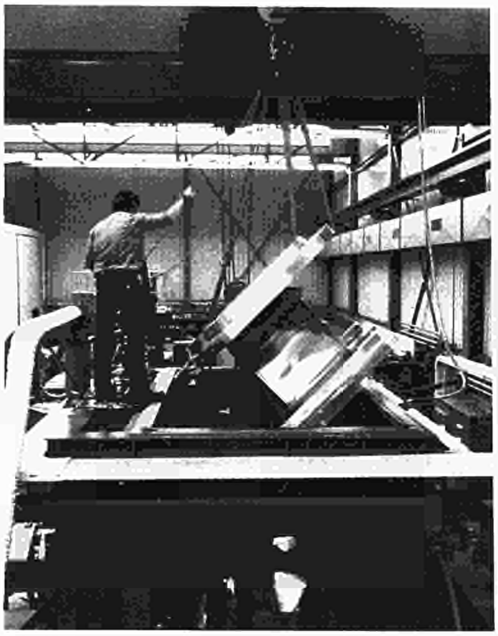
Centre ECN. It was completed, together with removal of all in-beam collimators, at the end of December.

The overall schedule of the replacement operation indicates that manufacture and testing of the new vessel remain critical.

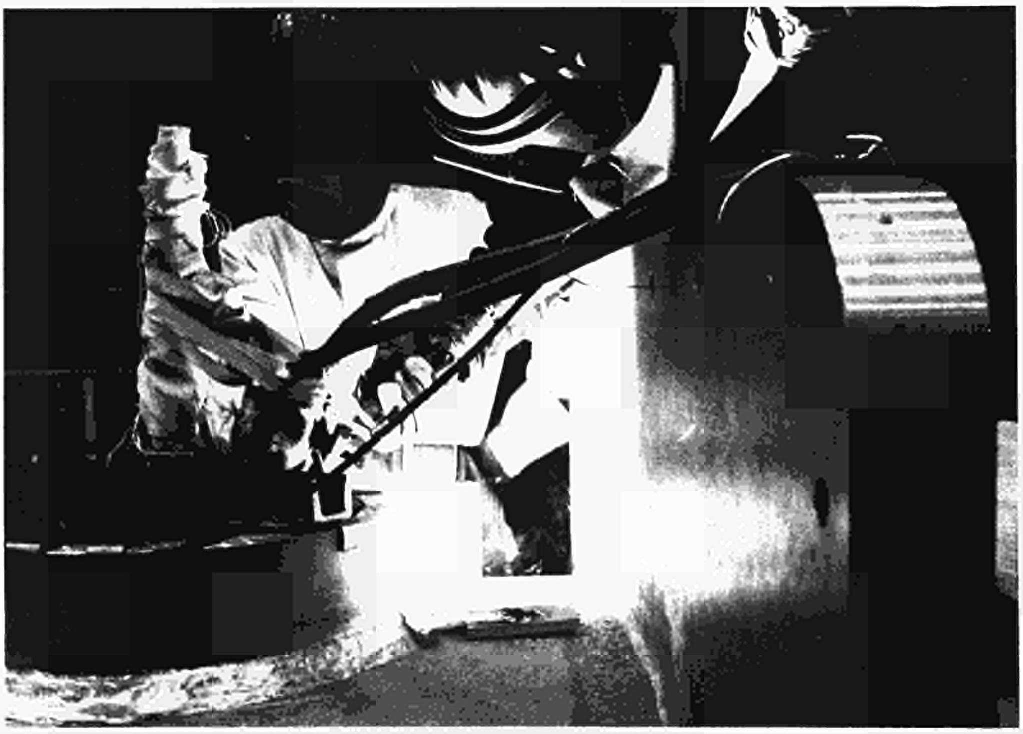
Delays, mainly caused by welding problems, have pushed the scheduled vessel delivery time from end 1983 to May 1984.

During the year 1983, the problems of defects in thick section aluminium alloy welds are not fully understood.

The scheduled start to full power routine operation after the replacement is in August/September 1984.

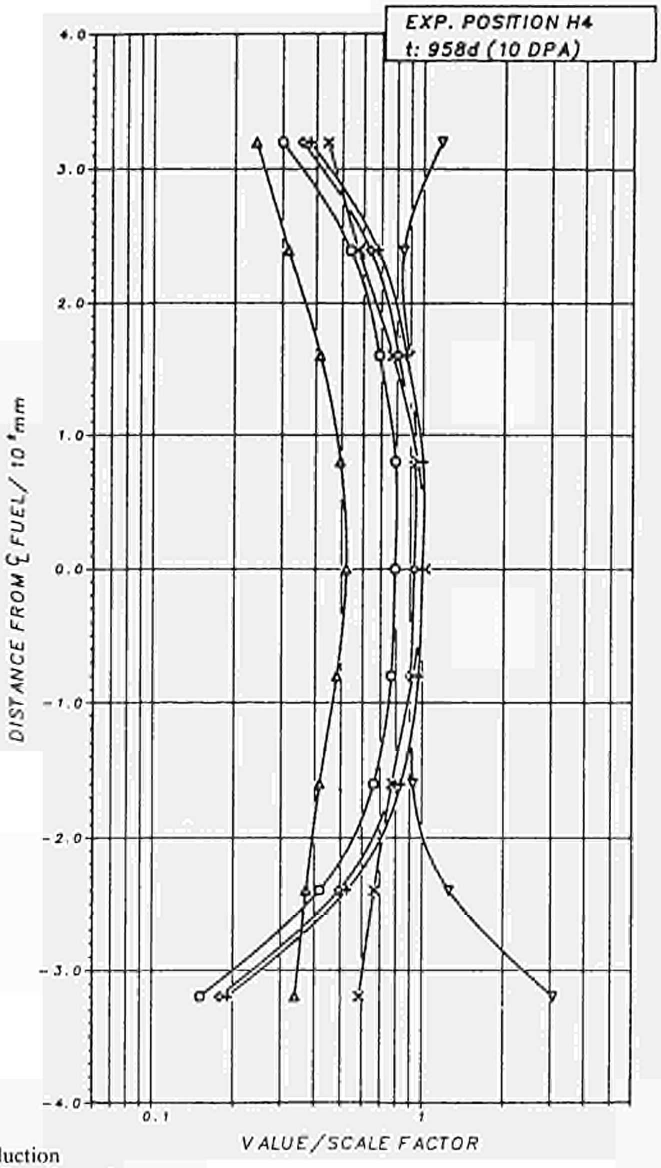


Vessel replacement
Core box with bulkheads being lifted out of the electron-beam welding chamber (May 1983)



Vessel replacement
Welding of a nozzle the convection valve
(December 1983)

Photographs by courtesy of KMS "De Schelde"



DPA and gas production distributions as well as the ratio between helium and DPA level for neutron fluence values under experiment conditions (steel irradiation)
The scale factor(F) is given in the legend below

○ = fast fluence F = $10^{26}m^{-2}$
△ = therm. fluence F = $10^{26}m^{-2}$
+ = DPA F = 10
x = helium F = 10^{-4}
◇ = hydrogen F = 10^{-4}
▽ = appm helium/DPA F = 10

3.1.2. Hot Cells

Hot cell facilities available for the HFR programme comprise:

- the dismantling (DM) cell on top of the reactor pool,
- a series of lead cells,
- a series of lead and concrete cells in the adjacent Dutch research establishment ECN.

