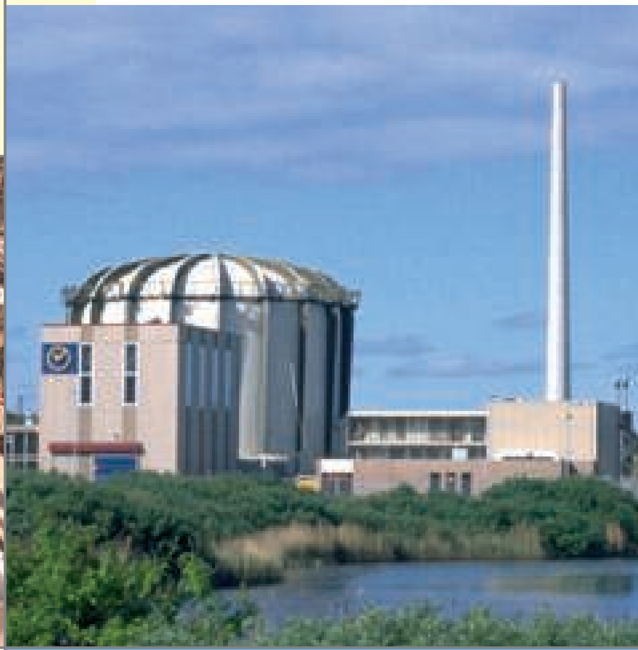
Operation and Utilisation of the High Flux Reactor



Annual Report 2003

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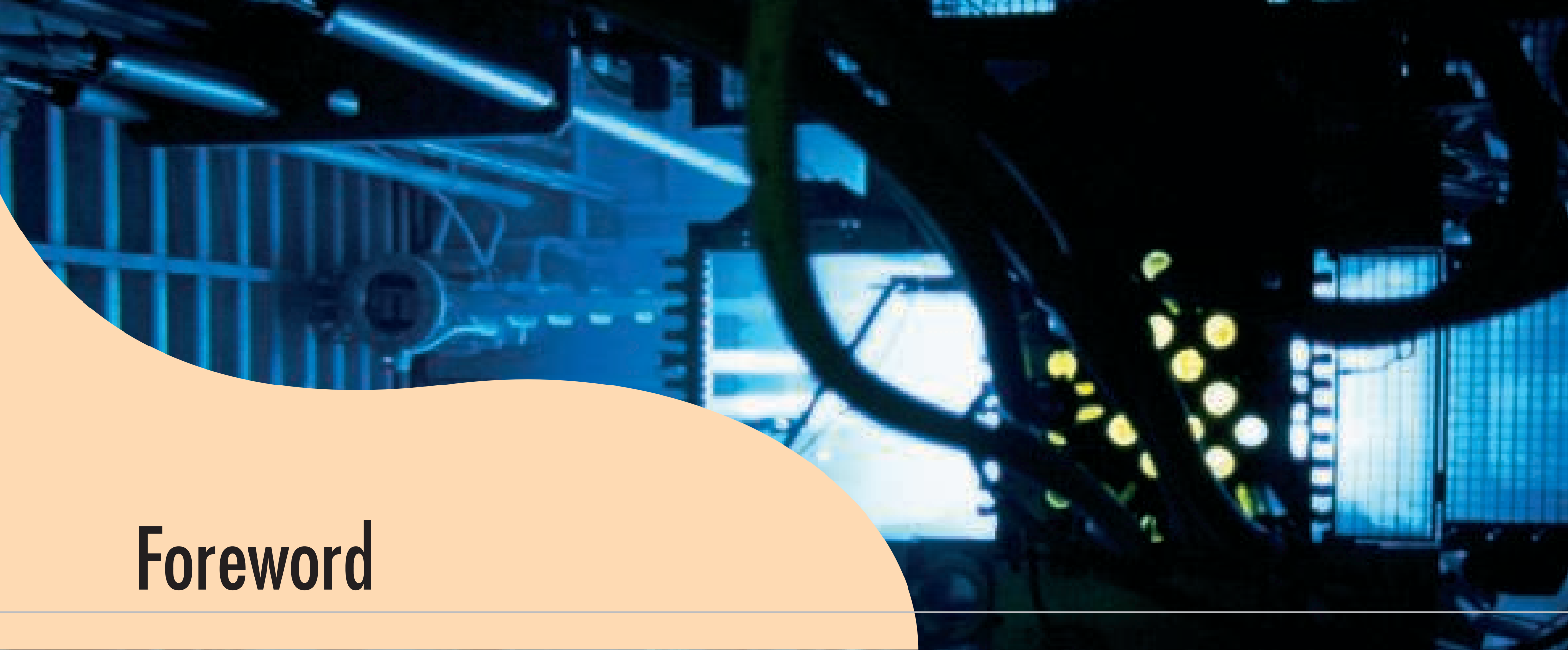


Foreword

2003 was a very busy year at the High Flux Reactor (HFR) in Petten. It was the last year of the 2000-2003 Supplementary Programme financed by France, Germany and The Netherlands. A new Supplementary Programme was negotiated with the stakeholders. On 19th February 2004, the Council adopted a new Supplementary Programme for the period 2004-2006. The new financing comes from The Netherlands and France only. It is the last time that a Supplementary Programme will be used as the legal framework for the operation of the HFR. New mechanisms will be actively explored to secure operation beyond 2006.

In 2002, an extra shut-down period was agreed and used for an external safety culture review performed by an expert group of the International Atomic Energy Agency (IAEA), the definition of an improvement action plan and an external inspection of the welding anomaly observed during the 2001 inspection. The IAEA review concluded that the reactor was in good condition and made recommendations and suggestions for further safety improvements. As a consequence, a programme on safety culture improvement was set-up.

This programme consisted of more than 140 individual actions and was finally completed in January 2004. A follow-up INSARR (Integrated Safety Assessment of Research Reactors) mission will take place in the second half of 2004.

In addition, following the external inspection of the welding anomaly in 2002, a comprehensive action plan for structural assessment was set-up and completed in November 2003, after a new in service inspection which had taken place in September of the same year. The main conclusion of this action plan is that the reactor vessel can operate at least until 2015. Regular in service inspections will continue and a new material surveillance programme was put in place.

Last but not least, an application for a new operating licence was submitted jointly by the Joint Research Centre (JRC) and Nuclear Research & consultancy Group (NRG) to the licensing authorities. The main reason for a new licence was dictated by the decision to convert from High Enriched Uranium (HEU) fuel to Low Enriched Uranium (LEU) fuel and by recent changes in the Dutch Nuclear Energy Act, which called upon a 10-year re-evaluation of existing licences.

The application was the result of more than 3 years work and the total technical documentation amounts to 4450 pages.

The licence is expected to be granted mid-2004 and the beneficiary will be NRG. In this way, we will meet one of the recommendations of the IAEA: to have the licence in the hands of the operator. The JRC will nevertheless remain owner of the installation.

All the above achievements required a tremendous effort from all HFR staff as well as staff in the Institute for Energy (IE) and in NRG. I herewith seize this opportunity to thank them for their involvement which allowed to simultaneously complete the IAEA action plan, prepare for the new licence and prepare the ground for the new Supplementary Programme without impeding on their contribution to HFR's scientific output.

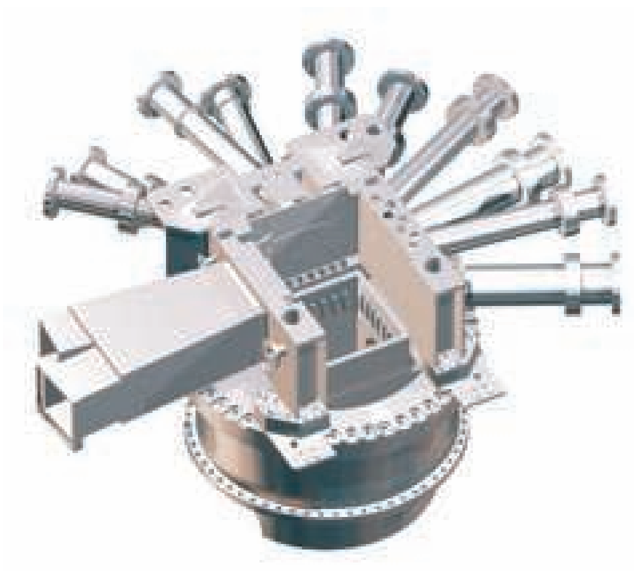
Marc Becquet
April 2004

Introduction

The High Flux Reactor Petten, managed by the Institute for Energy of the JRC of the European Commission, is one of the most powerful multi-purpose materials testing reactors in the world.

