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COMMISSION OF THE EUROPEAN COMMUNITIES

Multiannual Programme of the Joint Research Centre 1980 - 1983

1981 Annual Status Report

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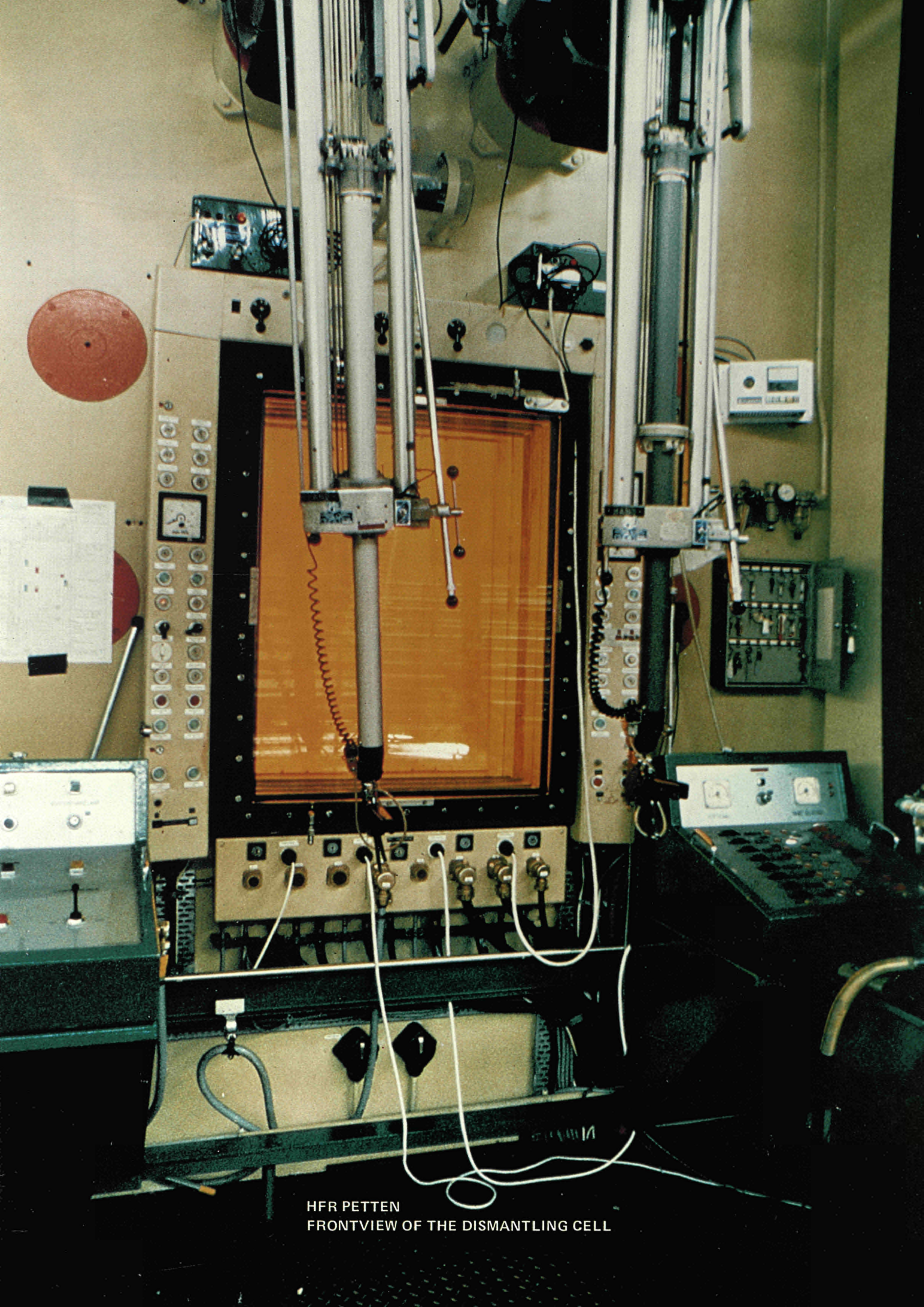


HFR PETTEN
FRONTVIEW OF THE DISMANTLING CELL

PROGRAMME MANAGEMENT

- OPERATION AND UTILIZATION WITHIN JRC PLURIANNUAL RESEARCH PROGRAMME
- OPERATION BY EXTERNAL ORGANIZATION UNDER CONTRACT
- PREDETERMINED FOUR YEARS' FUNDING, DETAILED ANNUAL BUDGETS
- LONG - TERM SUPPLY AND SERVICE CONTRACTS
- CENTRAL DECISION MAKING, VARIOUS ADVISORY COMMITTEES
- DETAILED PERMANENT PROJECT AND RESOURCE PLANNING
- INTEGRATED PROJECT WORKING GROUPS
- SEMI-ANNUAL PROGRAMME PROGRESS REPORTS AND FINANCIAL SURVEYS.

- TYPICAL HFR BUDGET :

REACTOR OPERATION AND MAINTENANCE STAFF (75)	20 %
REACTOR MODIFICATIONS AND DEVELOPMENT	8
GENERAL SITE SERVICES	17
JRC TECHNICAL AND ADMINISTRATIVE STAFF (88)	29
TOTAL FUEL CYCLE (IN EQUILIBRIUM)	15
MAJOR INVESTMENTS	2
ELECTRICITY, WATER, INSURANCES	4
EXPERIMENTAL EQUIPMENT	5
	100 %

OPERATION OF THE HFR REACTOR
1981

Research Staff	**41 persons**
Budget "Operation of the HFR"	**13.547 Mio ECU**
Manufacture of replacement vessel	**1.236**
Use of HFR by other JRC Programmes	**0.657**
Use by commercial clients	**0.185**
Total	**15.625**

Projects

Unlike most of the other JRC Programmes, "HFR Operation" is not formally subdivided into individual projets. For the sake of the Programme Progress Reports, however, three projects are defined:

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

On a lower level of subdivision, the term "project" appears again when referring to irradiation projects and individual supporting activities.

1. INTRODUCTION

Programme Manager:
P. von der Hardt

The Council Decision of March 13, 1980, concerning the 1980/83 JRC research plan, defines for HFR Petten:

F. OPERATION OF LARGE-SCALE INSTALLATIONS
Supplementary programme

F.1. Operation of the HFR reactor
(nuclear activity)

It also allocates a four years' budget of 52,22 Mio ECU and a staff of 88, of which 41 are research staff.

The proposed Technical Annex to the Council Decision reads as follows:

OPERATION OF THE HFR PETTEN

The operation of the reactor will continue to the benefit of the research programmes of the participating Member States and for the JRC's own requirements. Outside clients will also be able to use the irradiation facilities on payment.
During the next programme the teams will continue the maintenance and upgrading of the reactor and the development and improvement of the irradiation equipment and apparatus to enable this installation to hold its place among the most important means of irradiation of the Community.

2. RESULTS

2.1 Facilities and Services

2.1.1. Reactor *)

As one of the four most powerful research and test reactors in the European Community, HFR Petten is characterised by its simplicity in design and operation, resulting in both high reliability and great flexibility in use.
In 1981, the regular operation at 45 MW continued, according to a predetermined calendar, and without major problems from the plant and its components.
Six shipments of fresh fuel elements to the reactor site, and two transports of irradiated elements to reprocessing kept the local inventory on the previous level. Regular inspection and maintenance of all plant components have been carried out during the extended scheduled outages in January and July. The good health of the plant has been confirmed. The yearly routine leak test of the containment building yielded good results and the visual inspection of the core box walls of the reactor vessel showed no significant deviations from earlier inspections. Slight dimensional changes, mostly due to mechanical wear were detected but no signs of core box derformation due to irradiation effects were found. This is important in view of the operational safety of the present vessel after a 20 years' period: The first operation license was granted in November 1962.
In line with a traditional policy of permanent upgrading and modernisation, a large number of minor components have been replaced during the year. In addition the data acquisition and processing systems for the experiments and reactor data have been extended and partly modified to the latest standard.
Preparation for the dismantling of the present vessel with regard to its replacement by a new one, which has been ordered, are now fully initiated. A detailed vessel replacement scenario has been set up.

*) High flux materials testing reactor HFR Petten. Characteristics of facilities and standard irradiation devices. EUR 5700. (Revised edition 1981-1982).

HFR Petten

MAIN CHARACTERISTICS

TANK-TYPE MATERIALS TESTING REACTOR
45 (50) MW
H_2O COOLED/MODERATED — **Be MODERATED/REFLECTED**
MTR (PLATE) TYPE FUEL ELEMENTS,
93 °/o ENRICHED, 1 g ^{10}B PER ELEMENT
29 IRRADIATION POSITIONS, — **11 HORIZONTAL BEAM TUBES**
COOLANT PRESSURE 0,24 MPa, — **COOLANT TEMPERATURE 313 K**
ANNUAL AVAILABILITY 75 °/o — **AVERAGE UTILIZATION 76 °/o**

MAIN UTILIZATION

- **NUCLEAR SAFETY**
- **ENERGY**
- **PROTECTING OF THE ENVIRONMENT**
- **FUNDAMENTAL RESEARCH**
- **LIFE SCIENCES**

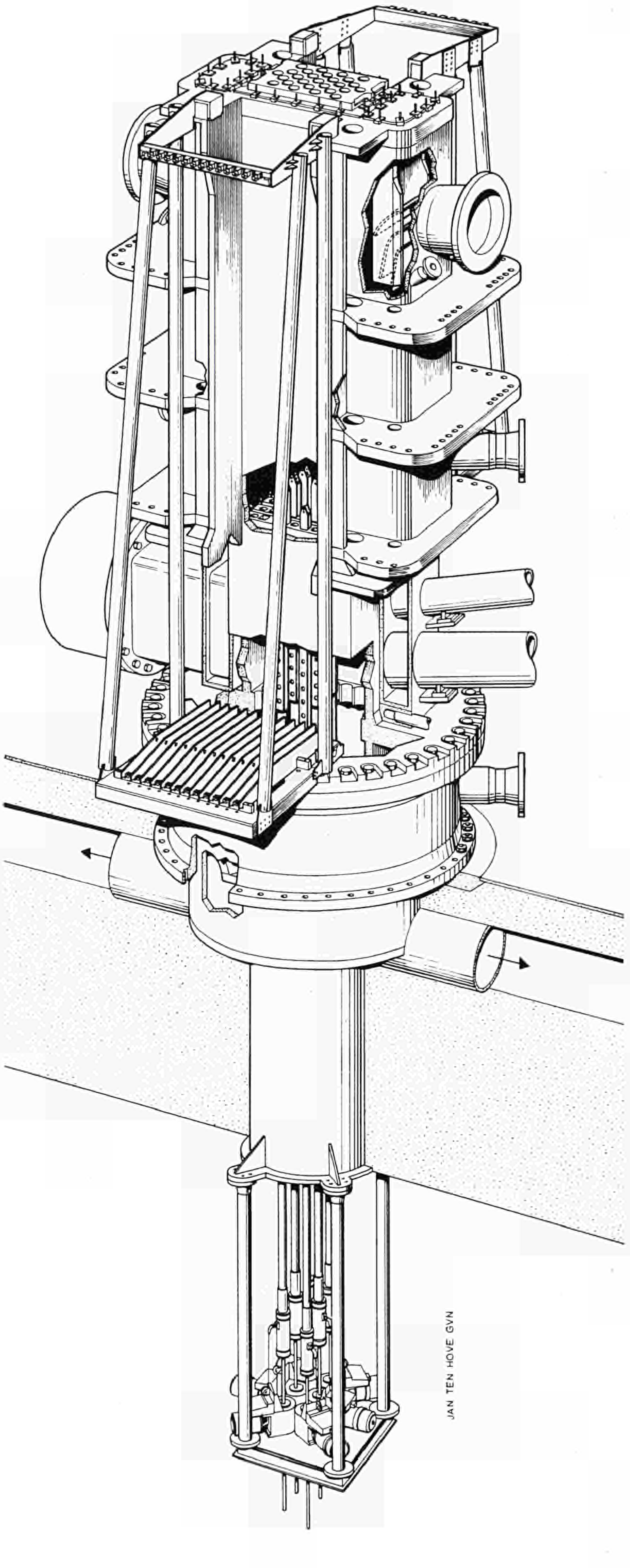
UPGRADING AND DEVELOPMENT

1966 - 1981

- POWER INCREASES 20 TO 30, 30 TO 45 MW
- INTRODUCTION OF BURNABLE POISON FUEL (1973/74)
- SEVERAL CORE CONFIGURATION CHANGES
- COMPLETE REPLACEMENT OF REACTOR AND GENERAL PURPOSE EXPERIMENTAL INSTRUMENTATION
- NEW IN-TANK EXPERIMENT PENETRATIONS (1976)
- SEVERAL IMPROVEMENTS ON MAJOR PLANT SYSTEMS
- IN-HOUSE COMPUTER CODE DEVELOPMENTS
- NEW REACTOR AND EXPERIMENT DATA LOGGERS (1980/81)
- NEW DISMANTLING CELL TRANSFER SYSTEM (1980/81)
- SECOND (BEAM TUBE) NEUTRON RADIOGRAPHY FACILITY (1981)