In 1983, the DM cell power manipulator has been entirely overhauled with the replacement of all seals, cables, connectors, and other organic components. The re-designed cell ventilation control system became operational.
Installation and testing of universal dimensional measuring equipment in the JRC lead cells have been finished.
Work has been continued to schedule on the large remote encapsulation facility EUROS: with most of the equipment available full scale testing can now be started.

3.1.3. Ancillary Services

Users of the reactor find access to the necessary ancillary services, ranging from drawing office, workshop, and several computer installations to a full spectrum of post-irradiation facilities (see above), and of neutron computation and dosimetry services.

During the year the computer installations have been modernized and upgraded, a.o. by

- improvement of the central data acquisition/processing system DACOS,
- enlargement of the possibilities of the three desk top computer installations,
- replacement of the theoretical analysis group's main processor by a modern machine,

- first operations with the JRC Ispra computer centre remote job entry.

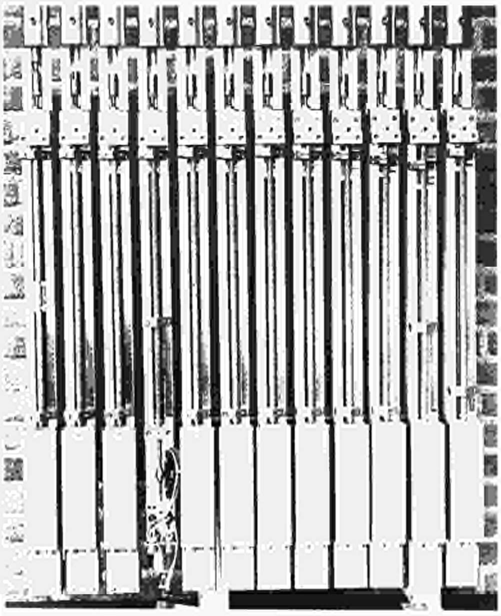
The accurate determination of HFR nuclear characteristics which is essential for the interpretation of many irradiation experiments has been pursued with the evaluation of the neutron metrology programme "FLUX 82".

New requirements have been determined, partially in the framework of collaboration with Japan and the United States, for neutron field and reaction computations in fusion material irradiation tests and for the underlying neutron dosimetry. The amounts of hydrogen and helium produced, and the atom displacement, in austenitic steels have been calculated for various HFR positions. It could be shown that thermal neutron absorption by capsule construction materials and specimens plays an important role in the gas production rate.

3.1.4. Irradiation Facilities

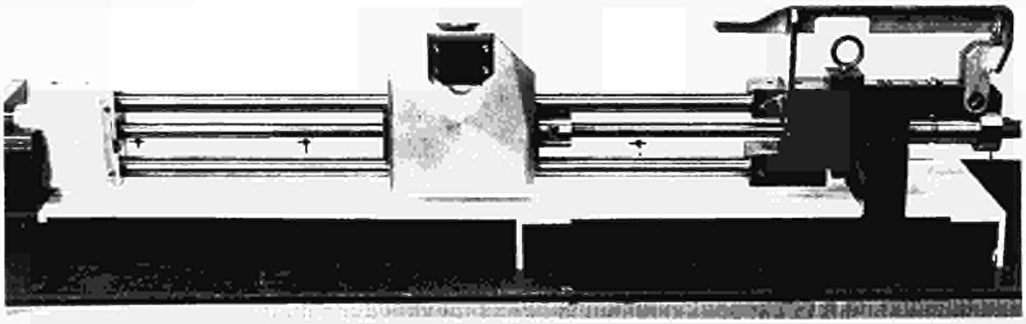
Users of the reactor find a number of basic standard facilities which are made available to them on a routine basis and which help to cut down on development time and cost.

Development, manufacture, and testing have been terminated in 1983 of new standard rig heads for in-pile capsules as well as of new horizontal displacement units for pool side experiments. Since most of the irradiation facilities used will be scrapped during the forthcoming reactor vessel replacement, manufacture of new material has been initiated during the year. For those experiments which are wired into a direct safety action new alarm circuits with a built-in two-out-of-three logic have been introduced.



a) Out of pile control mechanisms

b) In-pile "trolley"



Pool side facility: New horizontal displacement devices

HFR Petten

Standard irradiation facilities

1. Non-fissile materials testing
Graphite, stressed or unstressed, metal or graphite/He environment Ø/6...20 mm; 300 ...1200°C Specimen recycling.
Steel, unstressed, Na environment, tensile specimens, Ø/6...12mm, 550....650°C also: non-cylindrical (Charpy, CT, etc.). Short term facilities (reloadable during reactor operation). Neutron flux tailoring for Fusion reactor materials.
Low temperature Al specimen capsules (various sizes)
Graphite and steel creep facilities with on-line measurement or specimen recycling
In-core instrumentation test rigs
Under development: Fatigue and crack growth capsules.

2. Fissile materials testing, in-tank facilities
Single or triple, double-walled Na (NaK)-filled, 500...1000°C clad temperature, 400....1200Wcm^{-1}. Optional: Neutron screen, central thermocouple, fission gas pressure transducer,.... Single or double-walled HTGR fuel rigs, graphite/He environment, 100....1000Wcm^{-1}, 800...1500°C fuel temperature. Continuous fission gas sweeping and analysis.
BF_3 operated power transient facility.

3. Fissile materials testing, pool side facility (PSF)
Single-walled Boiling Water Fuel Capsule (BWFC), variable power, 70...150 bar water pressure, 200...800Wcm^{-1}, 250...350°C clad temperature. Continuous fission product monitoring. Pre-irradiated fuel pins.
Optional: Different types of fuel pin instrumentation
Double-walled, Na (NaK)-filled, single or double carrier capsule. Variable power, 500...1200Wcm^{-1}, 400...800°C clad temperature. Fuel pin length up to 500 or 1600 mm.
Optional: Different types of fuel pin instrumentation
Profilometer capsules.
Transient overpower loop
Under development: Encapsulation facility for pre-irradiated fuel pins.