The HFR is of the tank-in-pool type, light water cooled and moderated and operated at 45 MW. In operation since 1961, and following a new vessel replacement in 1984, the HFR has a technical life until year 2015.

The reactor provides a variety of irradiation facilities and possibilities in the reactor core, in the reflector region and in the poolside. Horizontal beam tubes are available for research with neutrons and gamma irradiation facilities are also available. Furthermore, excellently equipped hot cell laboratories on the Petten site provide virtually all envisaged post-irradiation examinations possibilities.



The close co-operation between JRC and NRG on all aspects of nuclear research and technology is essential to maintain the key position of the HFR amongst research reactors world-wide. This co-operation has led to a unique HFR structure, in which both organisations are involved. JRC is the owner of the plant (for a lease of 99 years) and the plant and budget manager; as well as, until 2004, the licence holder. JRC develops a platform around HFR as a tool for European collaborative programmes. NRG operates and maintains the plant, under contract, for JRC and, since the 2000/2003 programme, manages the commercial activities around the reactor. As of 2004 and pending granting of the license, NRG will become the licence holder.

Furthermore each organisation provides complementary possibilities around the reactor activities, such as the hot cell facilities of NRG or the experiment commissioning laboratory of JRC. HFR is also in the core of the Medical Valley association. This association between IE, NRG, Tyco, Urenco and hospitals leads to a Centre of Excellence, unique in Europe.

A co-operation agreement for the use of the HFR beam tubes was signed in 1999 between JRC, NRG and the Interfaculty Reactor Institute of the Delft University of Technology (IRI Delft). This agreement allows free access of the IRI teams to the HFR beam tubes and promotes a fruitful collaboration in the technological improvement of the HFR beam tubes.

HFR: Reactor Management

HFR Operation and Related Services.

In 2003 the regular cycle pattern consisted of a scheduled number of 285 operation days and two maintenance periods of 24 and 17 days with 10 days for In-Service Inspection (ISI). In reality the HFR was in operation for 288 days. This corresponds to an actual availability of 101 % with reference to the original scheduled operation plan (Figure 1). Nominal power was 45 MW with a total energy production of approximately 12857 MWd, corresponding to a fuel consumption of about 16 kg of U-235.

At the beginning of the reporting period, HFR operation was interrupted for regular maintenance and core reloading in preparation of cycle 03.01. Towards the end of the reporting period, the power distribution measurements for the FLUX 2003 programme were performed. At the same time, the yearly HFR reactor training programme was carried out. Activities performed in the framework of the regular HFR operators' training took place immediately after the scheduled ends of each cycle, from cycle 03.03 to cycle 03.11.

The operating characteristics for 2003 are given in Table 1. The reactor vessel ISI, originally planned to be performed during the summer maintenance period, was postponed to September along with a part of the other maintenance activities which were also planned for the same period.

Table 1 **2003 operational characteristics**

			OPERATING TIME					SHUT-DOWN TIME				
Cycle Begin-End	HFR Cycle	Generated Energy	Planned	Low Power	Nominal Power	Other Use	Total	Planned	Unscheduled	Number of Interruptions		Stack Release (of Ar-41)
2003		MWd	hrs	h.min	h.min	h.min	h.min	h.min	h.min	PD	Scram	Bq x E+11
01.01 - 27.01	03.01	1166.76	592	03.52	622.03		625.55	22.05				6.0
28.01 - 24.02	03.02	1129.32	592	03.49	601.30		605.19	66.41				6.0
25.02 - 24.03	03.03	1135.30	592	02.38	604.05	00.03	606.46	65.10	00.04	1	1	5.0
25.03 - 17.04	Maintenance period							504.00				
18.04 - 12.05	03.04	1133.33	592	07.39	601.27	00.15	609.21	62.39				4.0
13.05 - 09.06	03.05	1127.36	592	01.50	601.30	00.27	603.47	68.13		1		6.0
10.06 - 07.07	03.06	1126.05	592	01.54	600.11	01.01	603.06	68.54				6.0
08.07 - 23.07	Maintenance period							384.00				
24.07 - 18.08	03.07	1059.76	592	04.25	565.04	00.04	569.33	13.43	40.44		1	6.0
19.08 - 15.09	03.08	1075.23	592	02.11	572.54	00.10	575.15	72.55	23.50	1		6.0
16.09 - 25.09	Maintenance period and ISI					01.00	01.00	239.00				
26.09 - 20.10	03.09	1090.31	592	02.00	580.28	00.30	582.58	07.30	09.32			4.0
21.10 - 17.11	03.10	1129.88	592	03.45	602.15	00.32	606.32	65.28				6.0
18.11 - 15.12	03.11	1089.01	592	05.18	577.49	12.56	596.03	67.04	08.53		1	6.0
16.12 - 31.12	03.12	594.59	312	03.50	314.19		318.09	65.47	00.04	1	1	6.0
	TOTAL :	12856.90	6824	43.11	6843.35	16.58	6903.44	1773.09	83.07	4	4	67.0
Percentage of total time in 2003 (8760 h) :				0.79	78.12	0.19	78.8	0.20	0.95			
Percentage of planned operating time (6824 h) :				0.63	100.28	0.25	101.16					