FUTURE DEVELOPMENTS

- REPLACEMENT OF THE REACTOR VESSEL (1983)
- DEVELOPMENT OF REDUNDANT SHUT-DOWN SYSTEMS (1981/82)
- REPLACEMENT OF PRIMARY HEAT EXCHANGERS (1984/86)
- MEDIUM ACTIVITY LABORATORY (1986/87)
- MODIFICATION OF THE REACTOR BUILDING ENTRANCE/EXIT AREA (1981/82)
- ENLARGED COMPUTING FACILITIES (1981/82)
- NEUTRON BEAM QUALITY IMPROVEMENTS (1982/83)
- NEW POOL NEUTRON RADIOGRAPHY CAMERA, IMAGE ANALYSER (1982)
- STUDIES ON COMPLETE REACTOR INSTRUMENTATION AND CONTROL ROOM REPLACEMENT
- STUDIES FOR A POWER INCREASE TO 60 MW



NEW REACTOR VESSEL

2.1.2 Irradiation Facilities

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

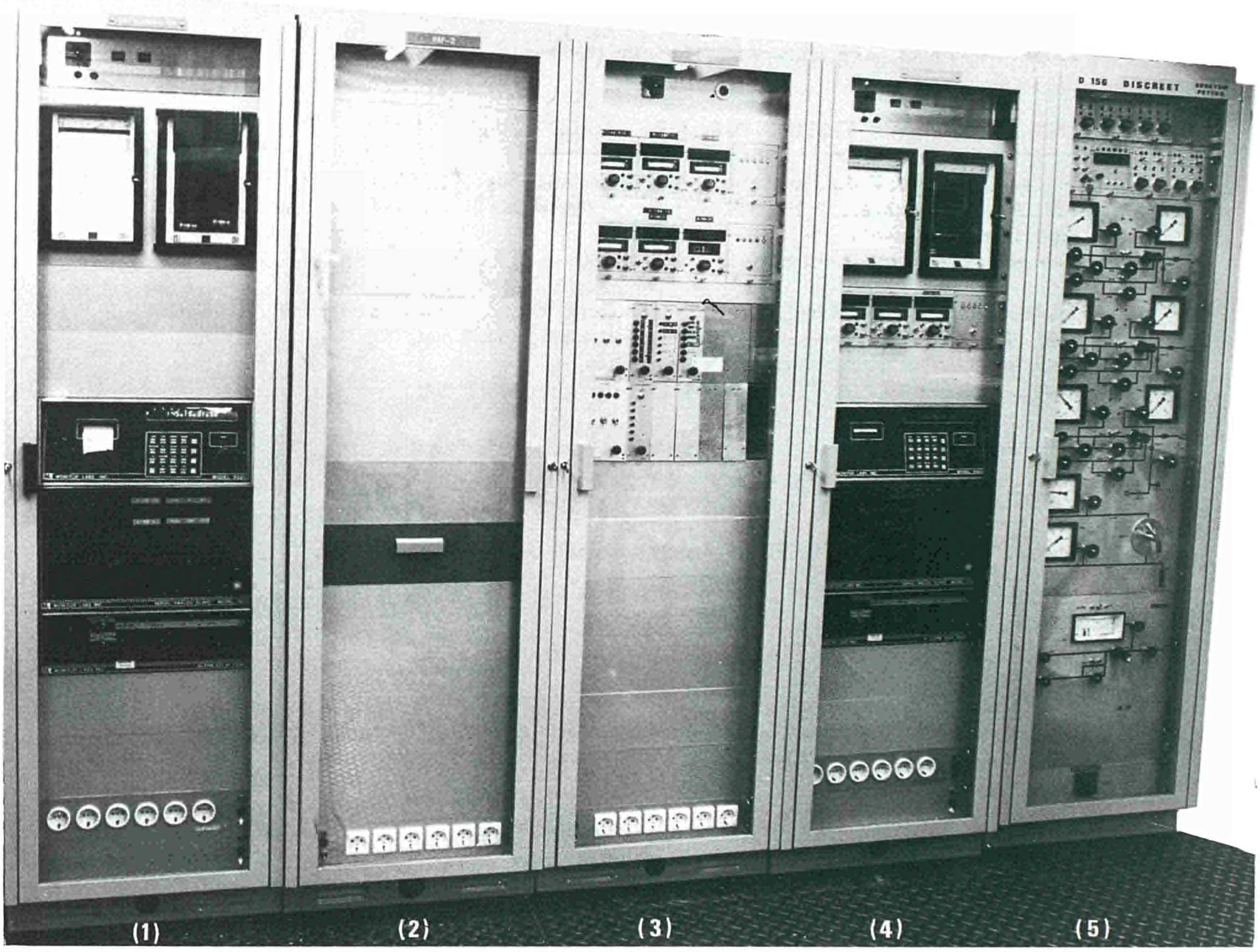
Highlights of the 1981 activities have been the setting into active operation of:

- a new neutron radiography installation,
- a large advanced fission product transport and analysis facility,
- reactor fuel elements with increased uranium loading,
- new data acquisition and processing equipment.

Besides this a number of other projects could be pursued:

- detail design and specifications for the future reactor vessel,
- manufacture of several new standard irradiation devices,
- work on new LWR and LMFBR fuel irradiation devices,
- manufacture and testing of new PSF 'trolleys' and improvements of the new PSF table,
- development of structural material creep, fatigue and crack propagation devices.

But generally spoken the development activities suffered from the work overload in the irradiation project sector and could not be pursued with the desirable intensity.



Arrangement of new experiment control panels: (1) data logger recorder; (2) extension for special equipment; (3) alarm, control and vertical displacement units; (4) data logger recorder; (5) gas panel for graphite creep experiments.

STANDARD IRRADIATION FACILITIES

1. NON-FISSILE MATERIALS TESTING

Graphite, stressed or unstressed, metal or graphite / He environment ∅ 6.....20 mm; 300........1200°C
Specimen recycling.

Steel, unstressed, Na environment, tensile specimens, ∅ 6.....12 mm, 550......650°C
also: non-cylindrical (Charpy, CT, etc.)

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.......1200 Wcm^{-1}
Optional: Neutron screen, central thermocouple, fission gas pressure transducer, ...

Single or double-walled HTGR fuel rigs, graphite / He environment, 100......1000 Wcm^{-1},
800.....1500°C fuel temperature. Continuous fission gas sweeping and analysis.

Under development: 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....800 Wcm^{-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....1200 Wcm^{-1},
400.....800°C clad temperature. Fuel pin length up to 500 or 1600 mm.
Optional: Different types of fuel pin instrumentation.
Profilometer capsules

Under development: Encapsulation facility for pre-irradiated fuel pins

4. MISCELLANEOUS

Different radioisotope production rigs, mostly reloadable during reactor operation

Gamma irradiation facility

Borosilicate glass pellet capsule

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

5. STANDARD OUT-OF-PILE CONTROL FACILITIES

Gas mixing and control panels
Cooling water control circuits
Micro-processor based data loggers
Data processing computer
In-pool diameter measurement, eddy current check, neutron radiography, gamma scan facilities

2.1.3. Ancillary Services

Users of the reactor find access to the necessary ancillary services, ranging from several computer installations and their software to a full spectrum of post-irradiation facilities.
More specifically, work on general-purpose support to HFR irradiation comprised :

- efforts to accurately determine the reactor's nuclear characteristics by a combination of detector dosimetry, self-powered neutron detector and gamma calorimeter measurements, by computations and by neutron spectrum measurements in mock-ups of graphite and steel experiments.
  Besides this an interlaboratory measuring program (REAL - 80) has been started to arrive at a realistic value for the uncertainty in integral radiation damage parameters, like displacement rate, fluence rate above 0,1 MeV etc.

- further extension of the introduced central twin-computer based data acquisition and processing system for reactor and experimental data by new data loggers.
  Updating of the existing system to the latest standard.

- making available a number of other standard control installations and other equipment for irradiation experiments within the basic service package of the HFR :

  - alarm collecting and processing units,

  - gas supply and control circuits,

  - cooling water supply and control circuits,

  - radioactive effluent disposal systems.

- making operational the new "dry" beam hole radiography camera for first tests,

- continued construction of the remote encapsulation facility EUROS.

  The EUROS project will provide the means of remote encapsulation of irradiated LMFBR fuel pins into specially prepared double wall capsules, loaded into the core or chimney and Pool Side Facility of the HFR.

  The state of the project can be summarized as follows:

  - the needed hot cell equipment is placed and partly tested,

  - completion and manufacture of special tools and auxillary equipment,

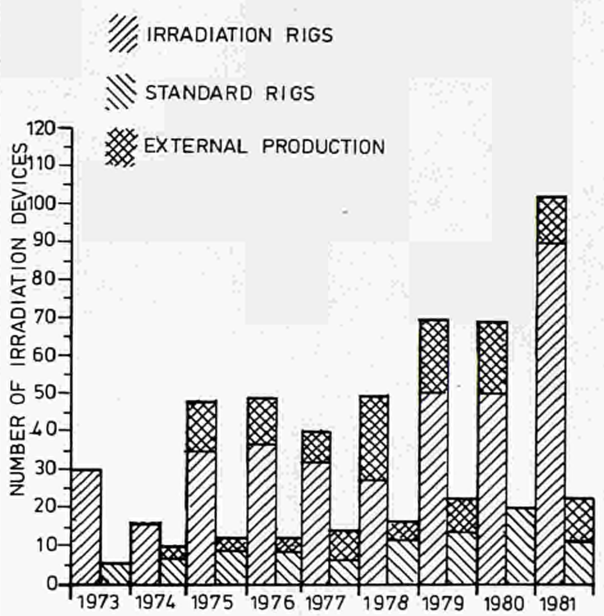
  - re-design and adjustment of the welding head in connection with the special Na-filling method,

  - ordering of the electrical systems and wiring for the hot cell,

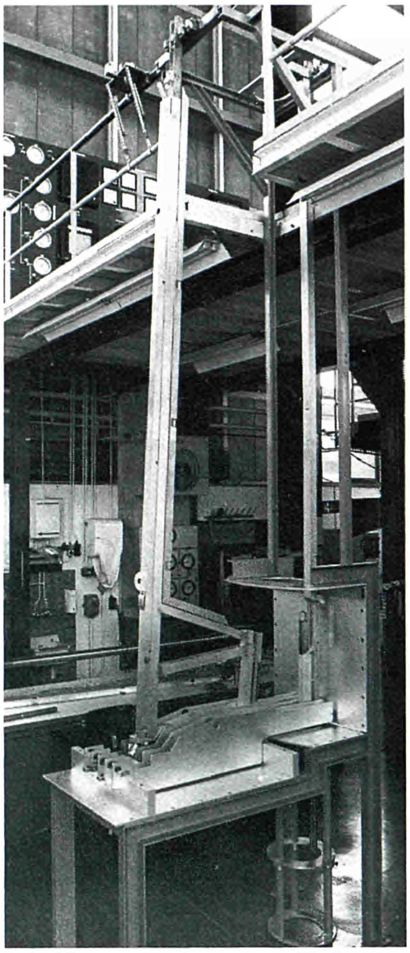
  - assembly of the capsule dummies.

- enlargement and refurbishing of the Testing and Commissioning (TEC) laboratory. Among other things, a new test stand for PSF irradiation devices is now available.