4. Miscellaneous
Different radioisotope production rigs, mostly reloadable during reactor operation
Gamma irradiation facility
Neutron activation analysis installation
Two neutron radiography installations
Beam tube nuclear and solid state physics equipment: Several diffractometers and spectrometers, mirror and filter systems, with ancillary cryogenic equipment and process computers
Under development: Pool side gamma scan facility.

5. Standard out-of-pile control facilities
Gas mixing and control panels, partially automatic
Cooling water control circuits
Micro-processor based data loggers
Data processing computer
In-pool diameter measurement, eddy current check, neutron radiography, gamma scan facilities
Multi-purpose hot cell facilities on site.

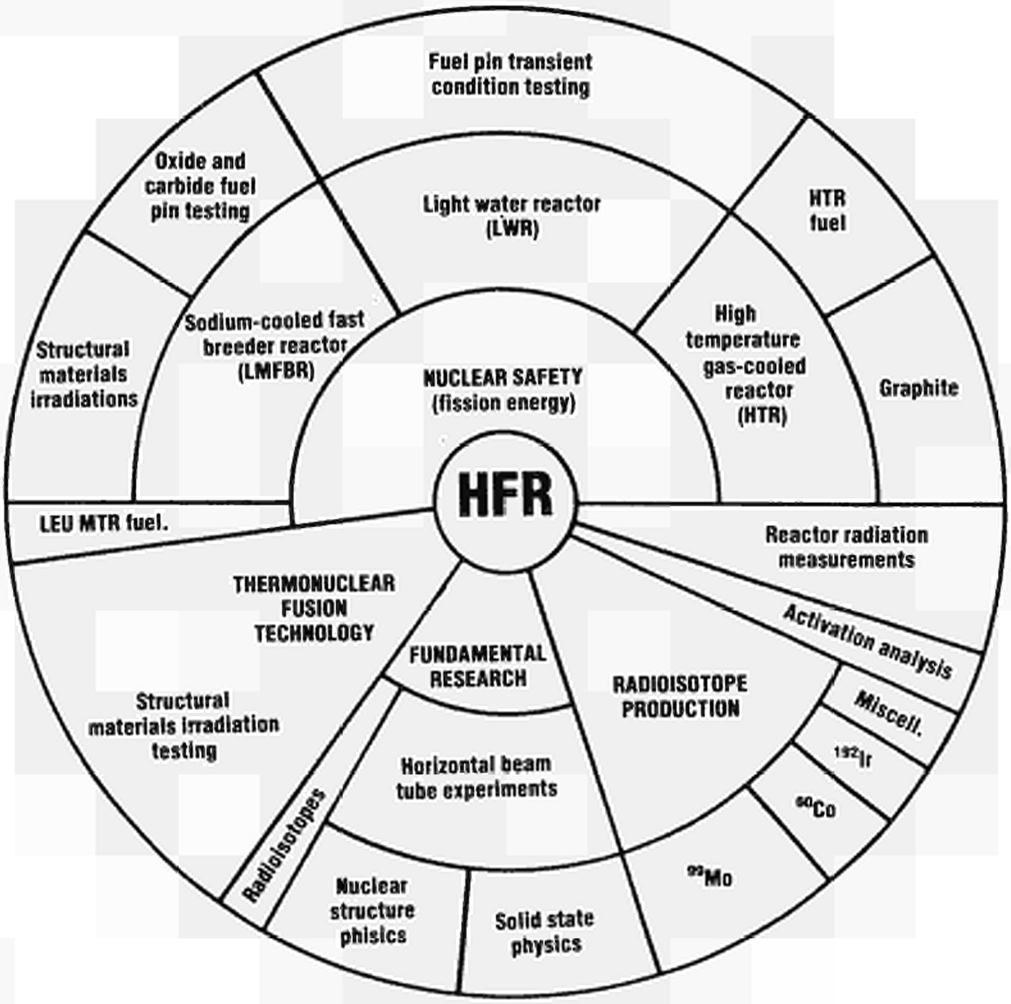
3.2. Utilization

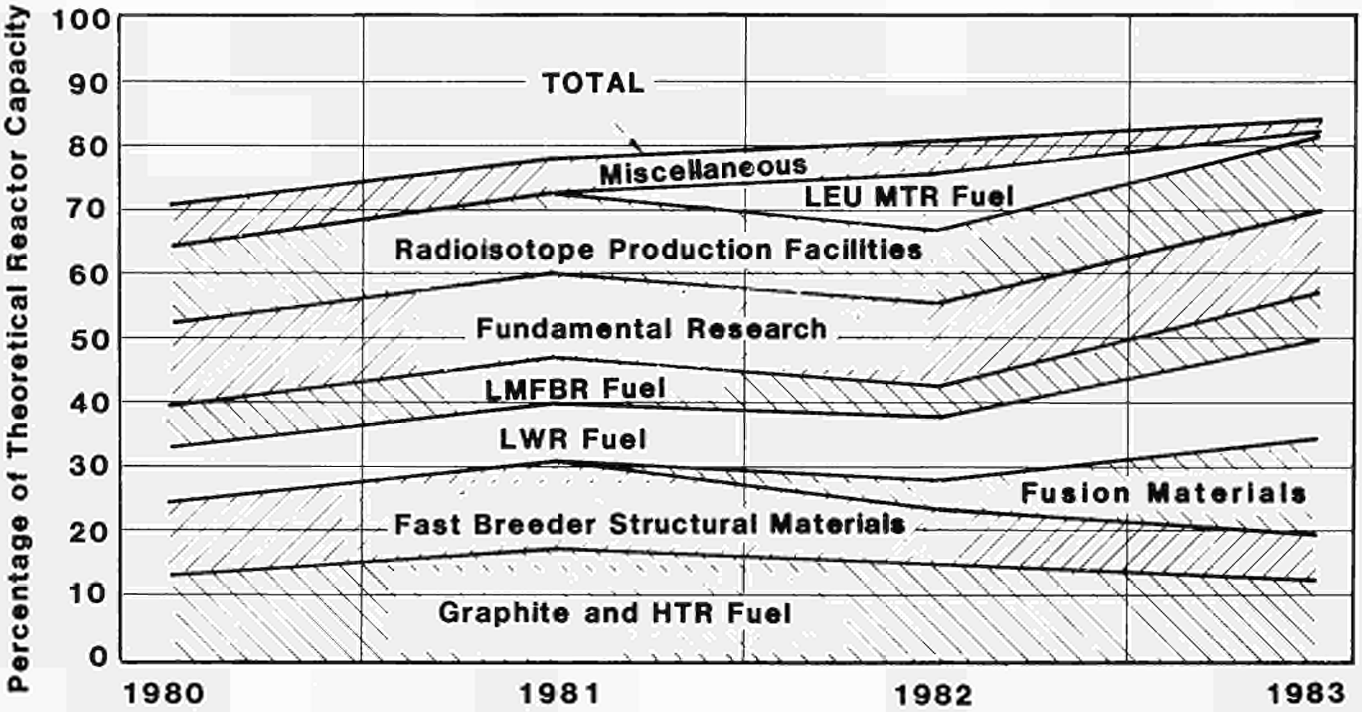
3.2.1. Scope

The experimental work carried out in HFR Petten originates from intense collaboration with teams from different research areas

- nuclear fission energy, especially under safety aspects
- thermonuclear fusion environment
- environment
- fundamental research
- radioisotope production for scientific, industrial, and medical applications.

1983 has been the year of another record occupation of the reactor with 84%. Several irradiation projects had to be delayed by the lack of reactor space.





High Flux Materials Testing Reactor (HFR) Petten
Development of the reactor utilization during the 1980/83 JRC programme period

3.2.2. Nuclear Fission Energy

High temperature gas-cooled reactor

The high temperature gas cooled reactor (HTR or HTGR) offers a number of advantages:
- high thermal efficiency, i.e. improved utilization of resources and reduced waste heat release
- large flexibility of its fuel cycle, including proliferation-resistant solutions
- high inherent safety
- utilization for high temperature chemical processes, including coal gasification and liquefaction (substitution of natural gas and oil), electricity.

The development of this reactor type is actively pursued in the Federal Republic of Germany, the U.S.S.R., and in Japan with contributions from a number of other countries.

HFR Petten has been in charge of test irradiations for two materials which are typical for the HTR:
- graphite as a predominant core structural materials
- coated particle fuel elements.

As a contribution to HTR core structural material irradiation testing, a large number of graphite samples has been irradiated since 1962. The HFR graphite irradiation programme supplies the necessary design base for future HTR types, starting with the steam generating plant, but including the nuclear process heat and the direct cycle concepts.
The irradiation capsules contain unstressed samples (fundamental properties programme) or creep specimens under tension or compression. They are irradiated in three to four fluence steps, with inter-

mediate measurement of their changed physical properties. For the reflector graphite materials, irradiation temperatures range between 300°C and 1150°C, up to extreme neutron fluences.
In terms of number of irradiated samples and neutron fluences this is the most significant graphite research work in the world.
Two graphite irradiations have been terminated in 1983.
Coated particle fuel element testing is performed in HFR Petten on reference coated fuel particle systems and production fuel elements for the UO_2 low enriched uranium (LEU) fuel cycle.