PD: Power decrease

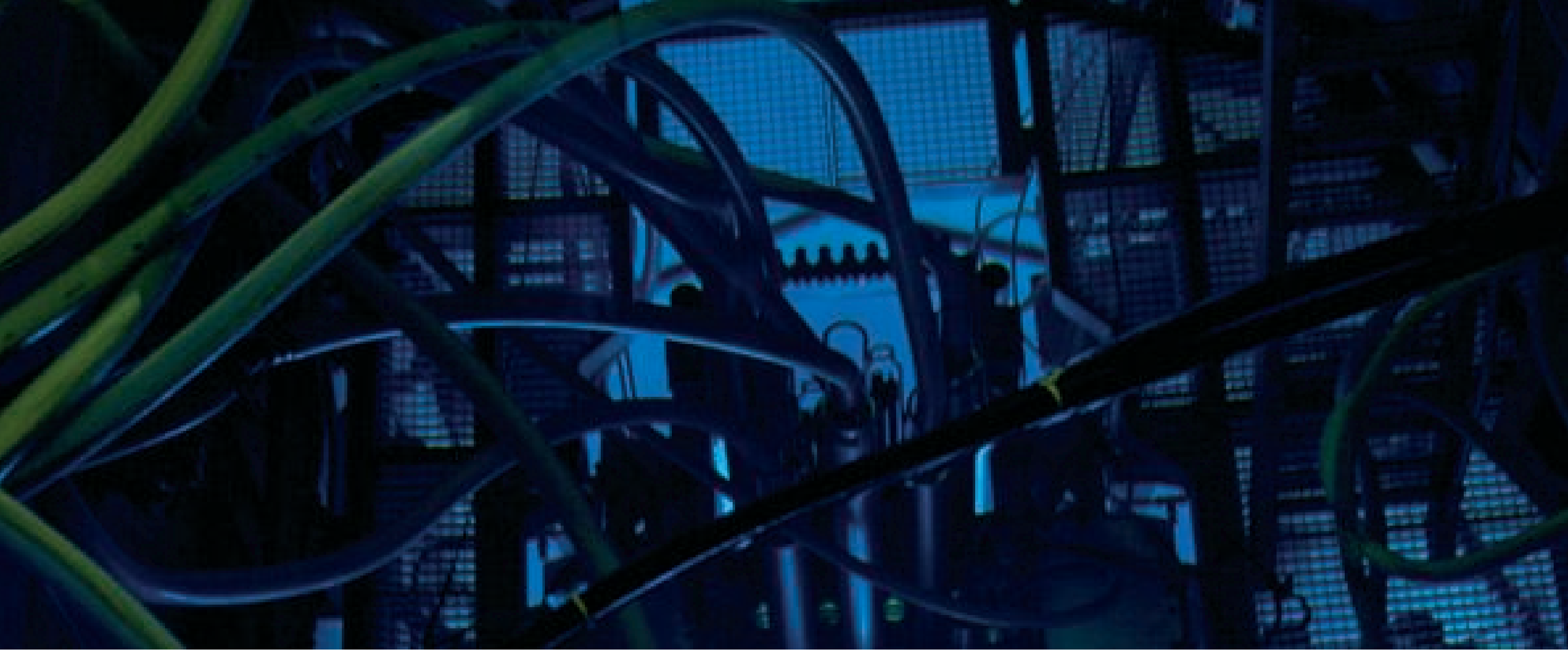


Figure 1 **HFR availability**

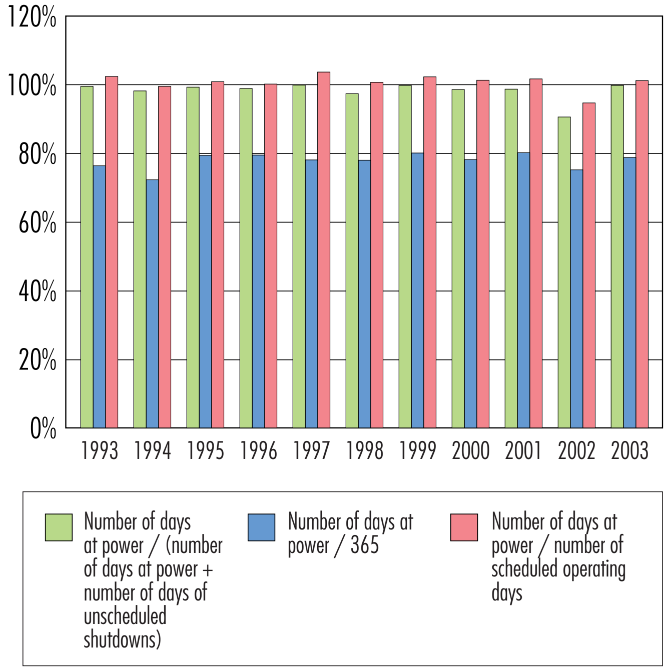
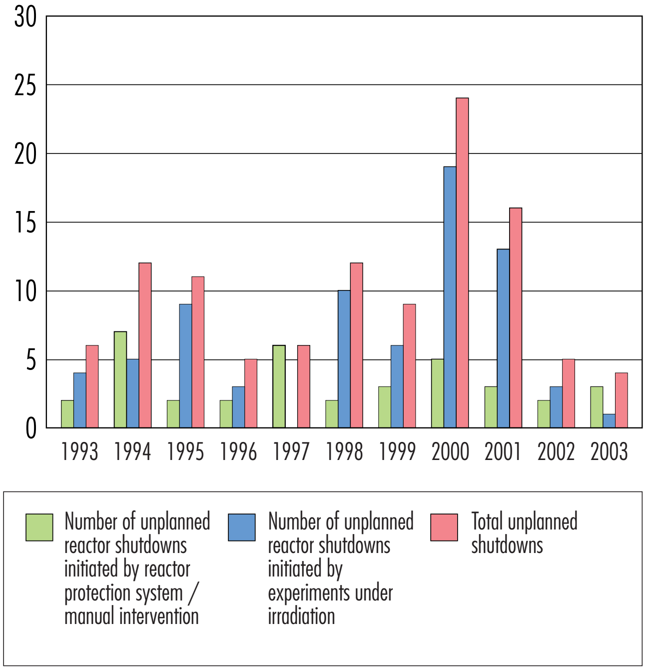


Figure 2 **HFR unscheduled shutdowns**



All details on power interruptions and power disturbance occurring in 2003, provided in Figure 2 above, show that only 4 scrams occurred. This value is the lowest in the last 10 years; two of the four scrams resulted from human intervention and two others were a consequence of a technical malfunction.

In 2003, a total of 153 visits to the reactor, involving 1321 people, were organised. Alongside international colleagues and relations in the medical world, a number of people from the local community took advantage of the open day during each cycle to visit the facility.

Safety and Quality Management

Safety

Safety Goals

The overall safety goal for a nuclear research reactor is to protect individuals, society and the environment by establishing and maintaining an effective defence against radiological hazards.

For this overall goal, the corresponding radiation protection objectives are:

- To ensure that the operation and utilization of a research reactor are justified under radiation protection considerations (justification principle)
- To ensure that during operational states radiation exposure of site personnel and the public remains below limits prescribed by national authorities and is kept as low as reasonably achievable (ALARA) (optimisation principle and individual dose and risk limit principle)
- To ensure mitigation of radiation exposure from accidents (intervention principle)

With respect to accidents the more detailed objectives are:

- To ensure that accidents are generally prevented
- To ensure that, for all event sequences taken into account in the design of the facility including those that have low probability, radiological consequences are small
- To ensure by both prevention and mitigation measures that accidents with significant consequences are extremely unlikely

Safety Concept

As part of the re-licensing project the Safety Design Concept has been elaborated. Its objective is to define and explain the boundary conditions, requirements and assumptions for the safety design basis of the HFR. The deficiencies identified in tasks of the project relating to hardware measures have been evaluated and solutions have been formulated, mostly within the frame of a more comprehensive modification package.

The Safety Design Concept consists of the following parts:

- Safety goals of the HFR
- Safety Philosophy
- Basic Safety functions
- Outline of the engineered safety features fulfilling the basic safety functions
- Definition of design criteria for safety systems, in conformance with the Reference Licensing Basis (RLB)[1]
- Postulated Initiating Events that must be considered

[1] RLB is a collection of international and national (Dutch) standards and guides issued specifically for research reactors which globally define the current safety requirements applicable to technical, operational, personnel and administrative features of a modern research reactor.

Quality

Among the new procedures implemented at the HFR in 2003, two played a central role in the enhancement of the safety culture.

The first procedure is "Root Cause Analysis at the HFR": it outlines the methodology, tasks and responsibilities involved in the identification of causal factors of selected incidents or dangerous occurrences thereby enabling the identification of adequate corrective actions to prevent recurrence. During the year, 5 occurrences have been analysed according to this procedure.

The second procedure is "Lessons Learned System at the HFR": it aims at effectively preventing recurrences of the same type of event by reviewing good practices and lessons learned from other facilities. During 2003 a first collection of data from several sources has taken place and has been screened for possible impact / applicability to the HFR.
2003 was also the year of the first HFR self-assessment organised by the HFR Safety Culture Workgroup (SCWG) with the participation of the licence holder, the operating organization and the regulatory body; the exercise, which took place on April 04, was moderated by a safety culture expert from IAEA.

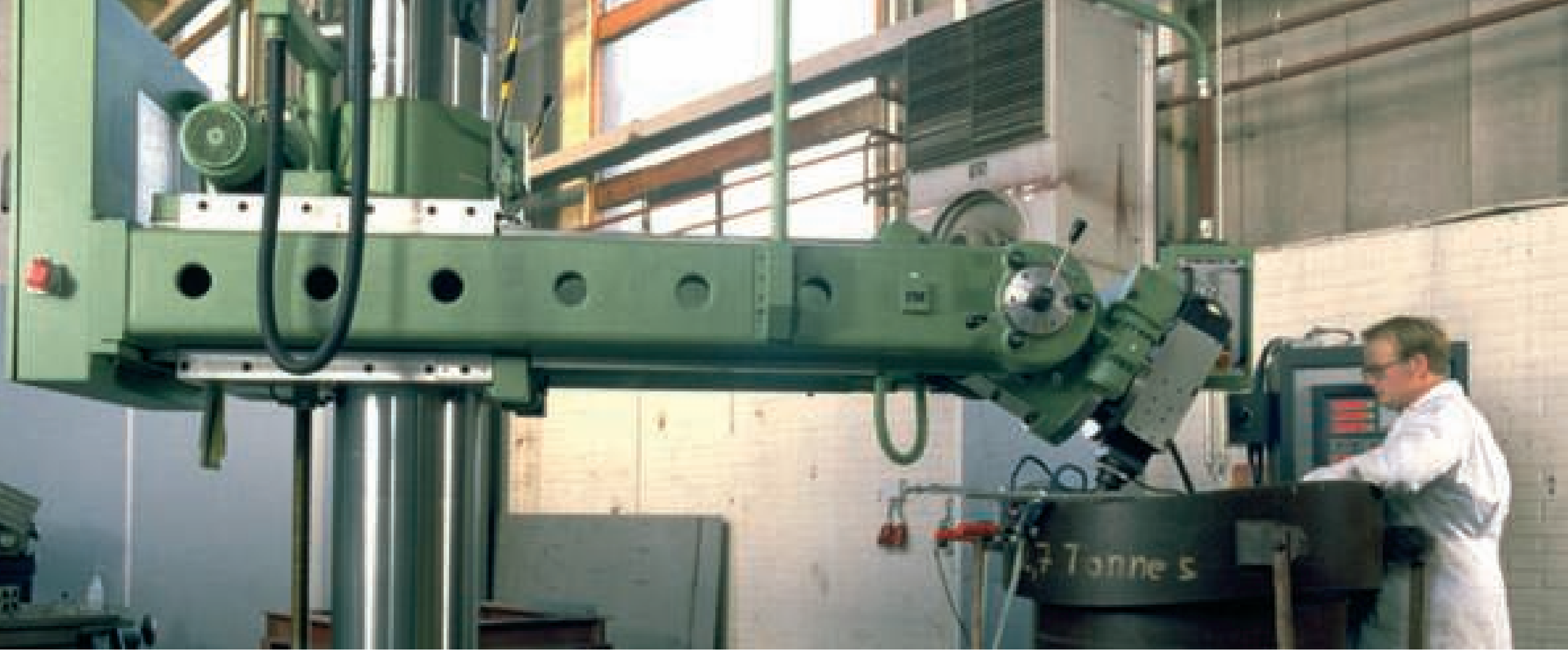
The self-assessment was focussed on the following items:
- Adequacy of membership of safety
- Adequacy of documentation and communication with regulator
- Learning from (near) misses and feedback system
- Housekeeping
- Safety and Production
- Understanding of the concept of safety culture
- Quality of and compliance with procedures and regulations.
- Management commitment to safety and leadership skills
- Future prospects, impact of subcultures