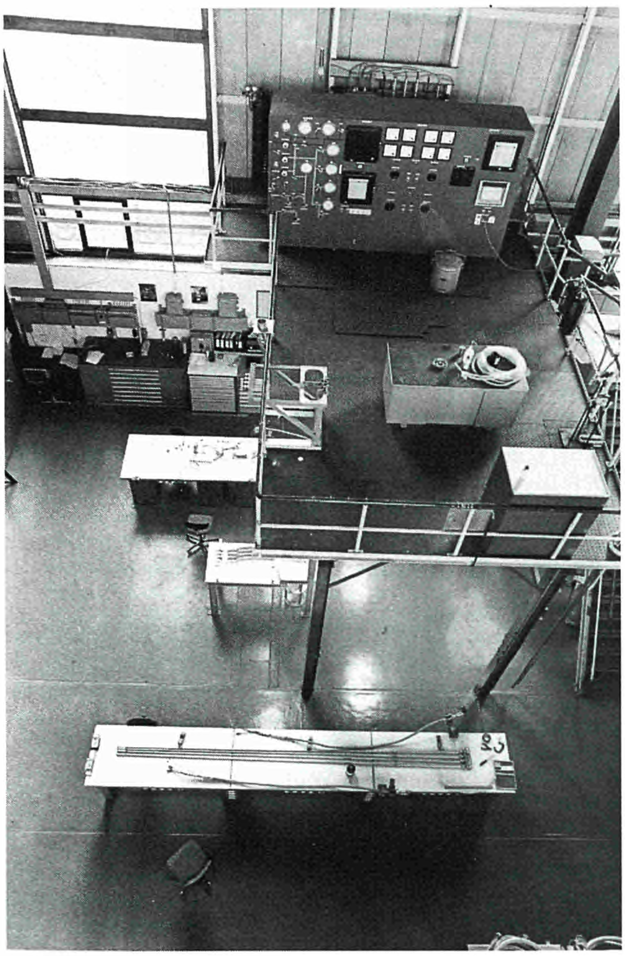
- construction of a glove box for handling fuel pins with contamination risk in the Assembly Laboratories.



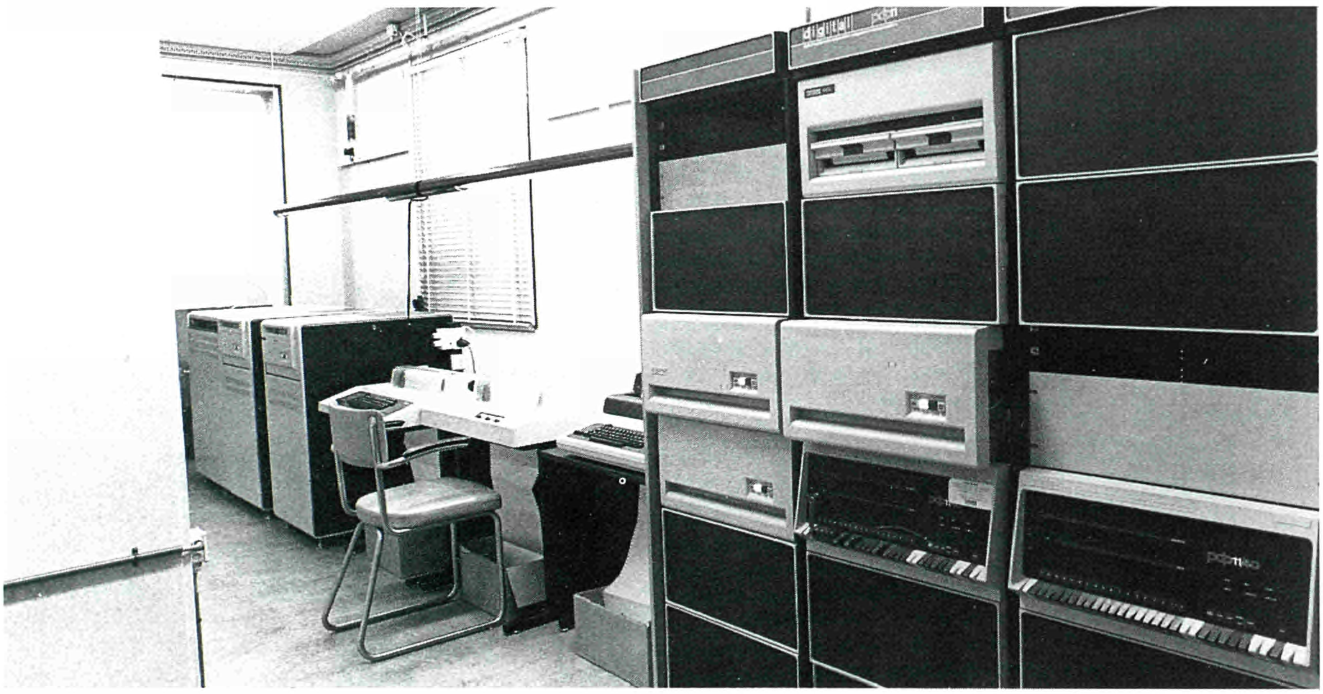
Survey of irradiation capsule assembled in the Assembly Laboratories



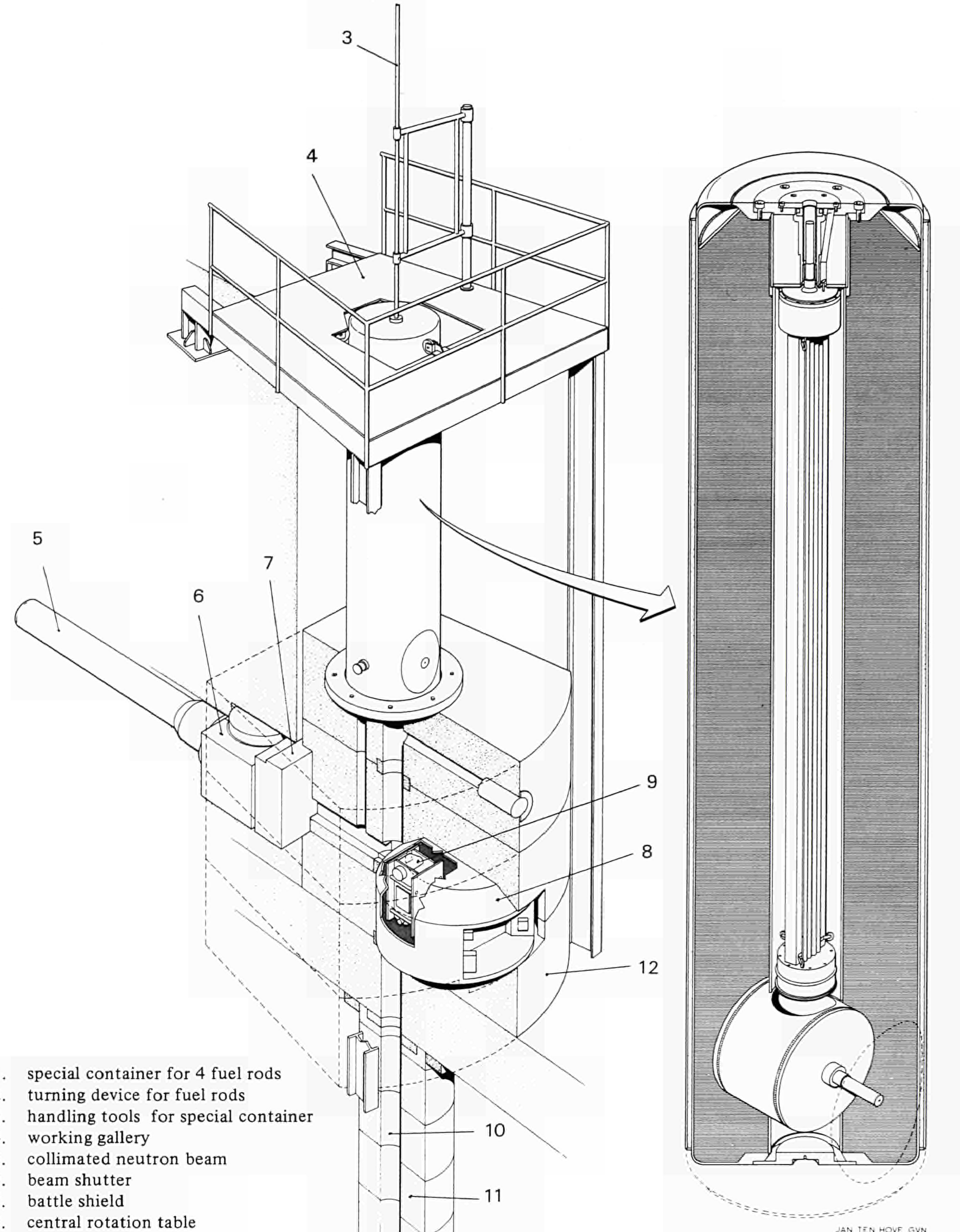
ANCILLARY SERVICES
Testing and Commissioning Bay.
New test stand for PSF irradiation devices.



ANCILLARY SERVICES
Testing and Commissioning Bay.



ANCILLARY SERVICES
Data acquisition system DACOS. Computer room (partial view).



1. special container for 4 fuel rods
2. turning device for fuel rods
3. handling tools for special container
4. working gallery
5. collimated neutron beam
6. beam shutter
7. battle shield
8. central rotation table
9. neutron radiography camera
10. vertical channel for special container with 4 fuel rods
11. lead shielding column
12. biological concrete shielding.

Container:

useful length	2500 mm
useful diameter	235 mm
weight	17.0 t
shielding	250 mm lead

Neutron radiography. "Dry" beam hole camera (HB 8).

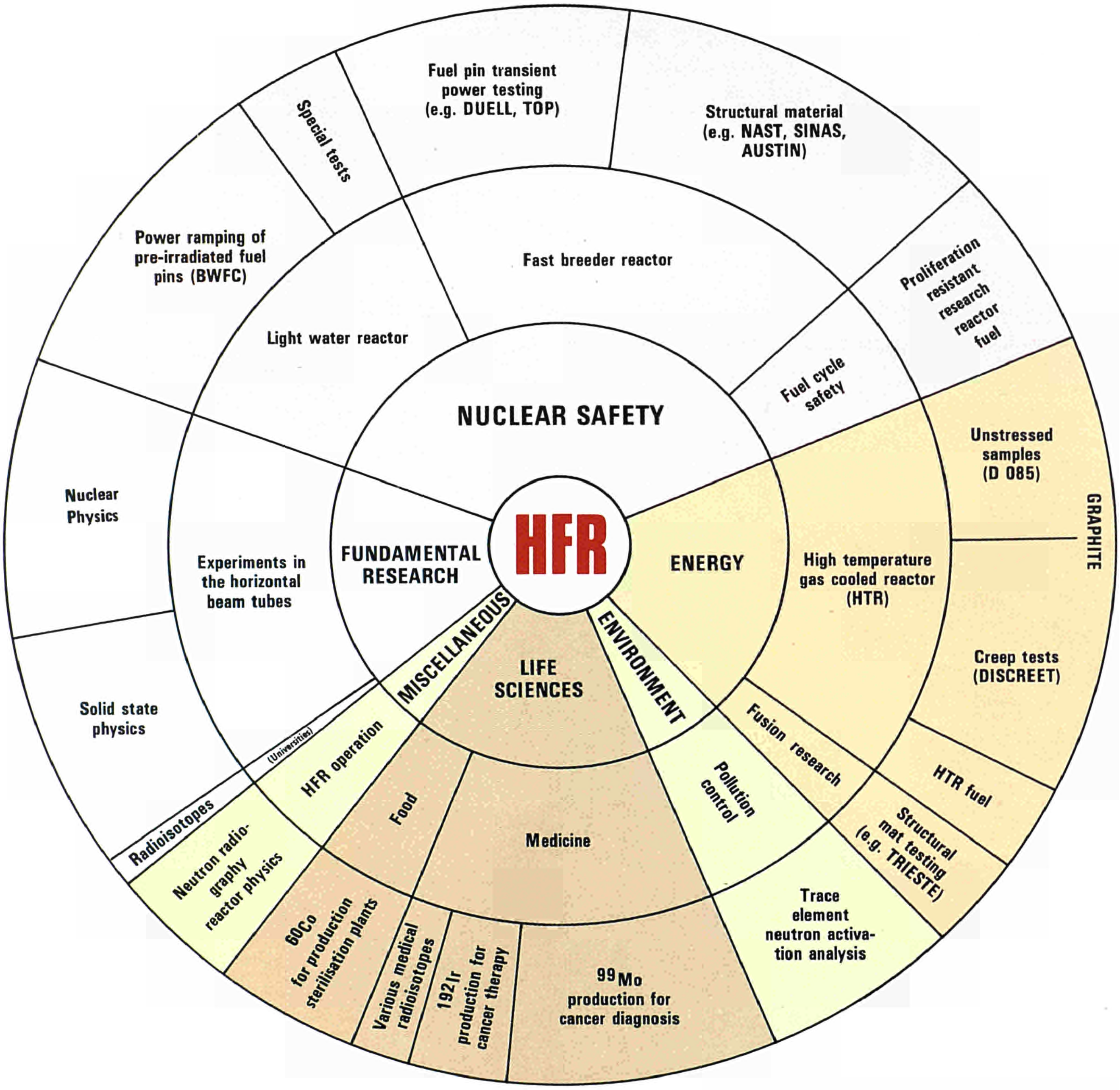
2.2 Utilization

2.2.1 Scope

The experimental work carried out in HFR Petten originates from the following research fields:

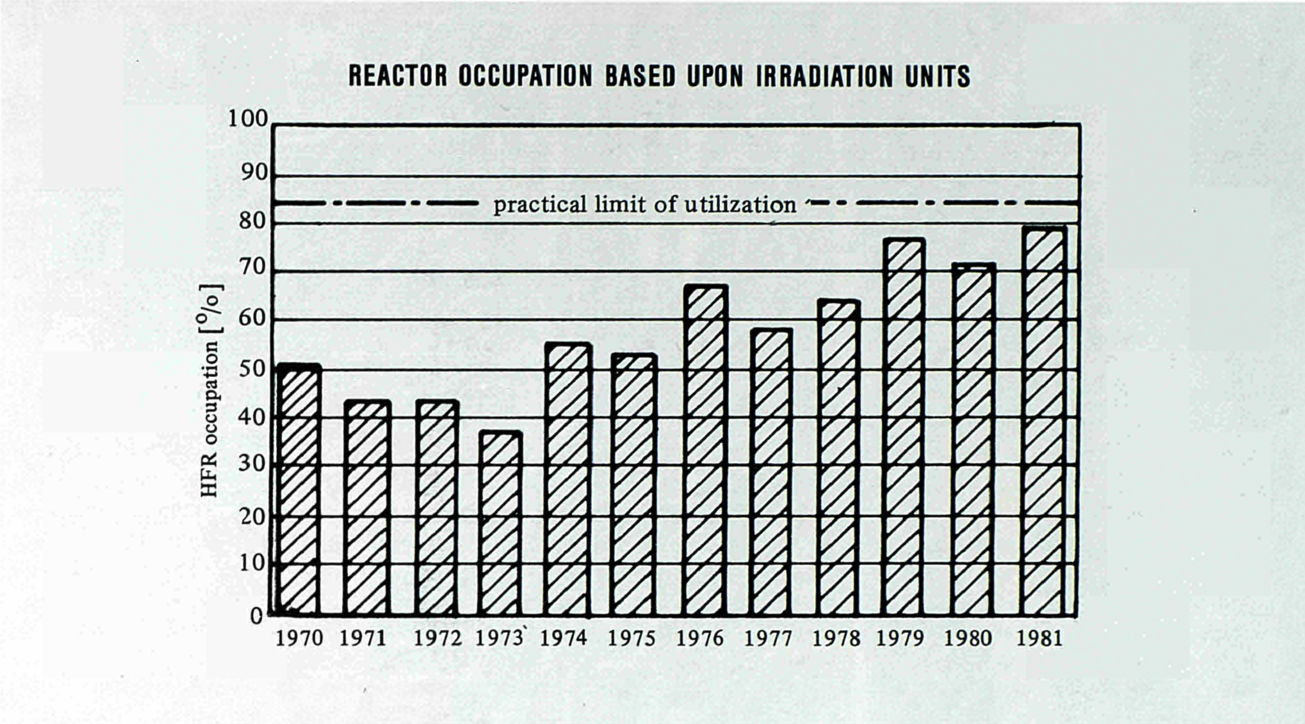
1. nuclear safety
2. energy
3. environment
4. fundamental research
5. life sciences (medicine and food)
6. miscellaneous

Their relative importance in reactor utilization is shown in the circular diagram below.



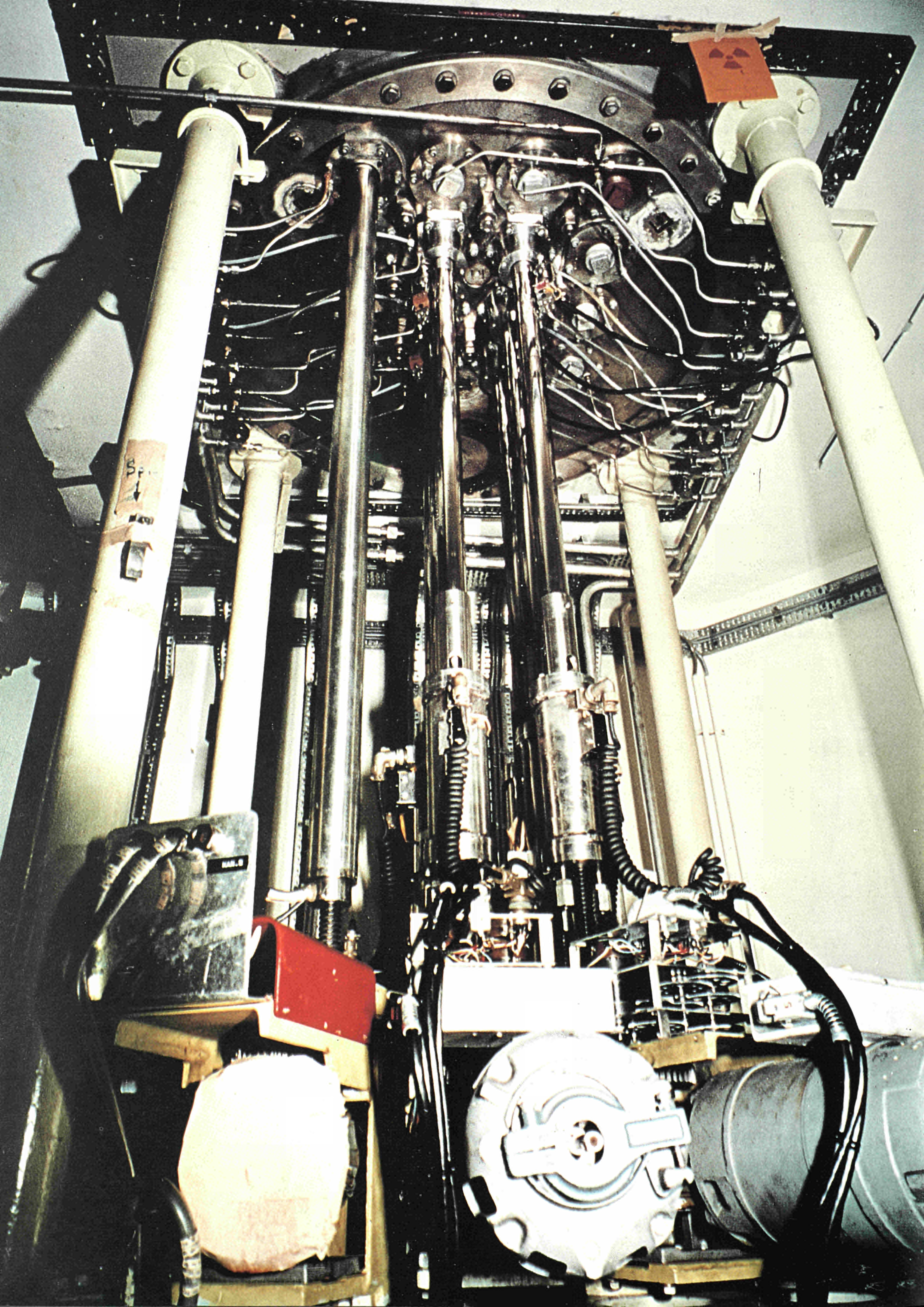
HFR Petten 1981/82 Utilization Scheme

The occupation of the reactor by experimental devices exceeded 80°/o of its theoretical capacity, setting a new mark in 20 years of HFR operation.



Typical topics of HFR utilization are treated in the following paragraphs.

Next page: HFR Petten. Sub-pile room with control rod drive mechanisms.



2.2.2 Nuclear Safety

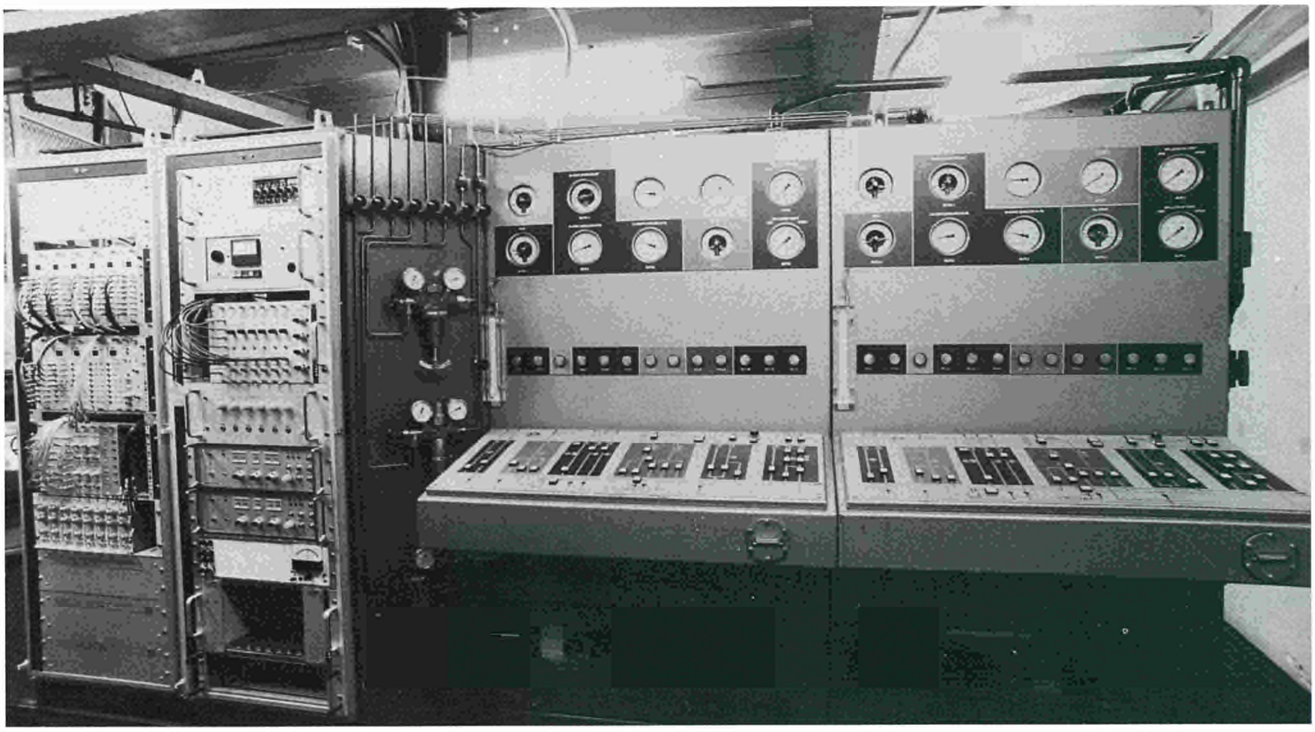
Light Water Reactor and Fast Breeder Reactor

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 or three 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.
Similar experiments have been developed since 1977 for fast breeder reactor fuel pins of which 8 to 12 are submitted to transient power irradiations every year in specially designed capsules. 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.
Another safety problem in breeder reactors concerns the response of neutron-irradiated structures to mechanical stresses including vibration and shock. Nearly 1200 stainless steel specimens have been irradiated in HFR over the past six 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. The present trend goes to fracture mechanics experiments and in-pile creep studies.

The 1981 achievements can be summarized as follows;

- transient condition testing of 22 pre-irradiated light water reactor fuel pins,
- nine operational power transient tests on fast breeder fuel pins, one fast breeder fuel pin loss-of-cooling test.
- irradiation of about 200 stainless steel samples for investigations into safety aspects of the mechanical behaviour of irradiated structures,
- assembly of a prototype capsule and completion of the necessary out of pile installation in the frame of an irradiation which is managed by ECN*) and which is designed to study the behaviour of short single UO_2 fuel pins (fresh and pre-irradiated) of LMFBR specifications under relatively slow and low overpower transients.

The increasing international importance of this research work for the nuclear safety part, has been shown on a conference at Sun Valley, Idaho, in August 1981: Ten out of the 43 papers presented by European authors referred, in part or totally, to work done in HFR Petten.