Three different in-pile tests were successfully terminated in 1983, i.e.

- one reference test on spherical reference fuel elements (60 mm diameter) at nominal and extreme irradiation parameters
- one failure rate test on components with reference coated particle fuel at extreme irradiation parameters
- one temperature gradient test on coupons with reference coated particle fuel at extreme thermal conditions.

Design of four new experiments has been started in 1983 which are planned for the period after the vessel replacement.

Light water reactors

A large part of the experiments carried out in HFR Petten concerns the behaviour of nuclear reactor core materials under transient and abnormal conditions. Fuel pins which have already operated for two to four years in light water power reactors are submitted to transients in specially developed irradiation capsules in order to test their resistance against abnormal conditions (overpower).
The accurate knowledge of this behaviour allows large power reactors to be operated with a maximum of assurance against the release of radioactivity (fission products).
The HFR BWFC (Boiling Water Fuel Capsule) experimental programme features 25 to 30 experiments per year, including their non-destructive tests before and after irradiation.
Work in 1983 consisted of the complete test cycle on 19 pre-irradiated fuel pins. Fourteen more pins have been irradiated for a fission product release project. A new development for a loss-of-cooling capsule has been pursued.
The in-tank facility POTRA, operating with BF_3 gas as variable neutron absorber, has been made operational.

Liquid metal cooled fast breeder reactors

Internationally several R&D programmes are pursued with the goal of qualifying

- advanced LMFBR fuel (carbide) under normal and abnormal conditions
- mixed oxide fuel under start-up and in-situ operational transients
- structural materials.

In 1983 four fuel pins have been submitted to "mild" power variations whereas two were tested under a sharp overpower transient (TOP test).
The translation of the HFR environment into real fast reactor conditions is achieved by a combination of particular neutron flux measurements and computer calculations. Certain irradiation devices use cadmium filters to simulate the fast reactor neutron spectrum.
Neutron gradient problems which had occurred in pool side facility irradiations of fast breeder fuel could be eliminated by specially designed directional absorber screens.
Another safety problem in breeder reactors concerns the response of neutron irradiated structures to mechanical stresses including vibration and shock. Nearly 2000 stainless steel specimens have been ir-

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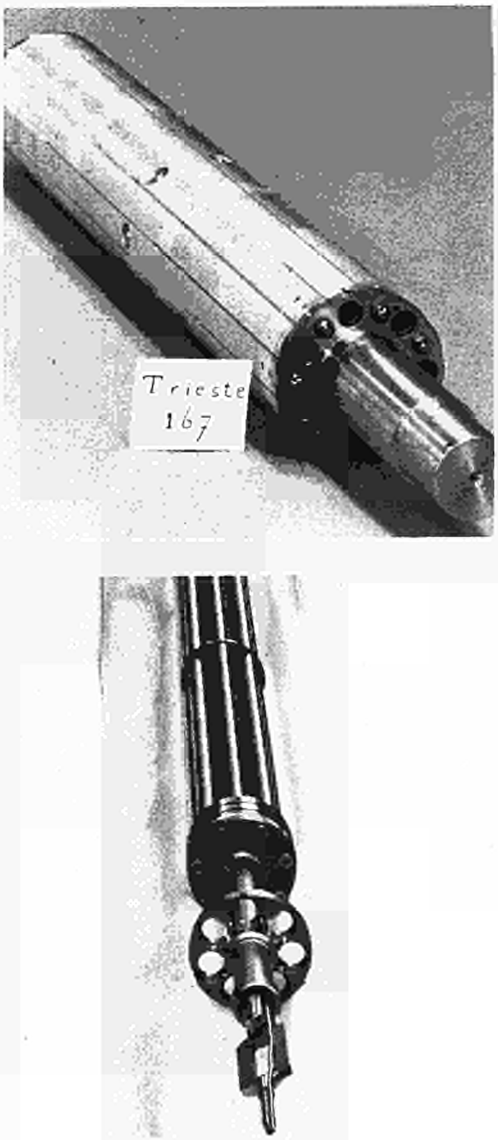
radiated in HFR over the past seven years, and transferred to post-irradiation mechanical testing in shielded laboratories ("hot cells"). The irradiations have supplied accurate information of material embrittlement by helium formation and fast neutron displacements.
On November 28, 1983, an irradiation test containing 144 austenitic steel samples for the JRC Ispra Reactor Safety Programme was terminated, after a record irradiation time of over 5 years (about 1.300 full power days). The damage achieved in the specimens corresponds to 30 dpa (displacements per atom) and 170 appm (atomic parts per million) of helium.