The results have been compiled in a table of strengths and weaknesses, including opportunities for improvements.

Inspection and Safety

A HFR International Safety Experts Team was set up to underpin and improve the high standard of nuclear safety at HFR; in this frame, JRC-IE, NRG and ECN are participating in the Reactor Safety Committee (RSC), which advises the directors of all three organisations on nuclear safety matters. The external experts are: Mr. H. Guyon (Institute Laue-Langevin Grenoble), Mr. T. van der Hagen (IRI Delft), Mr. U. Lindelöw (Studsvik Nuclear AB Nykoping), Mr. E. Koonen (SCK-CEN Mol), Mr. J. Karuza (GKN - Centrale Dodewaard). The kick-off meeting of the HFR International Safety Experts Team took place on May 16 in Petten.

Following the planning agreed with KFD a structural inspection of the HFR vessel took place on September 15. NRG Arnhem carried out the Inspection, using a fully qualified procedure agreed by KFD. During the inspection, officials from KFD as well as from Lloyds' Register were present. The results, which in the meantime have been accepted by KFD, show that the new qualified inspection of 2003 gave more accurate results and that sizes of the indications reported in 2001 and 2002 were overestimated.



Documents for the New Licence

In the beginning of 2001 the HFR team started the ambitious project of preparing a completely new documentation package finalized at the application for a new licence. This exercise will be reached in early 2004, upon transmission of the formal application for the new licence to the competent authorities.

The main goals of the project can be summarized in the following points:

- The evaluation of the HFR design and operation against current standards to assess its safety level
- The conversion of the core by refuelling it with LEU instead of the current HEU loading
- The preparation of an optimised modification programme to anticipate today's safety philosophy and safety standards
- The preparation of a Safety Report and of an Environmental Impact Assessment
- The performance of deterministic analyses to verify that the HFR meets the thermal-hydraulic/reactivity and radiological success criteria of a set of enveloping design basis accidents
- The performance of probabilistic analyses to provide assurance that no potential occurrences presenting a substantial risk to the public are overlooked in the deterministic safety analyses
- The evaluation of civil, electrical and mechanical ageing issues to ensure that systems, structures and components important for safety functions are effectively managed throughout the service life of the HFR

The resulting technical documentation for the new HFR licence consists of more than 5000 pages in approximately 70 documents, elaborated under a strict quality assurance programme and subjected to multiple reviews by internal independent reviewers, safety committee and national regulatory body (including external consultants).

SURP (HFR Surveillance Programme)

Issue of an Upgraded Version of the Design & Safety Report
In light of the expiration in 2003 of the current Design and Safety Report for the irradiation capsules written in 1986, a revision became urgent. Among others, new nuclear and thermal calculations were required; they were mainly performed by NRG. In July 2003 an upgraded version of the SURP Design and Safety Report has been issued by JRC and approved by the Reactor Safety Committee without remarks.

Campaign for Replacement of Neutron Monitors and Exchange of Mechanical Test Specimens
In the frame of the HFR surveillance programme, replacement of neutron monitors and replacement of some mechanical test specimens from both SURP-01 and SURP-02 irradiation capsules have been successfully carried out. The replacement campaign has taken place during the HFR ISI stop (September 14-23).

SURP-01, In-Core Surveillance Experiment RX-189-01
Opening of the SURP-01 capsule, unloading & replacement of neutron activation monitors, and exchange of three Compact Tension (CT) & four tensile specimens, all took place in period September 18 - 22. On September 23, after delivery of the SURP-01 capsule back to the HFR, it was placed in its irradiation position inside the reactor core.

SURP-02, Surveillance Experiment RX-189-02 in PSF
Opening, unloading of specimens, replacement of neutron monitors and exchange of mechanical test specimens from the SURP-02 irradiation capsule have also been carried out in NRG's Hot Cell Laboratory in the period September 15-18. From the SURP-02 capsule, three CT specimens have been extracted. As agreed, two new specimens from base material have been inserted. In the position of the third CT, 4 half-size CT and 3 tensile specimens made from "weld 22" material, provided by the JRC, have been loaded. The SURP-02 has been delivered back to the HFR on September 22 and placed in the Pool Side Facility (Position PSF 4), according with the procedure stated in the Design and Safety Report.

New activation monitors have been inserted in both SURP capsules. The former monitors will be evaluated in the Fermi Laboratory by the NRG-MMI group. NRG-MMI group is also in charge of performing the mechanical test evaluation of the extracted specimens.

Action Plan for Life Management of the Core Box Weld 22 West

The Weld 22 Action Plan refers to a 18-month programme of activities that have been performed by JRC-IE to reinforce the safety case for Weld 22 west on the HFR vessel.

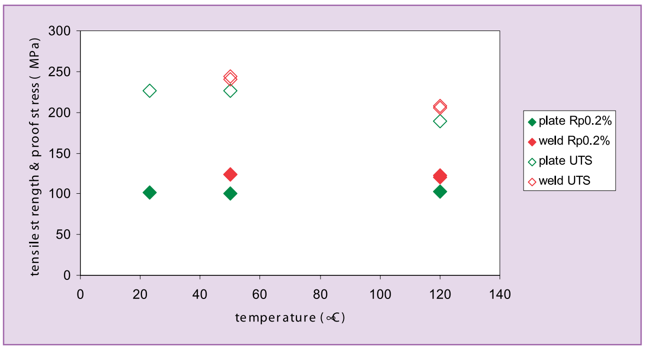
Background
During the fabrication of the vessel, small defect indications had been identified on Weld 22 and were judged safe at the time. They were monitored during ISI in 1988, 1991, 1994 and 1997, using standard techniques. In 2001, a new inspection method was used, indicating larger apparent defect dimensions. The subsequent integrity assessment confirmed that the safety margins were still adequate. An independent review by Serco Assurance in March 2002 confirmed the validity of the results, while proposing several follow-up actions to arrive at a definitive statement of the safety of the weld for the remainder of its design life. In response to this the JRC set up the Weld 22 Action Plan, utilising a range expertise from several IE Units.