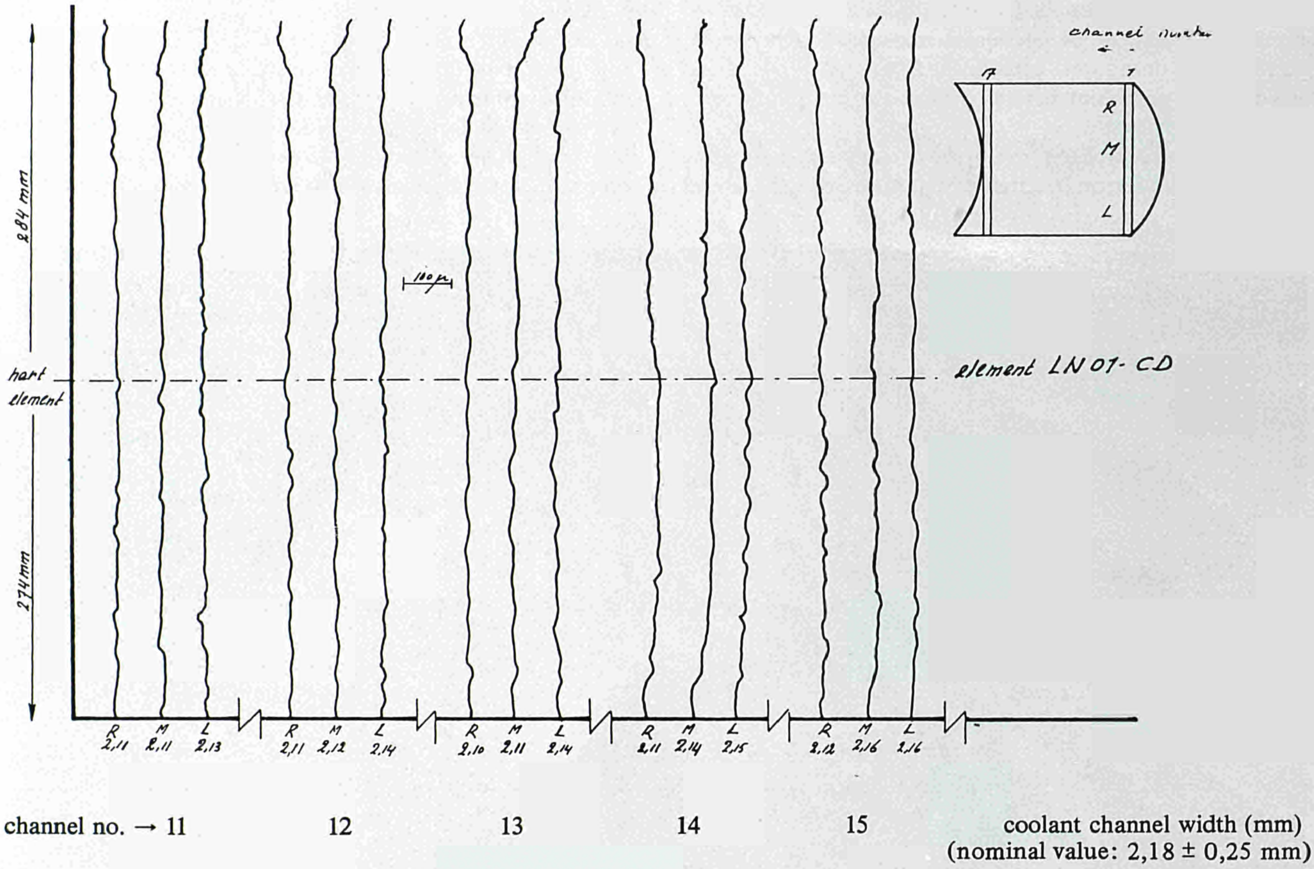


NUCLEAR SAFETY
Fast reactor fuel pin transient overpower experiment. Partial view of the control consoles being installed in the HFR building.

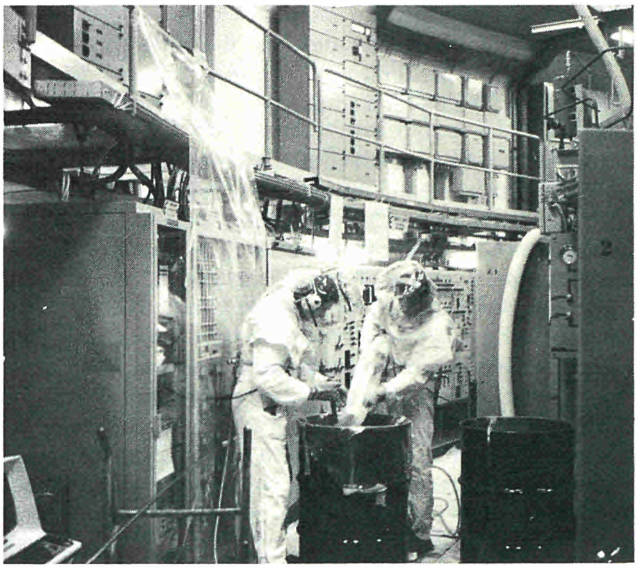
*) Netherlands Energy Research Foundation

Development of Proliferation-Proof Research and Test Reactor Fuel (Project "LOUISE")

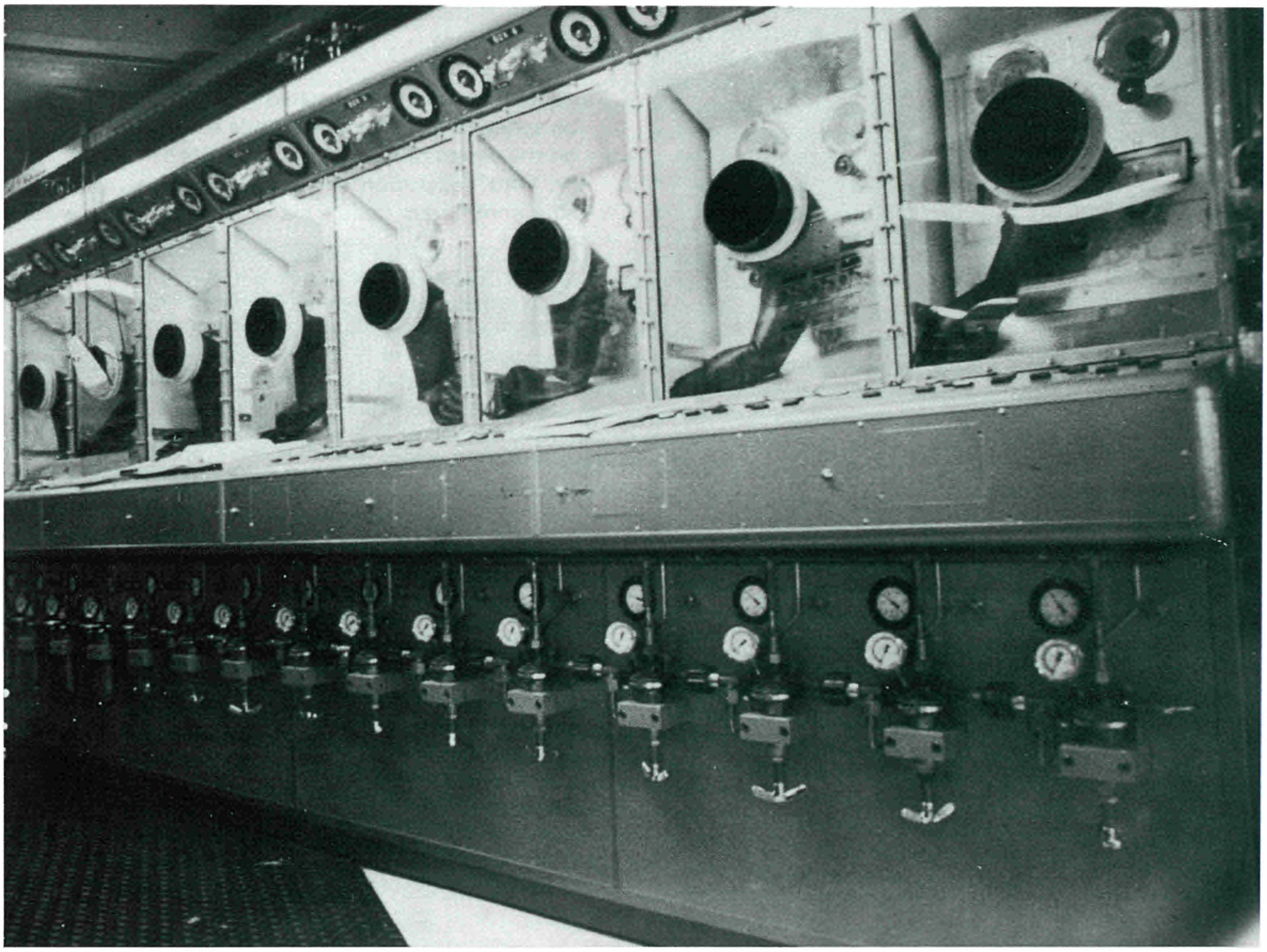
One of the recommendations of Working Group 8C of the International Nuclear Fuel Cycle Evaluation (INFCE) concerned the fuel of research and test reactors: wherever technically and economically feasible these reactors should be converted from the presently used highly enriched uranium to proliferation-proof 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°/o 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.
First full power test irradiations of two low enriched fuel elements which were subjected before irradiation to various measurements, tests and inspections, have been carried out in November 1981. Further experiments are planned for 1982.
Together with non-destructive and destructive post-irradiation analyses, they will provide the necessary technological basis for the future conversion of low and medium power research reactors (up to 5 . . . 10 MW) to proliferation-resistant fuel.



Petten reference LEU fuel element. Measurements using the ultrasonic channel width gauge.



NUCLEAR SAFETY
LWR fuel pin power ramp tests. Replacement of ion exchanger resin.



NUCLEAR SAFETY
Out-pile gas installation for simultaneous operation of 8 double-wall fuel capsules.

2.2.3 Energy

High Temperature Reactor

The High Temperature Gas Cooled Reactor (HTR or HTGR) offers a number of advantages :

1. high thermal efficiency, i.e. improved utilization of resources and reduced waste heat release,
2. large flexibility of its fuel cycle, including proliferation-resistant solutions,
3. high inherent safety,
4. utilization for high temperature chemical processes, including coal gasification and liquefaction (substitution of natural gas and oil).

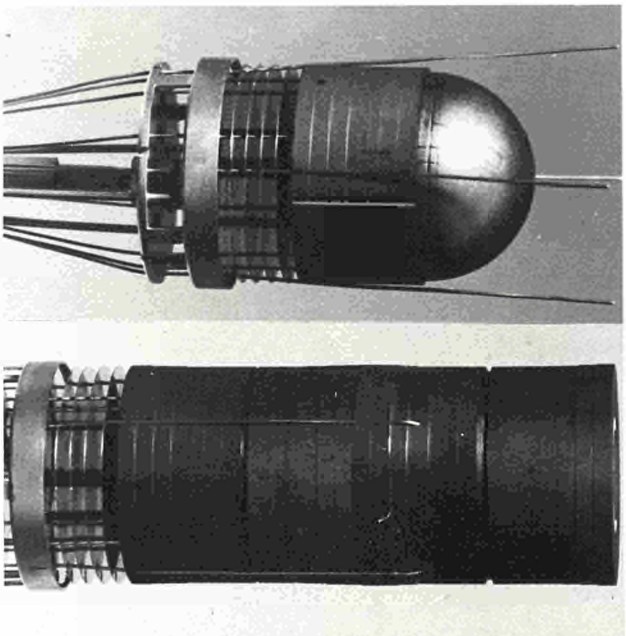
The development of this reactor type is actively pursued in the Federal Republic of Germany and in Japan with contributions from a number of other coutries.

ENERGY
HTR fuel sweep loops. New gamma spectrometer configuration.

HFR Petten has been in charge of test irradiations for two materials which are typical for the HFR :
- graphite as a predominant core structural material
- 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 intermediate measurement of their changed physical properties. For the reflector graphite material, 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.
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.

The activities were concentrated in 1981:
- on spherical fuel elements in-pile tests
- on the design of new irradiation tests
- on "hot" operation of new sweep loops, which enable continuous fission gas analysis and temperature control.