3.2.3. Thermonuclear Fusion

Fusion reactors, together with fast fission breeders and solar energy, are considered to be the potential new primary source, able to solve the problem of energy supply in the next century. For this reason, large efforts are being devoted worldwide into the research related to the controlled thermonuclear systems.
During the past several years there have been notable developments in this field. The physics of confinement and heating of plasmas has been investigated in a number of experimental machines in Europe, Japan, the USSR, and the USA.
As confidence on the potential of plasma systems to get conditions for ignition grows, more attention is paid to the steps forward to the achievement of commercial fusion power reactors and the related technological problems which are, amongst other things, materials problems. Fission test reactors like HFR can be used for irradiation testing of candidate fusion reactor materials. Work in HFR Petten is embraced by the 1982/86 European Fusion Technology Programme, an implementing agreement sponsored by the International Energy Agency, and the Fusion Technology Programme of JRC Ispra.
The first irradiations have been started in 1982 and their number increased considerably in 1983 (see table).
Supporting studies on neutronic aspects of fusion material irradiations in HFR and on the required metrology (dosimetry) have been pursued (see 3.1.3).



a) Lower (in-pile) part

b) Upper part

Thermonuclear fusion
In-pile creep facility TRIESTE

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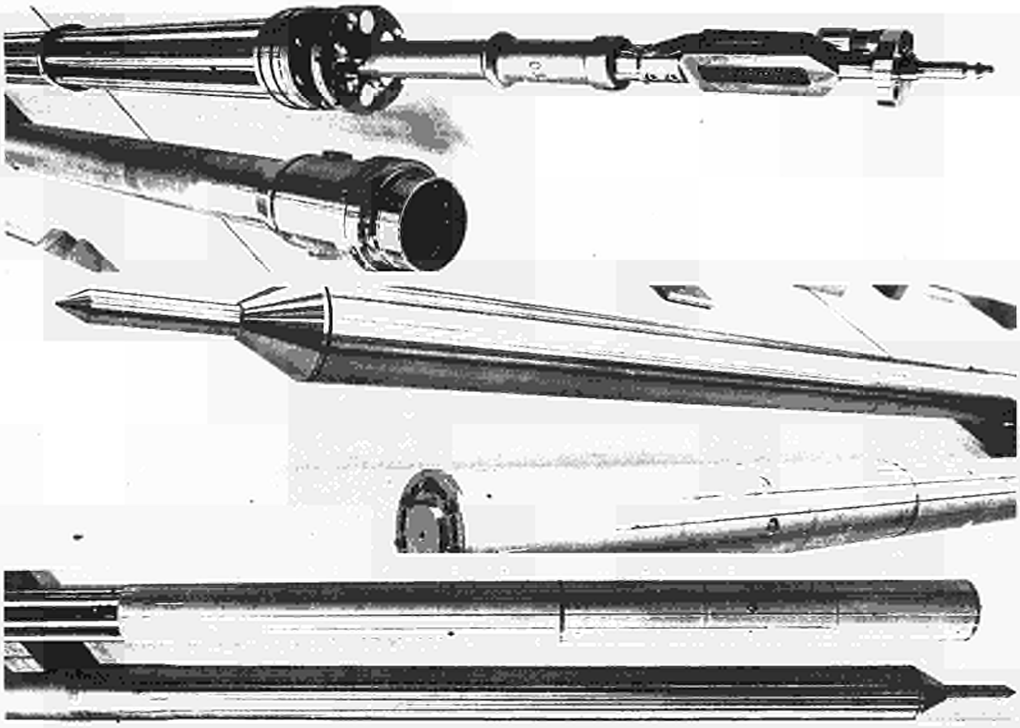
Project Name	Specimen Material	Test Type	Status	Remarks
SINAS	← Austenitic stainless steel →	Post-Irradiation tensile and creep tests Post-irradiation crack growth experiment	Three rigs irradiated in 1983	Seven specimen carriers
FRUST		Post-irradiation tensile	Under irradiation	IEA implementing agreement
	Austenitic stainless steel, incl. AMCR	Post-irradiation tensile	Two irradiations finished in 1983 Two new rigs under assembly	JRC Ispra Programme
CRISP	← Austenitic stainless steel →	In-pile creep measurements	Under assembly Irradiation 1984/86	On-line measurement
TRIESTE			Under irradiation	Intermittent measurement
LOCFIRE FATMAC		In-pile fatigue In-pile crack growth	Under development. Irradiation in 1985/86	
SUPRA	V_3Si	Fundamental research on radiation damage in superconducting materials	Irradiations carried out in 1983	
VABONA	V-5Ti	Radiation damage studies		
(CERAM)	Cu, W, ceramics	Radiation damage studies	Under development Irradiations in 1985/87	
EXOTIC	Ceramic breeder material, e.g. Li_2O, $LiAlO_2$, Li_2SiO_3	1) Irradiation testing, with parameter variation, of basic properties 2) Tritium release studies by means of in-pile extraction and on-line measurement	Under development Irradiations in 1984/87	
	Liquid breeder $Li_{17}Pb_{83}$	Tritium release and permeation under neutron irradiation	Under development	JRC Ispra

Highlights of the 1983 HFR work for fusion material R&D have been

- the irradiation of a large number of tensile specimens of European reference 316 and of AMCR austenitic steels
- start of irradiation of the long-term in-pile creep series TRIESTE
- the irradiation of a large number of V_3Si and V-5Ti samples,
- design and development work on several new projects.