Technical Investigations
The Action Plan combined the results of tasks relating to non-destructive inspection, stress analysis, material characterisation, welding residual stresses and fracture assessment. Features of the work included:

- Tensile, fracture and stress corrosion cracking tests on weld material (Figure 3) from the reserve vessel (previously data was only available for the plate itself)
- A new finite element analysis of the pressure and thermal stresses (Figure 4)
- Measurements and simulations of the weld residual stresses
- Preparation of welded plate samples with a range of intentional defects for use in the performance assessment of the non-destructive testing system

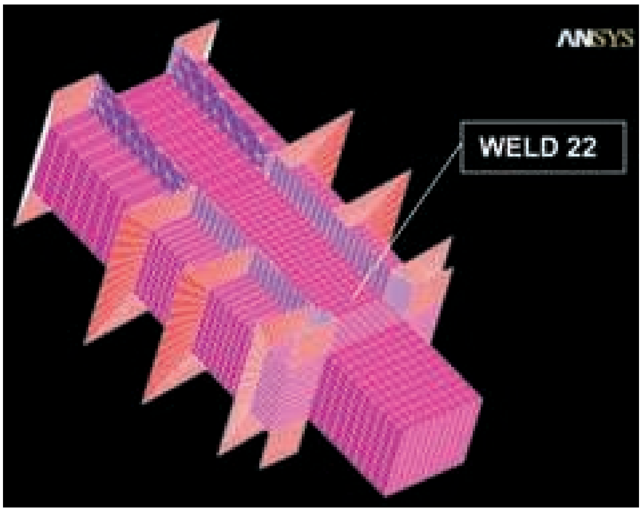
New Non-Destructive Inspection
In September 2003 NRG performed a new ISI of Weld 22 west using a qualified procedure approved by the Dutch regulator KFD. The dimensions of the defect indications were reduced compared to those obtained in 2001 and 2002. These data also confirmed that no growth is occurring. However these indications will continue to be checked, using the new procedure, as part of the regular three-year inspections of welds in the reactor vessel.

Figure 3



Lifetime Assessment
The results of the new non-destructive inspection were then used to update the fracture mechanics assessment under both operational and accident loads. This demonstrated that the present defect indications would need to be over twice their current size before risking a leak from the vessel to the reactor pool. Even in this situation the overall functionality of the vessel for shutdown would be maintained by the core support structure. It was concluded that the technical integrity of core box Weld 22 west can be assured up to the foreseen end-of-life in 2015.

Figure 4



Fuel Cycle

Front End

In 1999, the decision was taken to convert the HFR to LEU fuel, followed, in January 2000, by an exchange of diplomatic notes between the EC and the US authorities concerning the conversion to LEU and interim supply of HEU from the US. As a result, an export licence was obtained from the US Nuclear Regulatory Commission allowing HEU supply from the US to fuel the HFR for a period of four years. Quantities authorised for the first two years were delivered in 2000 and 2001. In early 2003, the quantities authorised for the third and fourth year were delivered successfully in a combined shipment.

During the year 2003 new fuel elements and new control rods were inspected at the manufacturer's site and delivered on schedule. A new order for manufacture and delivery of fuel elements and control rods was placed.

The prototype LEU fuel element delivered in 2002 was tested and irradiated up to a burn-up of 50%. On the basis of the positive test results the irradiation will be continued up to an average burn-up of 75%.

Spent Fuel Transport

In the early hours of June 11, the special police units started to assemble at the Institute for Energy in Petten, reinforced two hours later by mounted police, police dogs and a circling police helicopter. This was all part of the standard security operation associated with the transport of used fuel elements from the HFR reactor to the special Dutch storage facility COVRA in Vlissingen. At exactly 10:00 A.M., the 33 used fuel elements sealed in specially constructed containers left the IE site, accompanied by a convoy of police motorcycles and 30 special police officers. The convoy arrived safely in Vlissingen three hours later.

Back End

Following successful shipments of HFR spent fuel in 2000 (COVRA, central organisation for radioactive waste in the Netherlands) and 2001 (US Department of Energy Savannah River Site), further removal of spent fuel took place in 2003. In June a new MTR-2 container loaded with HFR spent fuel was transported to COVRA, where it was temporarily stored in the same building as the previous MTR-2 containers, prior to transfer to the HABOG facility for unloading and long-term storage of the spent fuel.

Construction of HABOG was completed in the second half of 2003. Queen Beatrix of the Netherlands officially opened the facility in September. In November another MTR-2 container with HFR spent fuel was shipped to COVRA. This container was directly transferred to HABOG, becoming the first spent fuel container to be unloaded in the new facility.

Visits and Visitors

Local Community Involvement

During 2003, the Institute for Energy pro-actively took steps to raise the awareness of the work performed in the HFR by extending a series of invitations to visit the Petten site to delegations of neighbouring "gemeenten" (municipalities). Each visit combined a series of short presentations on the role of the Institute, the HFR, its programmes and activities with a tour of the HFR facility. The series of visits started on Friday, January 17 with the visit of the Mayor of Zijpe and spanned the whole year, involving five neighbouring municipalities represented by their mayors and members of their respective councils (see Table 2). In addition, Mrs Gardelli, Director of the European School in Bergen, visited the facility on December 12.

Meetings and Seminars

In July, the JRC Working Group on Nuclear Activities (WGNA) met in Petten. The meeting focussed on Reactor and Nuclear Fuel Safety, the work programme content and evaluation.

Building on the success of 10 years of the JRC European Networks built in part around the HFR, a two-day international seminar was hosted on September 22-23 at JRC-IE on the topic "JRC European Networks on Structural Integrity of Safety-Related Components for Nuclear Power Plants". The goal of the Seminar was to establish a consensus on the future development of the European networking activities in the area of plant life management, and in particular structural integrity aspects, for the 6th Framework Programme and beyond.

On September 30 and October 01, the 9th Meeting of the JRC Decommissioning & Waste Management Expert Group took place in Petten.

On October 21-22, IE hosted a special Marie Curie event in the frame of a series of workshops aimed at raising the visibility of the Marie Curie Fellowships for Young Researchers. Some 75 Marie Curie Fellows from 14 different countries attended the workshop and visited the HFR facility as one of the guided tours.

Table 2 **Visits to HFR facility**

Date	Municipality	Mayor	Accompanying council members
January 17	Zijpe	Mrs A.M. van Apeldoorn-Pruijt	20
March 7	Bergen	Mr. L.Worm (deputy)	16
June 6	Langedijk	Mr. H.M.W.Ter Heegde	15
October 15	Harenkarspel	Mr. E. Huisman	14
October 31	Den Helder	MrJ.M. Staatsen	20

Other High-Level Political Visitors:

- Mr. J.A. Vijlbrief from the Dutch Ministry of Economic Affairs and Dutch member of the JRC Board of Governors visited the HFR on July 09
- R. Linkohr and G. Adam, Members of the European Parliament (MEPs) visited the Institute and HFR on October 14, in the frame of the inter-institutional dialogue with the European Parliament.
- On November 05, several important political visitors including Mr. P. Van Geel, Dutch Secretary of State for Housing, Regional Development and Environment (accompanied by 7 members of his ministry), the "Commisaris der Koningin" for North Holland Mr. H. Borghouts, and the Mayor of Gemeente Zijpe Mrs. A. Van Apeldoorn-Pruijt.

HFR: The Programmes

HFR as a Tool for European Programmes

EUROPEAN NETWORK AMES

The following activities have been carried out in HFR in the frame of the JRC Action Safety of Aging Components in Nuclear Power Plants (SAFELIFE) & the European Network Ageing Materials Evaluations and Studies (AMES)

PISA Irradiation

The scope of the Shared Cost Action PISA (Phosphorus Influence on Steel Ageing) is to measure, understand and model Phosphorus segregation at grain boundaries of steels and welds. In total, three irradiation campaigns were carried out in the LYRA rig at the HFR pool side facility; the last irradiation was successfully terminated in 2003. Important results were obtained supporting prediction of inter-granular fracture caused by phosphorus under the effect of irradiation. Typical PWR, VVER, MAGNOX materials were studied, namely ferritic steels, C-Mn plate, the IAEA reference PWR plate JRQ, a VVER 1000 base metal 15Kh2NMFA and a number of model alloys supplied by JRC-IE.

The LYRA-07 experiment for PISA is loaded with different specimens of the above-mentioned steels. The irradiation temperature is set to 285-290 °C for a fast fluence target of $\approx 5\cdot10^{22}$ $n\cdot m^{-2}$ (E>1 MeV). The irradiation of the third loading of the PISA project was successfully carried out within two HFR reactor cycles ending in October 2003. After irradiation, specimens are sent for testing to several project partners.