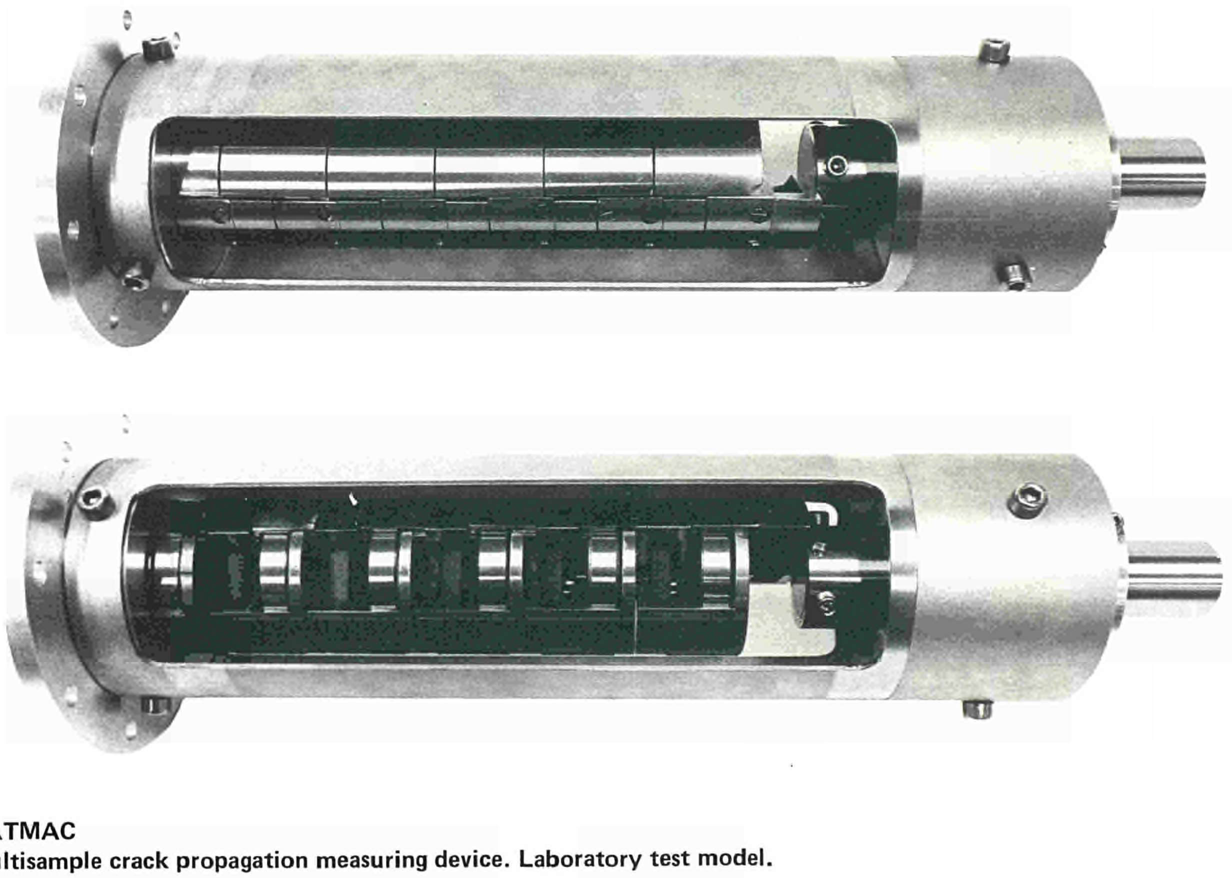


ENERGY
Prototype HTR fuel rig E 138-02. Upper capsule in two different stages of assembly.

Fusion Reactor

Fusion together with fast fission breeders and solar energy are considered to be the potential new primary sources, able to solve the problem of energy supply in the next century. For this reason a large effort is being devoted in the world and, in particular, in Europe, to 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 different systems which has been developed parallel.
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.
In the frame of a research programme on materials managed by JRC Ispra and dealing with the investigation on the feasibility of austenitic steel as structural material for the first wall and the blanket of a demonstration (DEMO) reactor. The design and construction state several irradiation projects have been started or continued at Petten in 1981:

- CRISP: Steel creep experiment with continuous strain registration
- TRIESTE/FRUST: Steel creep experiments with intermittent deformation measurement
- FATMAC: Experiment which will allow to irradiate CT type samples of candidate materials for first walls and/or blankets of fusion reactors under oscillating load, typical for fatigue tests



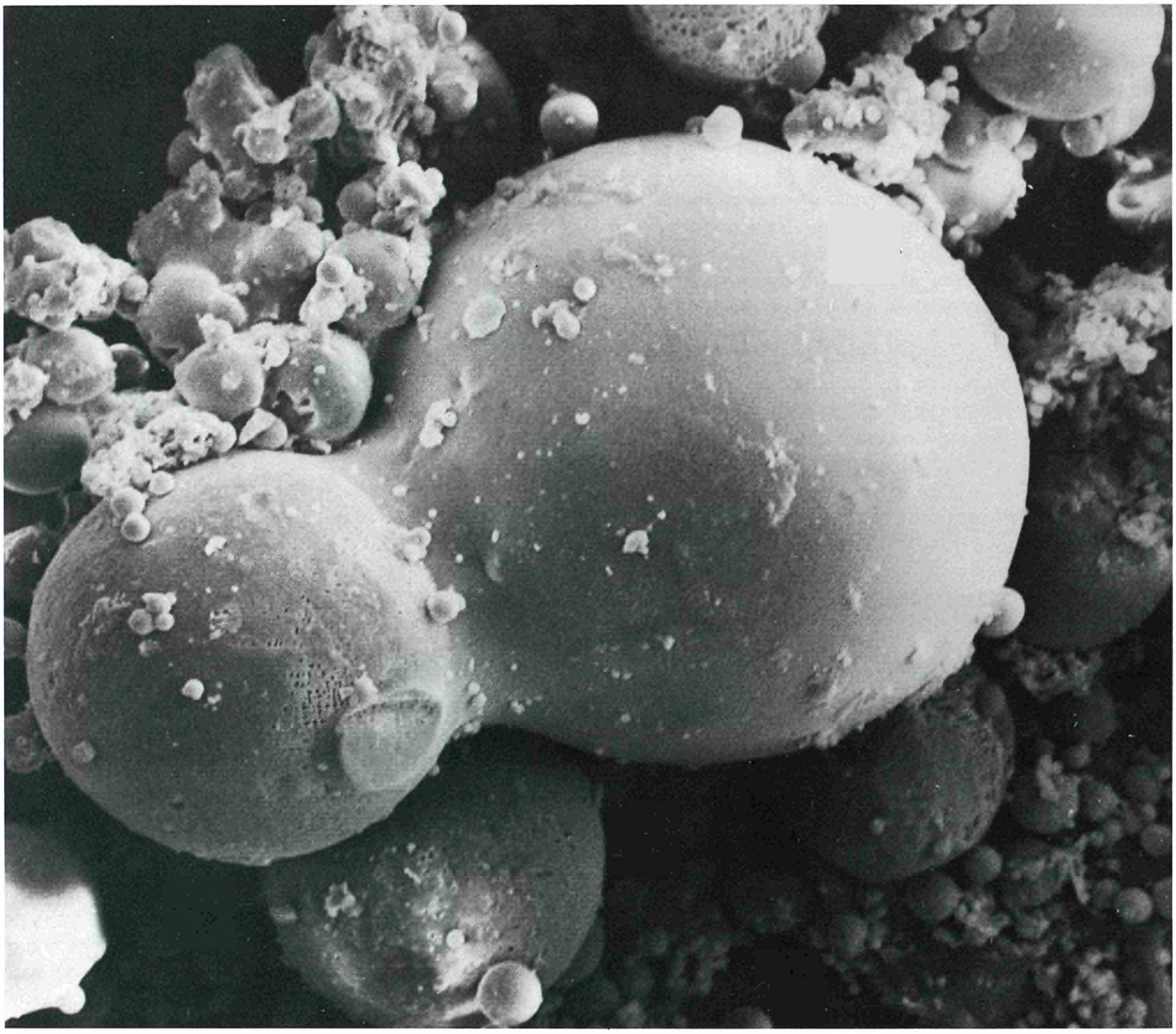
FATMAC
Multisample crack propagation measuring device. Laboratory test model.

2.2.4 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, like arsenic, mercury, cadmium, uranium, etc. Therefore it is a method, which can be used as an effective instrument for environment pollution control, e.g. for the determination of arsenic, 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.
The neutron activation analysis was performed in 1981 on a routine base, primarily in a purely instrumental way. The number of elements determined varies from 15 to 30 depending on the matrix. Applications at HFR Petten range from silicate rocks, coal and coal ashes (fly ashes) etc. to ultra trace analysis in human serum and -fractions.

In 1981 two new irradiation facilities for neutron activation analysis were put to use:

- The epithermal facility in the poolside (EPI--PROF), which enables the activation analyst to irradiate for up to 12 hours under a cover of 2mm Cd-metal, and which results to an enhancement of certain elements in the γ-ray spectrum.
- The prompt capture γ-ray facility in the neutron beam at HB4, which features a thermal neutron flux of about $10^7 cm^{-2} s^{-1}$ and is equipped with a sample changer.



Electron beam microscope picture. Fly ash from powder coal fired plants used in leaching studies of trace elements.

2.2.5 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 installation 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.

Solid State Physics

In 1981 four of the five experimental facilities for neutron scattering research have been in continuous operation. Also this year the research programme had narrow relations with the research at the Dutch Universities and it was often carried out as joint projects with participation of temporarily appointed scientists and guest scientists.

Instrumental

- The neutron diffractometer at beam beam HB5 had a thorough mechanical revision and modifications and improvements were made. For control and data handling a minicomputer was installed and required programmes were completed. The auxilliary χ-circle has been made suitable for application in texture investigations.
- The neutron spectrometer at beam tube HB1 in its modified form **DISCIPEL** (**Di**ffuse **Sc**attering **I**nstrument with **P**osition **E**ncoding **L**inedetector) has been improved by a few additions, it was thoroughly tested and has been in continuous operation since.
- The detector assembly of the four-cycle diffractometer was improved as to avoid scattering from the helium cryostat.
- A new liquid helium cryostat with variable temperature for both single crystals and powders has been completed.

Research

The research programme carried out by means of the HFR neutron scattering facilities covered several topics in crystallography, chemistry, solid state physics and metal physics. They comprised the following subjects:

- Several structure determinations carried out by means of both single crystal and powder diffractometry.
- Spin density distributions in 3d metal alloys for which electronic structure properties strongly deviate from normal averaging. In these experiments extinction phenomena could be carefully correlated with the microstructure of the alloys.
- Phase diagrams and transitions in antiferromagnetic systems. Several magnetic phases could be established in a one-dimensional chain system. Phase transitions in a compound with broken symmetry were studied and critical phenomena around a phase boundary investigated.
- The kinetics of decomposition and clustering of pseudo binary alloys. The neutron scattering results compare very well with advanced model calculations.
- Structure of liquid alloys of alkali metals.
- Texture investigation of course grained rolled steel.

Based on this work there have been seven external publications and three PhD theses.

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.

Scientific programme

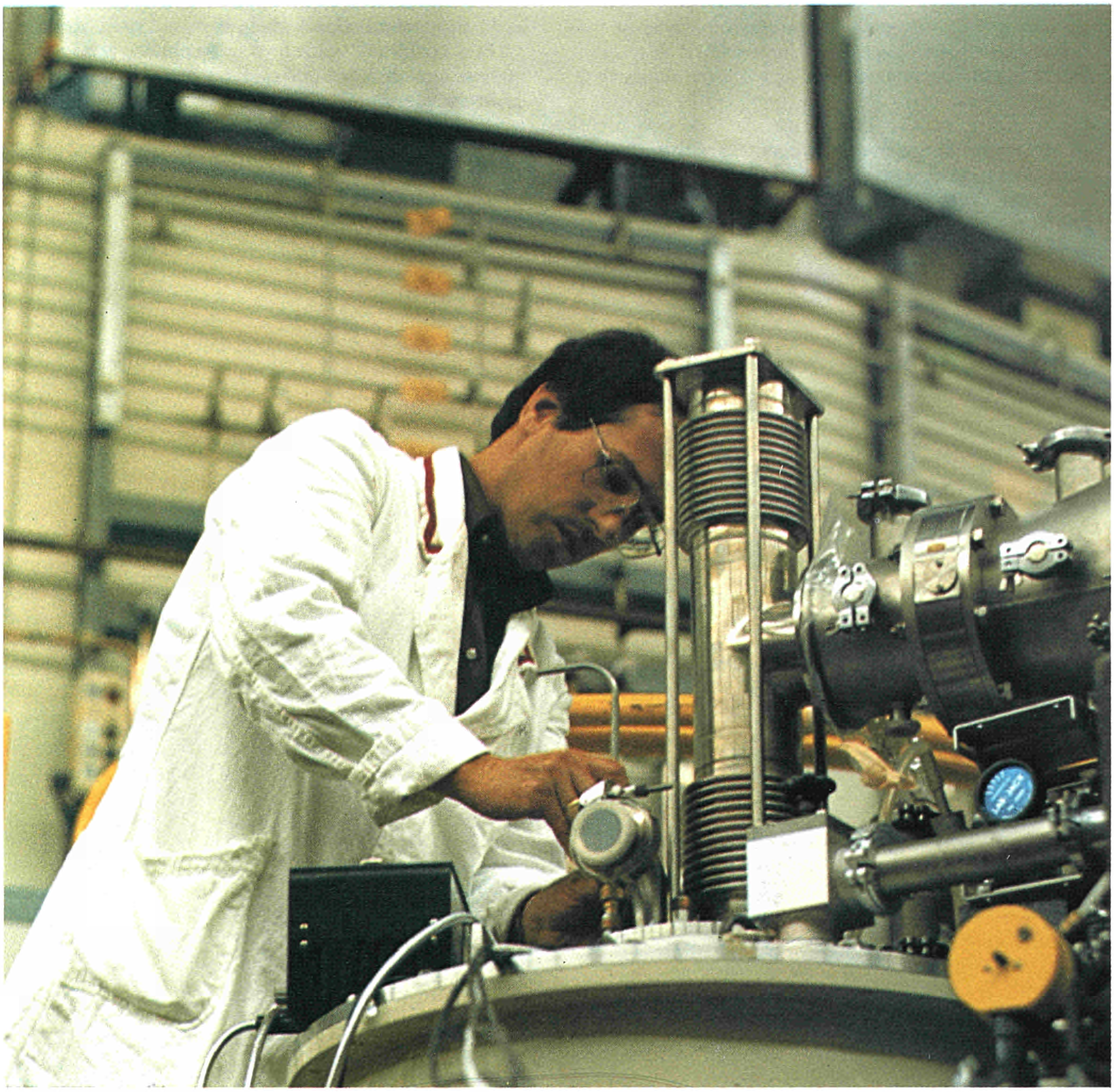
Low energy nuclear spectroscopy has been carried out on nuclei in the 2p shell. Measurements on circular polarization of γ-rays following capture of polarized thermal neutrons have been performed with isotopically enriched Cu and Ti samples. Capture of polarized neutrons in polarized ^{63}Cu nuclei has been studied. With a 24 keV neutron beam the cross section for the $^{3}He(n,\gamma)$ reaction has been measured. A parity interference measurement has been installed at a polarized beam.
Theoretical studies have been rounded off on the systematics of binding energies of p-states and on the energy distribution of radiative strenght. The $^{45}Sc(n,\gamma)$ spectrum was interpreted in terms of the statistical model. The edition of a book on Nuclear Structure was rounded off in collaboration with colleagues at Dutch Universities.