HFR staff also provided expertise on fusion material irradiation testing in numerous meetings of European and international working groups.



Thermonuclear fusion
In-pile creep facility TRIESTE
Capsule components prior to specimen loading

3.2.4. Protection of the Environment

Neutron activation analysis is a very efficient and accurate method for the determination of a large number of trace impurities and contaminants. Therefore it is a method, which can be used as an effective instrument for environment pollution control, e.g. for the determination of arsenic, mercury, cadmium, uranium, selenium and antimony in residues from coal-firing by means of a sensitive radiochemical procedure, which has been developed recently.

In the field of activation analysis HFR Petten offers several facilities over a wide range of irradiation times and sample volumes, using both conventional and prompt gamma ray techniques, i.e.

- the epithermal low flux facility in the pool (PROF)
- the fast rabbit system FASY in HB-10
- the prompt capture gamma ray facility in HB-4.

In 1983, the fast rabbit system FASY came to completion by a full automation of the storage and processing of the irradiation data and the γ-ray spectra.

The thermal flux is $4 \times 10^{13} cm^{-2} s^{-1}$ over a capsule volume of 0,8 ml.

Return-times down to 300 ms can be reached.

The outer shuttle is separated from the inner sample capsule during return. In total, 2997 samples have been irradiated in FASY during the year.

The Cd-shielded Pool side Rotating Facility (Cd-PROF) has been reshaped and retested. Flux monitoring is done with thin iron rings.

The facility for prompt capture γ-ray measurements was rebuilt and a sample changer for 3 ml teflon tubes was installed. The array was defined in terms of background and specific count rates under the principal peaks in the region of 100 - 2000 keV.

The facility is used for the determination of H, B and some lanthanides in samples of ≈2 grams using counting times 1000 (B) to 20.000 seconds. Eventually, Cd and most major constituents can be essayed as well by extending the counting time.

Other applications of neutron activation analysis have been

- the determination by instrumental neutron activation analysis (INAA) in the FASY of Se on the $ng.g^{-1}$ level in blood and foodstuffs
- the determination of As, Se and Sb in both sea- and fresh water by NAA pre-separation and- concentration, evaporation as hydrides and adsorption to active carbon
- the determination of B in fly-ash by prompt capture γ-ray measurements.

In total, irradiations for neutron activation analysis and prompt capture γ-ray measurements yielded ≈ 2 x 10^4 elemental determinations.

3.2.5. Fundamental Research

Certain interactions of neutrons with matter, like prompt gamma emission after neutron capture, scattering, diffraction, etc., can be used for studies of fine structures of nuclei or crystal structures of solids. The installations around the reactor use "beams" of neutrons extracted from the core through horizontal tubes. Spectrometers arranged around the target area measure intensity, energy orientation and polarization of the emitted radiation, which are then analysed by means of computer codes.

Nuclear physics

General

As in the previous years four horizontal beam tubes have been used by the FOM-ECN Nuclear Structure Group in cooperation with university laboratories and other nuclear research centres. This year three members of the group obtained a doctor's degree on the basis of their experiments at the beam tube facilities, and in this way the number of such degrees in nuclear physics was brought to eighteen. In the frame of an evaluation procedure initiated by the foundation FOM, a scientific programme and budget proposal for the years 1984-1988 has been prepared.

According to this proposal it is intended to pursue fundamental experiments besides other applications of neutron capture techniques if these activities are judged favourably by an independent group of international experts.

Scientific programme

Running measurements

Some unforeseen beam time was available and besides rounding off the projected programme on neutron capture in polarized light nuclei, it was possible to perform feasibility studies on equipment planned for the new 24 keV beam. It was shown to be possible to polarize low energy neutrons by transmission through polarized protons in a TiH_2 sample at 10 mK and 8 T. Such low temperatures and high magnetic fields have been used as a standard procedure throughout the year.

External publications

Besides the already mentioned doctor's theses eight publications in international journals have appeared. A book on "Symmetries in Nuclear Structure" was published which has been edited in collaboration with colleagues at Dutch universities.

Facilities

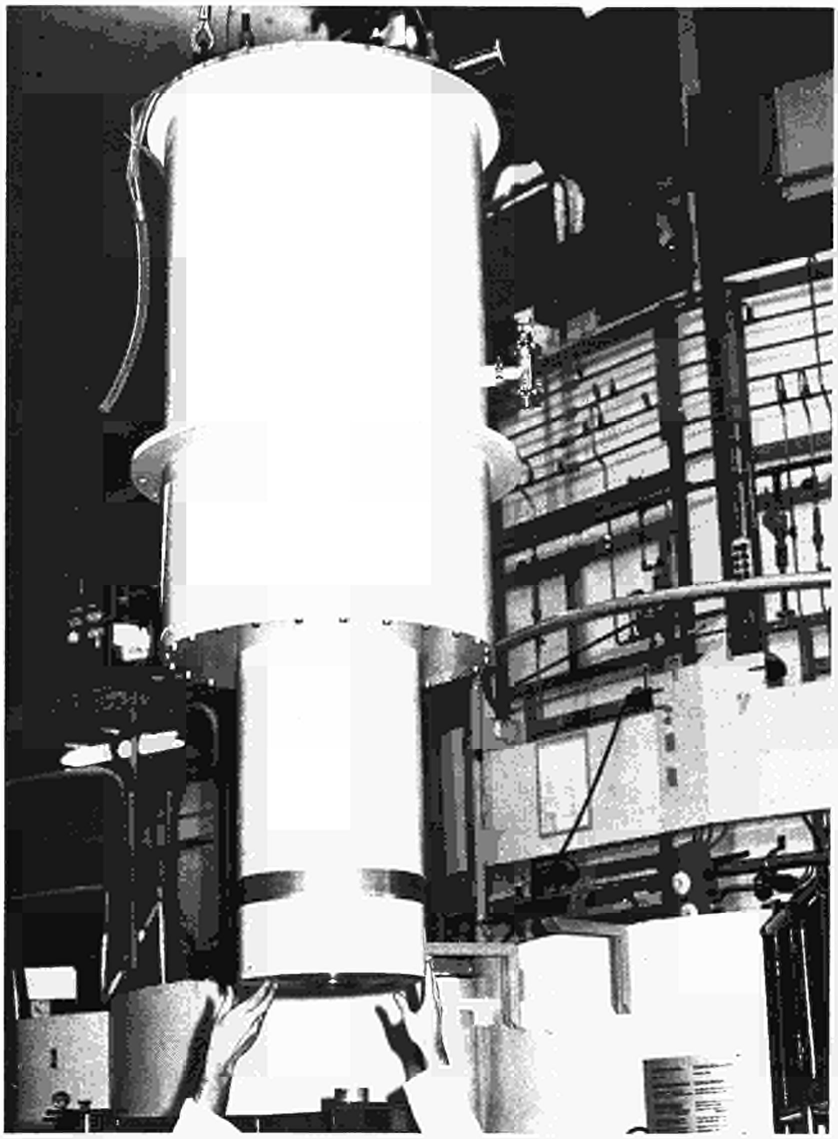
All experimental facilities have been dismantled in November, in preparation of the vessel replacement. Particular techniques had to be applied for the safe recovery of the mirror facility in HB 0. Design assistance has been supplied for developping the new HB 11 - HB 12 beam tubes which will be installed together with the new vessel.