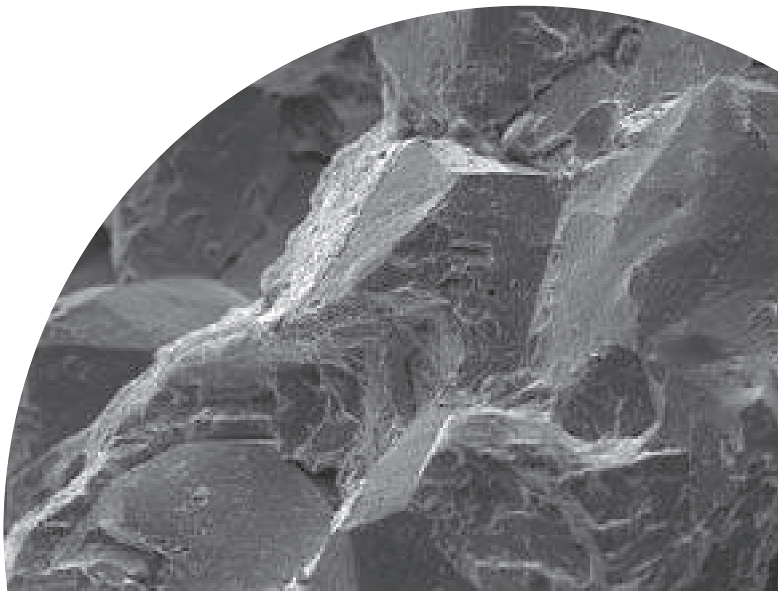
The PISA programme is establishing a database on the levels of phosphorus and carbon at grain boundaries as a function of steel type, specific heat treatment and irradiation conditions. Modelling activities at MPA Stuttgart and at the University of Liverpool have gained significant momentum. A progress that has already been made is the formulation of a physically-based, analytical expression for phosphorus segregation to grain boundaries under irradiation.

New LYRA Rig Construction

The existing LYRA rig is the key for the SAFELIFE-AMES irradiation programme and its replacement has to be considered and planned given that it has already carried out 8 successful irradiation campaigns (see Table 3). Hence, a new and improved LYRA irradiation rig was designed. Its commissioning is expected during 2004. The new rig will then be tested and used as a reserve for the existing one.

Table 3 **Irradiations in Lyra within AMES**

LYRA I	REFEREE - Nuclear Electric	190 °C for $11.5\cdot10^{22}$ $n\cdot m^{-2}$
LYRA II	RESQUE / REFEREE	255 °C for $8.17\cdot10^{22}$ $n\cdot m^{-2}$
LYRA III	MODEL ALLOYS	270 °C for $6.11\cdot10^{22}$ $n\cdot m^{-2}$
LYRA IV	PISA I	200 °C for $5\cdot10^{22}$ $n\cdot m^{-2}$
LYRA V	FRAME	290 °C for $20\cdot10^{22}$ $n\cdot m^{-2}$
LYRA VI	PISA II	290 °C for $5\cdot10^{22}$ $n\cdot m^{-2}$
LYRA VII	PISA II	290 °C for $18\cdot10^{22}$ $n\cdot m^{-2}$



HIGH TEMPERATURE REACTOR TECHNOLOGY NETWORK - HTR-TN

Objectives:

In response to growing interest in HTRs worldwide and on the initiative of JRC, HTR-TN was established in April 2000. The main objective is to recover, maintain and develop HTR technology from Europe and elsewhere with the ultimate goal of developing advanced HTR technologies. These activities support industry in the design of power plants complying with the various stringent requirements of sustainability, economic competitiveness, safety, waste production and social acceptability.

Since its creation, HTR-TN performed very successfully and contributed to an efficient EU-wide exchange including the organization of specialist meetings, seminars and conferences. Further information can be found at http://www.jrc.nl/htr-tn.

Achievements in 2003:

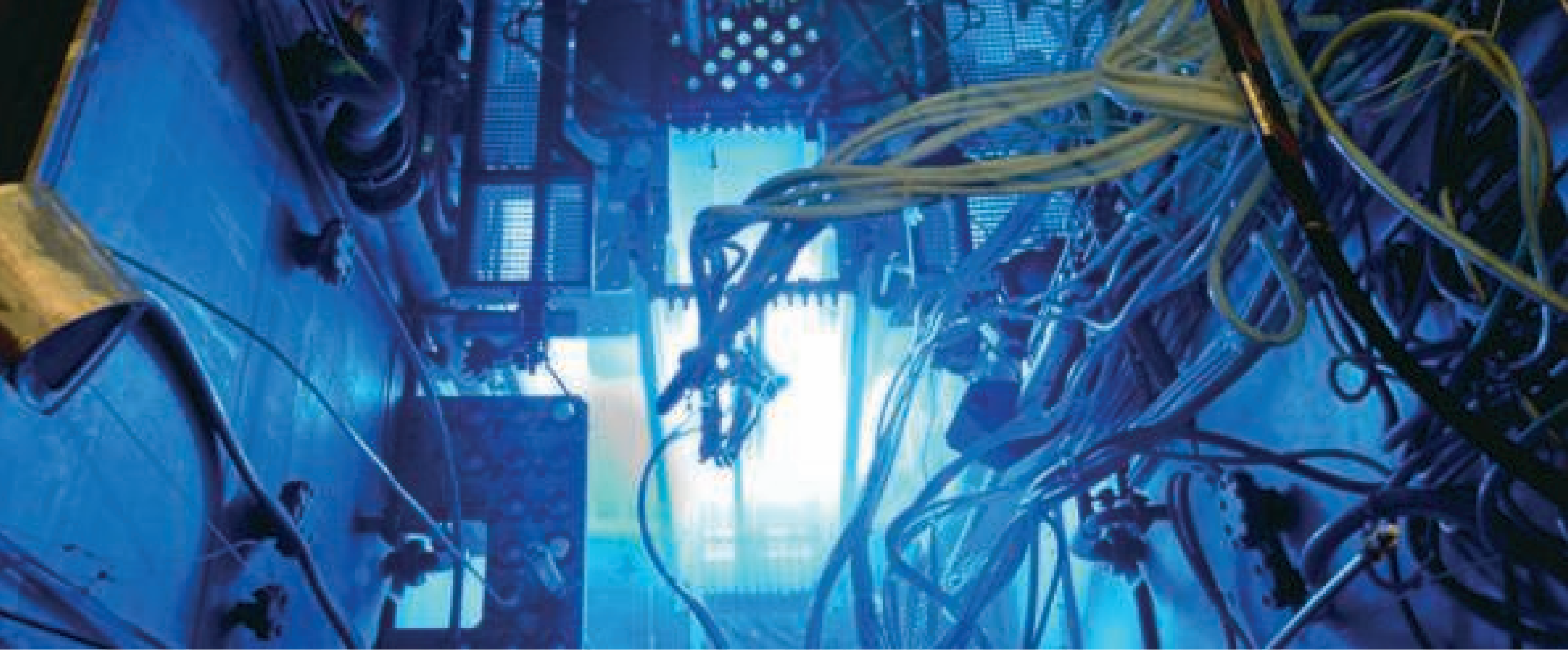
JRC-IE continued operating this network, contributed to the coordination of related projects and provided technical input through both institutional and competitive actions.

HTR-TN is currently driven by 21 partners and observers from research and industry; one partner and one observer joined in 2003.

During two Steering Committee meetings and five Executive Task Group 1 meetings, the network partners efficiently co-ordinated and supervised the execution of HTR-related R&D projects within the EU's 5th Framework Programme and prepared a new consistent Integrated Project (V/HTR-IP) for the 6th Framework Programme to be submitted for approval in April 2004. Consequently, the split into several thematic projects will gradually disappear over the next years thus enabling a simplification of the network structure. HTR-TN provided significant input to the preparation of proposals for three related integrated projects, namely EXTREMAT dealing with material issues in extreme conditions, GCR-MINWASTE focusing on the minimization of waste from gas-cooled reactors and INNO-HYP for the development of massive hydrogen production technologies, for which a high temperature reactor is a promising option.

HTR-TN has also followed-up on several ongoing International Science and Technology Centre (ISTC) projects and supported a new ISTC project proposal from the Russian Federation. Several international contacts, in particular in China and Japan were maintained to benefit from existing cooperation agreements on a variety of technical matters.

HTR-TN has gained further momentum and visibility through the Euratom participation in the Generation IV International Forum (GIF) in July 2003: much of the network's technical achievements have been and will be used as Euratom input to the related GIF projects. Several HTR-TN partners were appointed members of high-level GIF bodies and of GIF project review committees. The leading company in HTR-TN, Framatome-ANP, is expected to tender for the construction of a VHTR demonstration plant in the USA.