1. The new nuclear orientation set-up is operational at a temperature below 10 mK at HB2.

2. At the new 24 keV neutron beam HB4 a flux density of $1.2 \times 10^{6} cm^{-2} s^{-1}$ has been reached. With this beam the cross sections for some light elements will be remeasured.

3. A Compton suppression spectrometer has been installed and used to measure on low energy gamma transitions.

4. In the frame of a tripartite agreement a polarized neutron beam has been equipped with a longitudinal guide field to produce neutrons with spin direction along the beam.



Nuclear Physics. Preparing the nuclear orientation set-up at HB2 for start-up.

2.2.6 Life Sciences

Radioisotopes for Medical Applications

Diagnosis and therapy of cancer have made increasingly use of a short-lived radioisotope called "Technetium 99 m" (^{99m}Tc) which can be produced in high purity by radioactive decay of another short-lived radioisotope, viz. "Molybdenum 99" (^{99}Mo).
^{99}Mo is produced in HFR Petten by two different techniques :

1. irradiation of molybdenum (activation route)
2. irradiation of highly enriched uranium (fission product route).

The production of ^{99}Mo in HFR Petten has been increased in 1981 to fulfil the growing demand. Presently up to two transports with ^{99}Mo leave Petten every week, according to an exact time table.

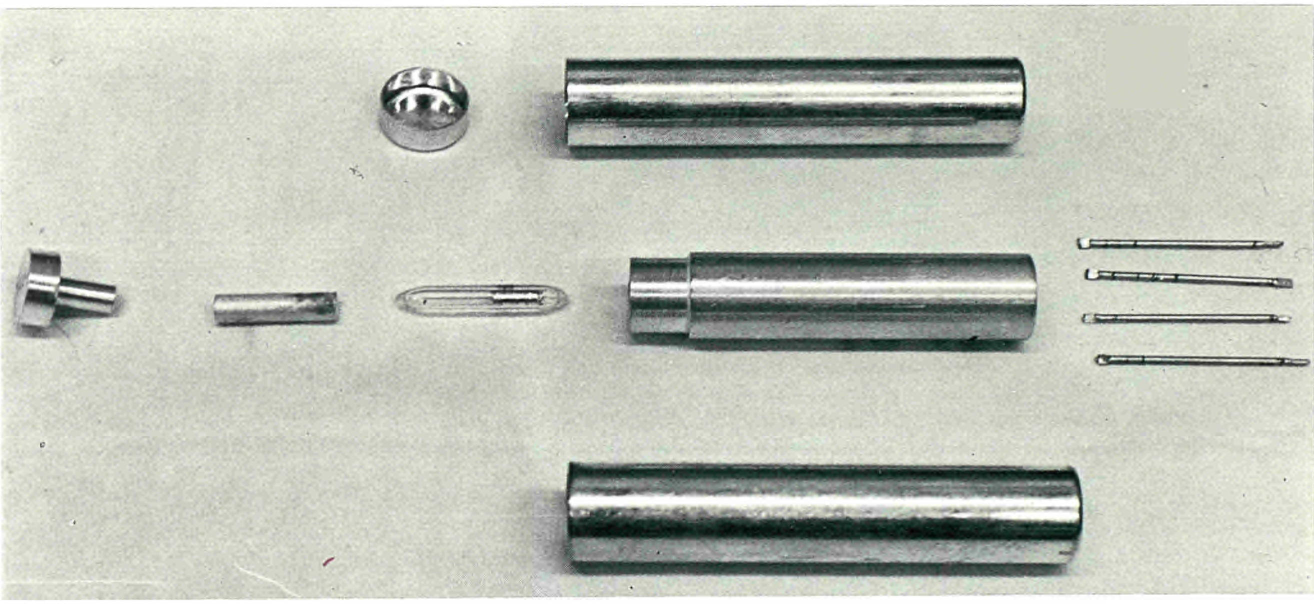
Most of the other isotopes produced in the HFR in 1981 (e.g. ^{192}Ir) have been for medical applications. In total, 2380 individual samples have been irradiated.

Activation Analysis for Medical Research

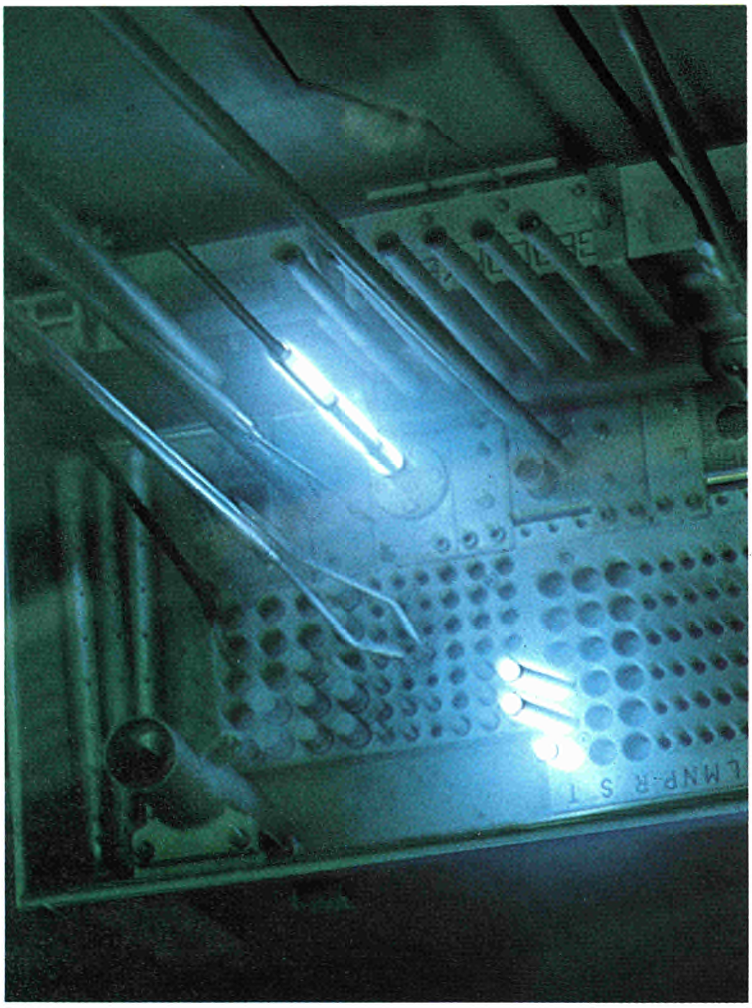
There is an increasing attention for the importance of trace elements in the human body. Much research in medicine bears upon the relationship between clinical diagnosis and deviating trace element contents. Though there is no direct proof, selenium is regarded to be one of the essential trace elements, this also with respect to the possible relation between cancer and selenium in the human serum.
Activation analysis done at the HFR Petten is partly devoted to such trace elements studies and in 1981 the selenium was of special interest.

Radioisotopes. Other Applications

An irradiation facility for the production of ^{60}Co has been constructed in order to satisfy the future large demand for this isotope in food-stuff sterilisation plants. Large scale production of ^{60}Co for an outside contractor will start in 1982.

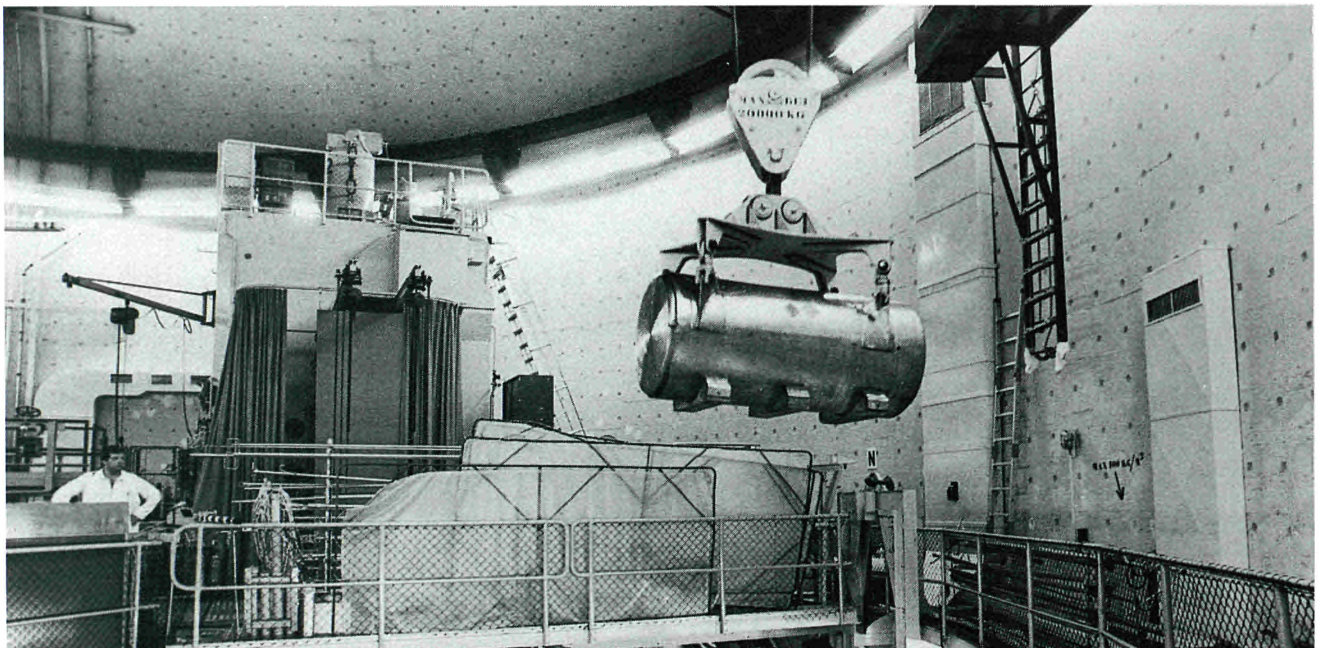


Capsule for the irradiation of Pu-244 for an irradiation and calibration program of the JRC Geel.