Solid state physiscs

Neutron scattering research on solid state physics has been carried out by the exploitation of four horizontal beam tubes. At these beam tubes five experimental facilities are located which have been in continuous operation. A major part of the research programme was carried out in close relations with Dutch universities and industrial laboratories.
Neutron radiography by means of cold neutrons has been considered and the design of modification of the existing facility has been initiated. All beam facilities have been dismantled in November 1983 and removed in preparation of the reactor vessel replacement.

Instrumental

- For a simpler and more reliable beam tube control new collimators and cubicle shieldings have been made.
- For the spectrometer at HB 3 a new control computer has become available and



Fundamental research.
Nuclear physics. Removal of the liquid helium cryostat from horizontal beam tube HB2 (November 1983).

HIGH FLUX MATERIALS TESTING REACTOR HIGH FLUX MATERIALS TESTING REACTOR HIGH FLUX MATERIALS TESTING REACTOR PETTEN
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a modified helium cryostat provides for spin density investigations at low temperatures by means of polarized neutrons.

- For the test experiment on a variable heavy water reflector at the R_2-0 reactor at Studsvik the D_2O-tank has been completed, the detection equipment has been installed and provisions for an experiment with a beryllium reflector were made. Safety considerations were made and licencing has been arranged for.

Research

- The neutron scattering investigations carried out by means of the HFR facilities comprised topics from crystallography, magnetism, metal physics and molecular dynamics.
- Experiments using the four-circle diffractometer have provided for the solution of many crystallographic structure problems raised by research groups from the Foundation Scheikundig Onderzoek Nederland.
- Many detailed crystallographic and magnetic structure studies could be made by means of the powder diffractometer. Among them were the analysis of the magnetic structures of various phases of solid oxygen and the determination of magnetic structures of some Heussler alloys with specific electronic band structures.
- A study of intermediate phases in some antiferromagnetics and of the phase transitions between them has been completed.
- Significant progress has been accomplished in a study of a mixed system of components with very different anisotropic magnetic ordering. It seems that these results may give support to new theoretical developments.
- Spin density studies of some transition metal alloys have been completed at room temperature and will be followed by experiments at low temperatures.
- Gamma diffraction experiments have been carried out at Missouri Univerity Research Reactor on nickel with different deformation treatments to compare with neutron studies of extinction phenomena. The result will provide detailed charge density distributions.
- The dynamics of molecular groups in a system generally known as $MEM(TCNQ)_2$ have been studied to interpret their correlation with drastic changes of the electric conductivity.
- A study of order and disorder in liquid alloys of alkali metals with tin has been carried out and was completed.
- Short range ordering in a decomposing alloys system could be detected by measuring satellite scattering in CuNiFe alloys with isotopic substitution.
- Structure and structural relaxation has been studied in detail by means of diffuse neutron scattering on iron-nickel-phosphor and iron-nickel-boron metallic glasses.

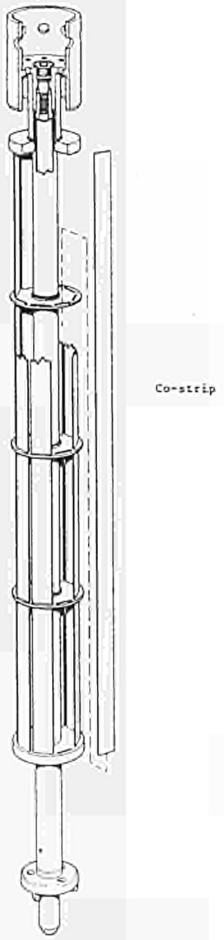
3.2.6. Radioisotopes

Radioisotopes are produced in HFR Petten in a variety of multi-purpose or dedicated facilities.

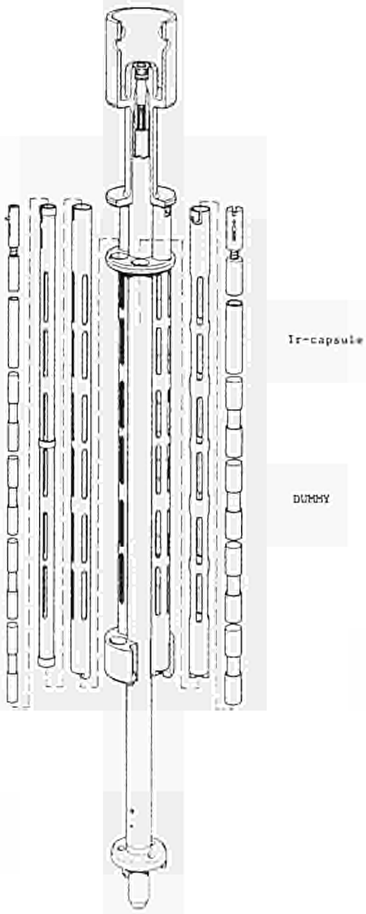
In 1983 the production remained approximately on the same level as in previous years, both in terms of the total number of targets irradiated and of the irradiation capacity used. Main isotopes produced have been ^{99}Mo, ^{60}Co, and ^{192}Ir for medical applications and for sterilization plants.

Radioisotopes. ^{99}Mo production from irradiated ^{235}U

Photograph by Courtesy of KfK Karlsruhe



Irradiation facility for Co-strips



High flux facility for isotopes (HiFi)

3.2.7. Miscellaneous

Development of proliferation - proof research and test reactor fuel (Project "LOUISE")

One of the recommendations of Working Group 8C of the International Nuclear Fuel Cycle Evaluation (INFCE) concerns the fuel of research and test reactors: wherever technically and economically feasible these reactors should be converted from the presently used highly enriched uranium to proliferation - proof reduced enriched material.