EUROPEAN NETWORK ON NEUTRON TECHNIQUES STANDARDISATION FOR STRUCTURAL INTEGRITY - NET

The European Network NET was launched in May 2002 with 35 participating organizations from 11 European countries and South Korea. Its main objective is to support progress toward improved performance and safety of European energy production systems. To this end three task-groups (TG) have been established by the NET steering committee. The present report summarises work performed in 2003 in NET-related activities.

NET Workprogramme Development and Execution

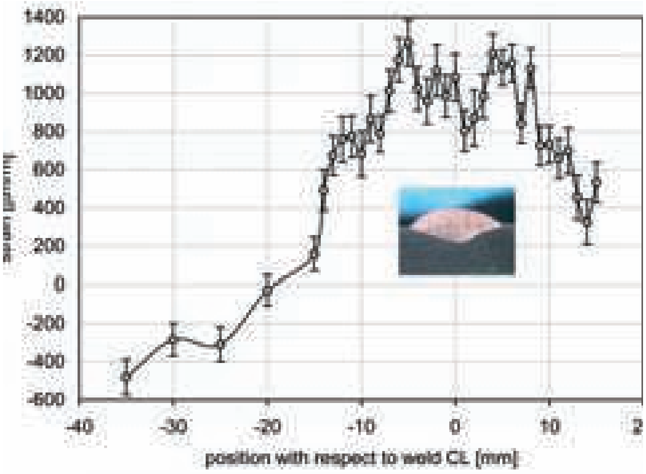
TG1 – Single Bead on Plate Weld

Four specimens have been welded by automated procedure for non-destructive and destructive residual stress measurements. During welding deposition, temperature and strain data have been recorded for calibration of the numerical models of the thermal and stress analyses. Additional weld and parent material has been provided for materials characterisation.

In 2003 materials data have been obtained for both parent and weld materials at various temperatures. The residual stress measurement round robin campaign has been initiated; three neutron facilities and one X-ray laboratory have already performed the investigations.

A sample of data obtained at the HFR is shown in Figure 5. The problem definition for the numerical round robin is well underway and will be finalized by June 2004.

Figure 5



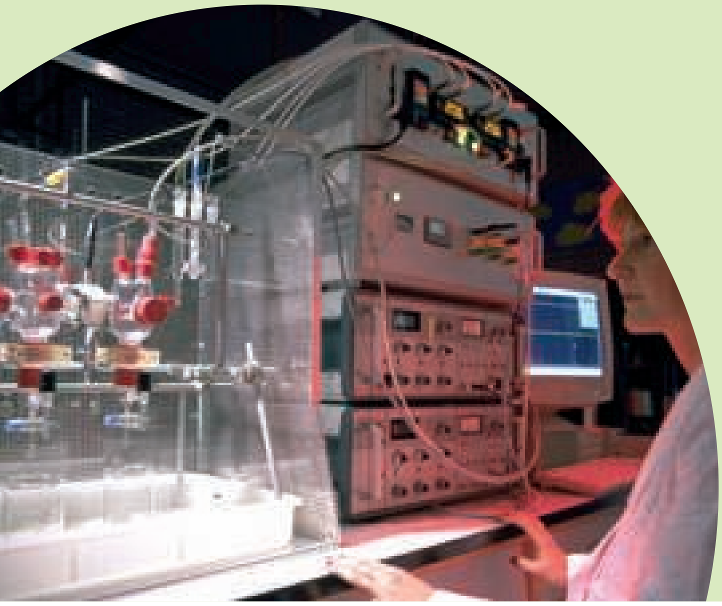
Transverse distribution of longitudinal strains in single weld bead on a stee plate measured at HFR/CPSDF (NET-TG1 round robin)

TG2 – Assessment of Post-Weld Stress Relief Heat Treatments

After thorough discussion of the work programme of TG2 at the steering committee meeting in June 2003 in Berlin, specimens have been manufactured in accordance with the decisions taken at that meeting and subjected to post-weld heat treatment at various temperatures. Experimental round robins for stress analysis will commence in 2004. The problem definition for the numerical analyses is underway.

TG3 – Assessment of Effects of Thermal Ageing to Cast Duplex Stainless Steels

Numerous specimens with varying degrees of thermal ageing have been procured for the work within this TG. To this end measurements by small-angle-neutron-scattering have been obtained at three neutron facilities. Analysis of the data is ongoing.



Standardization Activities

Between 2001 and 2003, the joint ISO & CEN / TC138 Ad-Hoc-Group 7 (AHG7) has drafted an international Technical Specification on a "Standard Test Method for Determining Residual Stresses by Neutron Diffraction". In the course of 2003 AHG7 was convened three times by the NET manager. The final draft of the document has been submitted in October 2003 to the CEN & ISO Committees on Non-Destructive Testing for the Two-Months-Inquiry. Adoption of the international Technical Specification by CEN and ISO is expected in the course of 2004.

Other Activities

The NET team manages and participates in a computational round robin aiming at the development of advanced numerical techniques for the prediction of residual stress in multi-pass Dissimilar Metal Welds (DMWs), by detailed simulation (3D, real time, bead by bead) of the welding process Activity related to Network for Evaluation of Structural Components (NESC). The performance of models will be verified based on neutron diffraction data.

NET Related Shared Cost Activities

ADIMEW
Assessment of aged piping DMW integrity; completed

ENPOWER
Assessment of novel methods for weld repair; ongoing

HITHEX
Development of advanced Ceramic Matrix Composites (CMC) for ultra High Temperature (HT) heat exchangers; ongoing

INTERWELD
Investigation of irradiation induced material changes in the Heat affected zones (HAZ) of Reactor Pressure Vessel (RPV) welded internals; ongoing

HFR: The Programmes

HFR as a Tool for Medical Applications

BORON NEUTRON CAPTURE THERAPY - BNCT

BNCT is a tumour-targeting form of radiotherapy under development. It can currently only be performed at nuclear research reactors, such as the HFR. BNCT is based on the ability of the isotope ^{10}B to capture thermal neutrons to produce two highly energetic particles, namely a helium (α) particle and a lithium ion. When these particles are produced selectively in tumour cells, they can, in principle, destroy the cancer cells whilst sparing the surrounding healthy tissue, thus opening an effective improved modality for cancer treatment.

The first clinical trial on BNCT in Europe was started at the HFR in October 1997 in close collaboration with the University of Essen, which provided the clinician holding the medical responsibility. The clinical trials are supported through Shared Cost Actions (SCA) from DG RTD whilst beam research and facility maintenance / upgrade were supported by the Institutional programme.

Since 1997, other reactor centres in Europe have also started BNCT trials, namely: at the FiR-1 reactor Otaniemi (Finland), the R2-0 reactor Studsvik (Sweden), the LVR-15 reactor Rez (Czech Republic) and the TRIGA MkII reactor Pavia (Italy). BNCT trials continue elsewhere in the USA and Japan. A new member to the list was added in 2003, with the start of clinical trials at the RA-6 reactor Bariloche (Argentina).

Competitive Activities

Clinical Trial of BNCT for Glioblastoma (EORTC Protocol 11961)

The last patient in this trial, namely patient number 6 in cohort 4, was treated in 2002. General conclusions are that no dose limiting effects have been observed and, in comparison with alternative treatments, life expectancy is no worse and quality of life is enhanced. Based on recent analyses, a clinical decision will be taken in 2004, as to whether to start a 5th cohort or not.

Other Clinical Trials

Under the Fifth Framework Programme, three clinical trials received funding in "Quality of Life and Management of Living Resources", contract no. QLK3-CT-1999-01067.

- EORTC Protocol 11001: ^{10}B-uptake in different tumours using the boron compounds BSH and BPA

  This trial looks into the possible uptake of boron into different tumours, including thyroid cancer, head and neck cancer and liver metastases. The latter, if successful in terms of significant uptake of boron in the cancerous cells, would be one of the major steps towards performing extra-corporal liver treatment by BNCT at the HFR, as demonstrated recently at the University of Pavia's TRIGA reactor.
  With respect to the protocol, 6 patients were entered into the study in Essen, where patients received either BSH or BPA. During surgery to remove the respective tumour, tissue samples were taken from the tumour and surrounding healthy tissue. Subsequent boron concentrations were measured in over 4000 samples at HFR's HB7 facility, using Prompt Gamma Ray Spectroscopy.
  With respect to the possibility to treat liver cancer at the HFR, calculations have been performed by JRC using the neutronics code MCNP, whilst several meetings were held in the Netherlands, Germany and Italy between the surgeons from Pavia and Essen, and the physicists from Pavia and Petten.