LIFE SCIENCES

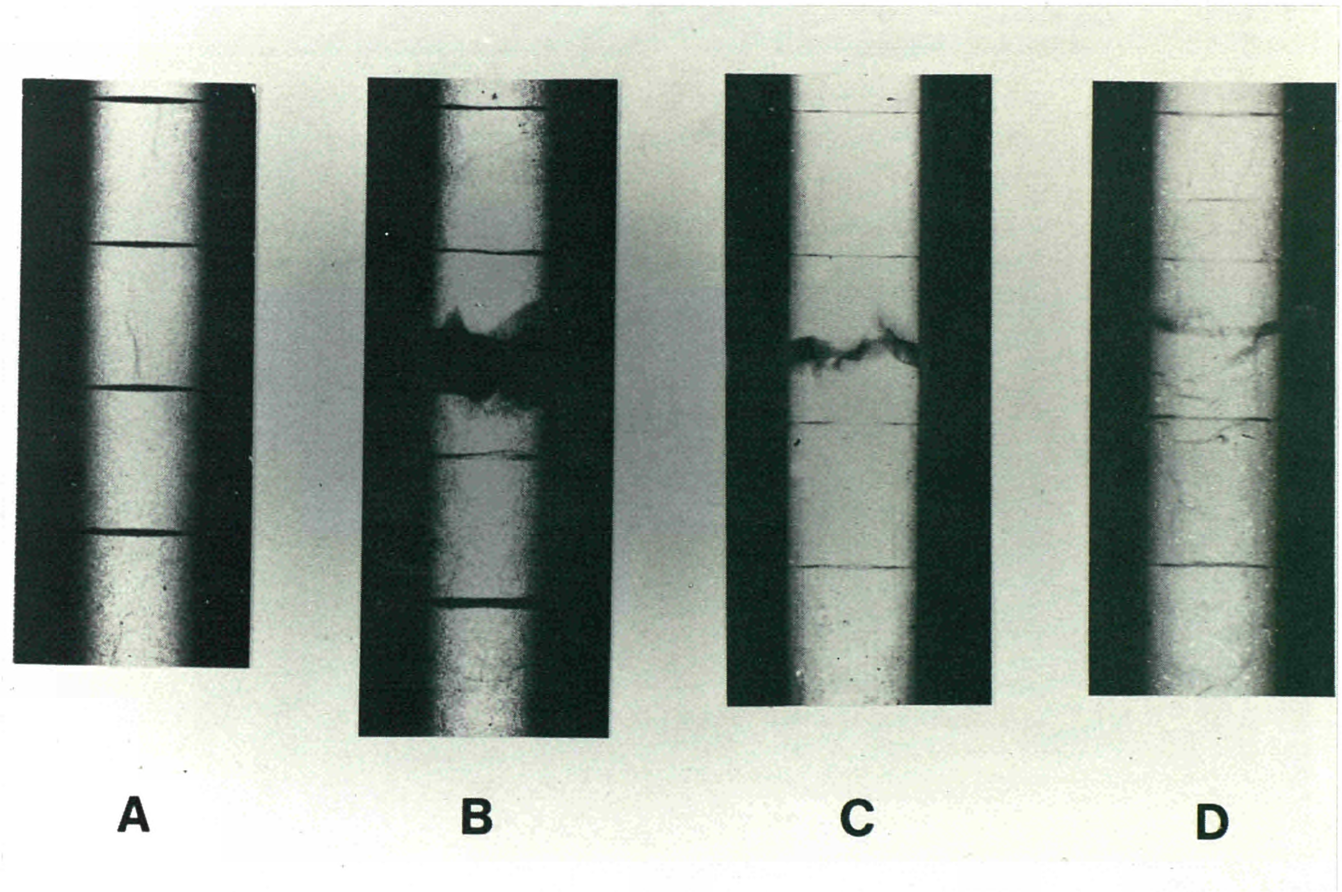
Irradiated U^{235} samples for the production of Molybdenum-99 for cancer diagnoses



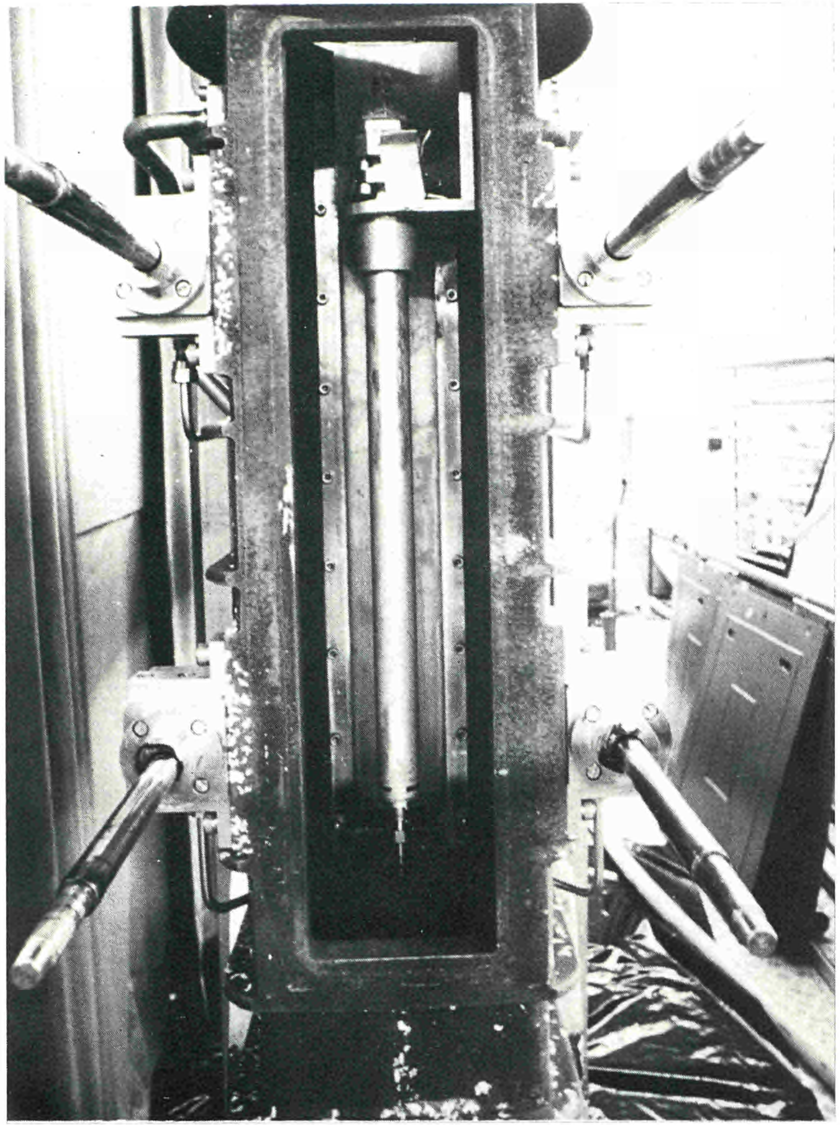
Special transport container Moly loaded with irradiated Molybdenum-99 samples before shipment

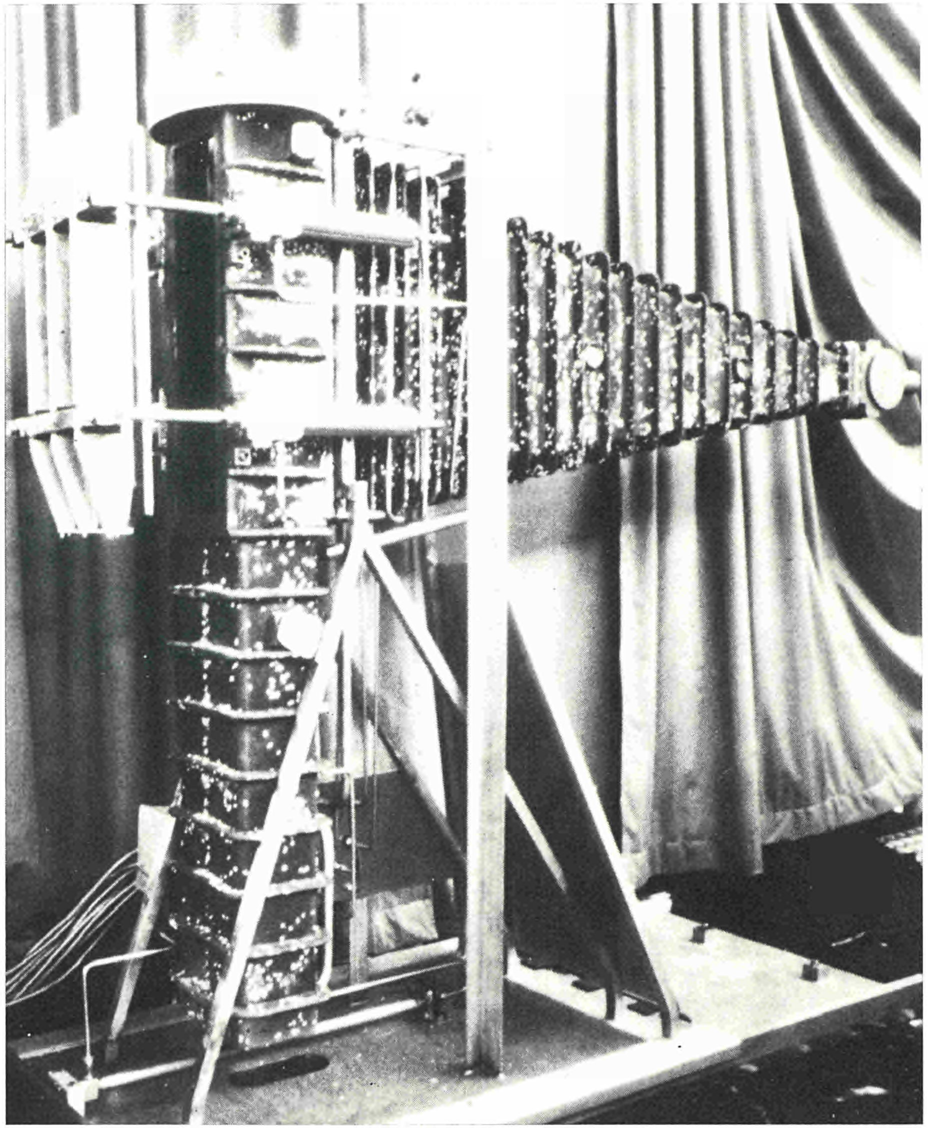
2.2.7 Miscellaneous

Neutron radiography is used at HFR Petten on a routine basis for the control of irradiated experimental equipment and for the examen of neutron-induced structural changes in fissile material. 263 neutron radiographs have been taken and evaluated in 1981.
In order to perform neutron radiographic examinations of long (> 2m) spent fuel rods from power reactors a dry neutron radiography facility has been developed at ECN, using the neutron beam from beam tube HB8 of the HFR. The facility became operational for first tests in 1981.
In this frame it is of interest that nine papers could be contributed to the First World Conference on Neutron Radiography at San Diego, USA, 7-10 December 1981, about Petten based neutron radiography installations and their applications.
Several special test devices have been loaded in various reactor positions throughout the year, including:
- a nuclear heating calorimeter,
- a capsule with aluminium specimens for reactor vessel material surveillance.



Neutron Radiography.
Healing of pellet separation (A-before, B-after incident, C and D after further irradiation time of approx. 700 resp. 2000h)





NEUTRON RADIOGRAPHY

PSF neutron radiography camera outside the pool. View from the casette side on a loaded dummy capsule.

PSF neutron radiography camera outside the pool during maintenance.

3. CONCLUSIONS

HFR Petten has been operated in 1981 in fulfilment of the 1980/83 JRC Programme Decision.

Both reactor operation and utilization data have been met within a few percent of the goals set out in the annual working schedule, in support of a large variety of research programmes.
Major improvements to experimental facilities have been introduced during the year and future modernization has been prepared.

HFR Petten

UTILIZATION

WHY ARE THESE EXPERIMENTS CARRIED OUT IN THE HFR ?

- **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 AND LARGE CONTROL EQUIPMENT
- **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

UTILIZATION

1981 ACHIEVEMENTS

- FAST BREEDER REACTOR 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 :
  10 FUEL PINS TESTED UNDER TRANSIENT CONDITIONS
- LIGHT WATER REACTOR FUEL PIN POWER RAMPING FOR IMPROVED OPERATING ECONOMY AND SAFETY :
  POWER RAMP TESTS ON 22 PRE-IRRADIATED FUEL PINS
- HIGH TEMPERATURE GAS-COOLED REACTOR GRAPHITE AND FUEL ELEMENT IRRADIATIONS :
  CONTRIBUTION TO THE DATA BASE OF THE HTGR: 1150 GRAPHITE SAMPLES UNDER IRRADIATION, SOME UNDER STRESS (CREEP SAMPLES)
- RADIOISOTOPE PRODUCTION, ACTIVATION ANALYSIS :
  2380 SAMPLES AND CAPSULES IRRADIATED FOR MEDICAL AND INDUSTRIAL APPLICATIONS, ENVIRONMENTAL POLLUTION CONTROL, RESEARCH PURPOSES
- NUCLEAR STRUCTURE AND SOLID STATE PHYSICS EXPERIMENTS :
  CONTINUOUS UTILIZATION OF EIGHT HORIZONTAL BEAM TUBES. IMPROVEMENTS ON SEVERAL EXPERIMENTAL SET-UPS
- NEUTRON RADIOGRAPHY, NEUTRON DOSIMETRY DEVELOPMENT :
  263 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.

4. HFR PUBLICATIONS, 1981

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- *J. Bordo, F. Mason, P. Zeisser*
  Application of Epithermal Neutron Radiography to Performance Tests on Advanced LMFBR Fuel
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  Annual Status Report 1980: Operation of the High Flux Reactor
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  EUR 7164 FS

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