Studies on such novel fuel elements have been carried out at HFR Petten since 1977. As a contribution to the technological development, an element has been developed and designed for irradiation testing of research reactor fuel with 20% enrichment. This project managed by ECN, is covered by a large international collaboration involving the Argonne National Laboratory, USA, CERCA, Romans, France, NUKEM, Hanau, Germany and the International Atomic Energy Agency, Vienna, Austria.
Four test elements have been irradiated in 1982/83, and post-irradiation examens were completed in 1983. They confirmed the uneventful performance of UAl_x-Al and U_3O_8-Al elements with 2,1 g.cm^{-3} uranium density. Studies for the irradiation, probably in 1985/86, of about
6 g.cm^{-3} U_xSi_y-Al elements have been initiated.

4. Conclusions

HFR Petten has been operated in 1983 in fulfilment of the 1980/83 JRC Programme Decision. The reactor was shut down, end November, for replacement of vessel and ancillary equipment. Reactor operation and maintenance data have been met within a few percent of the goals set out in the annual working schedule. Reactor occupation exceeded the planned figures with a record number of experiments carried out in support of a large variety of research programmes.
Preparations for dismantling of the old reactor vessel and its peripheral installations have been terminated successfully.

HFR PETTEN
Utilization. Advantages.

- **Fusion reactor material studies:**
  Several proven irradiation facilities under operation Advanced neutron computation and metrology. New devices under development

- **Fast breeder reactor structural materials irradiations:**
  Many highly reliable irradiation capsules and special hot cell equipment available

- **Fast breeder reactor fuel pin testing under abnormal conditions and under operational transients:**
  Long-standing expertise, availability of the PSF and of special in-pile instrumentation, advanced control equipment

- **Light water reactor fuel pin power ramping:**
  Availability of the PSF, large control equipment, and several large computer codes

- **High temperature gas cooled reactor graphite and fuel element irradiation:**
  Modern sweep loop facilities, well-known flux spectra, several proven capsule types, hot cell re-encapsulation facility for active samples

- **Nuclear structure and solid state physics experiments:**
  Numerous experimental installations, long-standing expertise

- **Radioisotope production, activation analysis:**
  Regular reactor operations, many special facilities, high neutron fluxes

- **Neutron radiography, neutron dosimetry development:**
  Modern, purposeful equipment, well-known flux spectra

- **Six computing and data acquisition/processing installations available**

HFR PETTEN

Utilization. 1983 Achievements

- **Fusion reactor materials:**
  14 experiments finished during the year

- **Fast breeder reator structural materials irradiations:**
  Irradiation and hot cell testing of 200 vessel steel specimens

- **Fast breeder reactor fuel pin testing under abnormal conditions and under operational transients:**
  Six fuel pins tested under transient conditions

- **Light water reactor fuel pin power ramping for improved operating economy and safety:**
  Power ramp tests on 19 pre-irradiated fuel pins

- **High temperature gas cooled reactor graphite and fuel element irradiations:**
  Contribution to the data base of the HTGR: 50 graphite samples under irradiation, some under stress (creep samples). Three fuel tests.

- **Nuclear structure and solid state physics experiments:**
  Continuous utilization of eight horizontal beam tubes. Improvements on several experimental set-ups.

- **Radioisotope production, activation analysis:**
  1500 samples and capsules irradiated for medical and industrial applications, environmental pollution control, research purposes, 3000 samples examined by neutron activation analysis

- **Neutron radiography, neutron dosimetry development:**
  230 neutron radiographs taken. Contributions to HFR flux level and spectra knowledge, and to international dosimetry work

- **Non-proliferation:**
  Contributions to the development of reduced enrichment fuel for research reactors

5. HFR Publications 1983

1. P. von der Hardt (Ed.)
"Annual Status Report 1982: Operation of the High Flux Reactor"
EUR 8534 EN

2. P. von der Hardt (Ed.)
High Flux Reactor Programme Progress Report
July-December 1982 (COM 4070)

3. P. von der Hardt
"Fusion materials in-pile crack growth testing"
CEC Workshop on Special Purpose Materials, Petten, 3 May, 1983

4. H. Röttger, P. von der Hardt (ed.)
"Irradiation Technology"
Proceedings of an International Topical Meeting at Grenoble, France, September - October 1982
EUR 8429

5. P. Zeisser, H. Röttger
"Description of the HFR Petten as a Materials Testing Reactor"
International Symposium on the Use an Development of Low and Medium Power Research Reactors,
Cambridge, Massachusetts (October 1983)

6. P. Zeisser, K. Husmann
"Utilization of the Materials Testing Reactor HFR Petten"
ibid

7. P. Zeisser, J. Konrad
"Radioisotope Production at the HFR Petten"
ibid

8. P. von der Hardt
"Radiation Effects Experiments at Test Reactors"
ibid (invited)

9. P. von der Hardt (ed.)
High Flux Reactor Programme Progress Report
January-June 1983

10. P. von der Hardt
"HFR Petten, Gegenwart und Zukunft"
BMFT-Seminar, Bonn (October 28, 1983)

11. P. von der Hardt
"Materialien für Fusionsreaktoren, Bestrahlungsexperimente in Spaltungsreaktoren"
KFA-Seminar, Jülich (Oktober 31, 1983)

12. R. Conrad, A.W. Mehner, G. Pott
"Bestrahlungserprobung und Auswertung der Daten für HTR-LEU Referenzbrennelemente im HFR-Petten"
Jahrestagung Kerntechnik 1983, Berlin, Germany, June 14-16, 1983

13. P. von der Hardt
"Test, research, and training reactors. The European situation".
Annual Meeting of U.S. Test, Research, and Training Reactor Managers, Cambridge, Massachusetts, October 20-21, 1983

14. P. von der Hardt
HFR Petten. Information Leaflet,
Edition 1983/84 (EUR 8477 EN)

15. J. Markgraf, R. Barbalat,
J.C. Domanus, F. Michel,
D.J. Taylor
Reference Neutron Radiographs (of nuclear reactor fuel)"
EUR 8916 EN EP (983)

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16. R. Conrad
"Development of ceramic tritium breeding materials, Irradiation testing and tritium recovery"
Ceramics Breeding Material Workshop, Garching (May 1983)

17. M.R. Cundy, G. Kleist, D. Mindermann
"Irradiation creep performance of graphite up to high neutron fluence"
Carbon 1983 Conference, London, UK (September 1983)

18. J. Markgraf
"Neutron Radiography Working Group (NRWG). Summary of activities and publications".
6th Int. ASM Conference "NDE in the Nuclear Industry", Zürich, Switzerland, November-December 1983.

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