- EORTC Protocol 11011: Early phase II study on BNCT in metastatic malignant melanoma using the boron carrier BPA

  The second trial will treat brain metastases of malignant melanoma using the boron compound, BPA. This last trial will be prepared in common with the EORTC BNCT Group, the EORTC Melanoma Cooperative Group and the Harvard/MIT BNCT group in the USA.
  The protocol was approved by the EORTC towards the end of 2003 but a recent amendment to the protocol has meant that it will require new approval (expected early 2004). As part of the trial, the treatment planning program NCTPlan (as used by the MIT/Harvard BNCT Group) will be used. As such, during 2003, an extensive validation exercise was performed, which included a thorough re-calculation of the source description of the radiation beam, involving a variety of dosimetry measurements at the HFR using ionisation chambers, pn-diodes and activation foils. Most of this work was performed by Cecile Wojnecki (Post-Doctoral grantholder), in collaboration with Essen and NRG physicists.
  In anticipation of the start up of this trial at the end of 2003, a dummy exercise, being part of the approval procedure, was performed. This involved the simulation of a patient treatment, as well as, preparation and production of all the associated paperwork. Furthermore, new Standard Operating Procedures (SOP) were written, of which there are currently over 60 available.

- EORTC Protocol 11002: Phase I real-time pharmacokinetically guided BSH escalation study of boron neutron capture therapy with glioblastoma patients at the Petten irradiation facility

  This trial has the objective to study the optimisation of the delivery of the boronated drug (BSH) in brain tumours, by means of doubling the boron concentration in blood, thereby doubling the boron dose in the tumour, which would require only half the irradiation time to achieve similar doses to those applied in trial 11961 and likewise, only giving half the irradiation dose to the healthy tissue.
  Due to the workload involved in liver treatment (and related protocol 11001) and in preparation for protocol 11011, this trial was given a lower priority; hence, little progress was achieved during 2003.

Participating hospitals and institutes in the above trials are the Universities of Münster, Reims, Essen, VU Amsterdam, Nice, Graz and München, as well as JRC and NRG. The medical responsibility falls under the Study Coordinator, Prof. dr. med. Wolfgang Sauerwein, and Clinical Coordinator, Dr. Andrea Wittig, of the Universitätsklinikum in Essen.

Missions, Symposia and Visitors

Numerous missions to discuss collaborative actions, attend progress meetings, conferences and symposia were part and parcel of the BNCT group's activities. Highlights included:

- Presentation entitled "Is there an optimal beam for BNCT Review of BNCT facilities and Quality Assurance Aspects" at the EORTC's annual International Meeting on Translational Radiation Oncology held in Lugano
- IE representative at the INRNE Sofia Bulgaria – JRC Information Days including a presentation entitled "Boron Neutron Capture Therapy (BNCT) and Radioisotope Production Activities at the High Flux Reactor Petten"
- Progress meeting with the NAS partners at Kaposvar University Hungary
- Discussions with the liver surgeons in Pavia Italy
- Keynote lecture entitled "Medical Applications at a Nuclear Research Reactor" at the Marie Curie Workshop held in Petten
- Attendance and presentations entitled "BNCT News from Elsewhere around the World" in Pisa at the Annual Meeting of the EORTC BNCT Group, an International Workshop on "BNCT: State of the Art" and the 3rd Meeting of the BNCT Young Members
- Visit for one week as part of the Essen/Petten and MIT/Boston collaboration programme of Dr. Stead Kiger, to assist and advise on treatment planning

Other Competitive Shared Cost Actions (SCA)

"A Code of Practice for Dosimetry for BNCT in Europe" (contract no. SMT4-CT98- 2145)

The final reports from this action were completed at the end of 2003[1]. Contributions and work performed by JRC form part of the reports. The final coordination was performed by NRG. The report on "Recommendations" will be presented to the International Commission on Radiation Units and Measurements (ICRU) as a possible publication under their auspices. The work performed is within one of the fields for standardisation in BNCT worldwide.

JRC Institutional Programme on BNCT

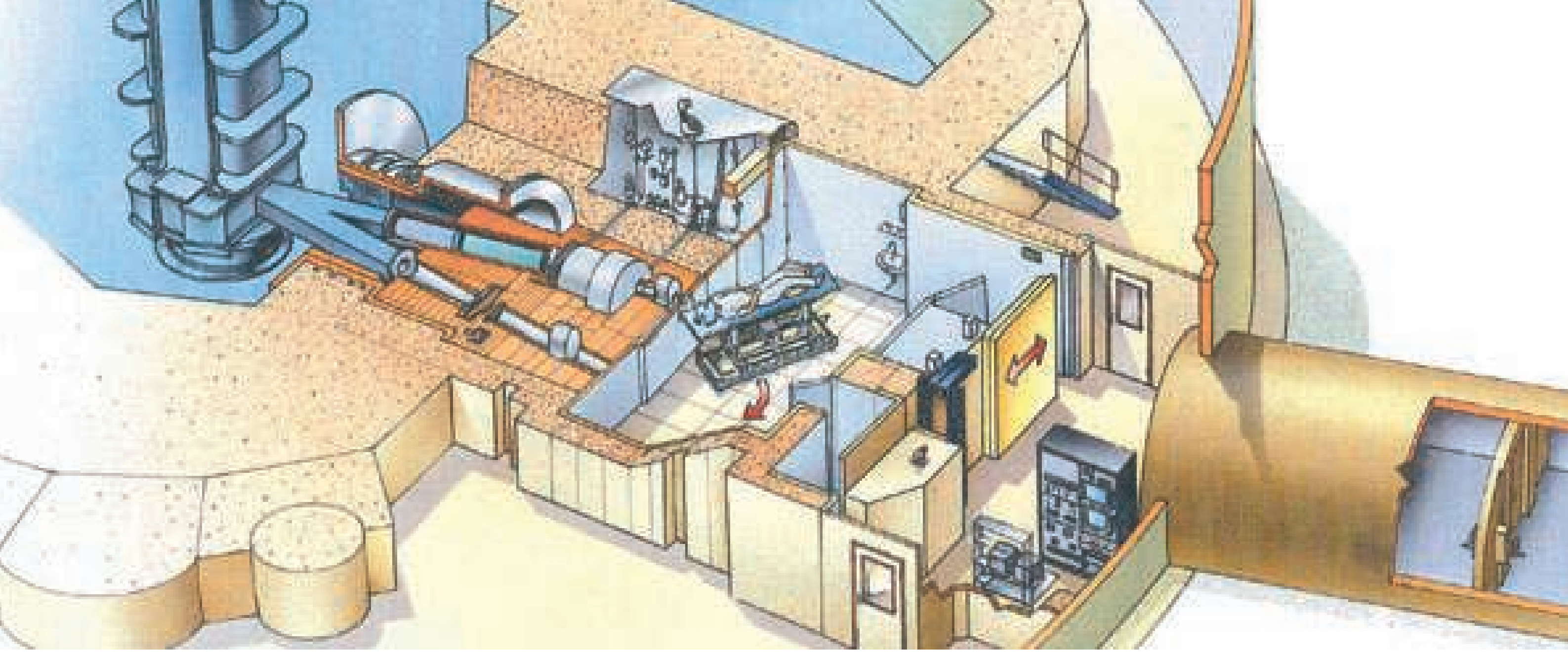
The research and development activities of BNCT at Petten are supported in the JRC's Institutional Research programme. The four-year programme has 4 prime objectives:

- Development and maintenance of existing facility
- Support to present trials and new trials
- Treatment planning activities
- Research activities, including: neutron beam improvement and design; application to different types of tumours; application to non-cancerous diseases; development of patient positioning devices; improvement of dosimetry; investigation of boron detection techniques; and development of microdosimetry

The facility has a maintenance and improvement programme, which is strictly followed. Within this topic, approval to utilise the facility for patient treatment and experimental work, ran out during 2003. As such, a new Design and Safety Report presenting the updates and improvements made during the last 5 years, as well as an extra Chapter on Operating Experience, was prepared and presented to the Reactor Safety Committee.

Under dosimetry, the main activities have been described above under EORTC Protocol 11011. A feasibility study for the treatment of other cancers has also been discussed (liver) in the same section.

[1] "Code of Practice BNCT Dosimetry. Synthesis Report, 21425/03.55341, NRG Petten
"Code of Practice BNCT Dosimetry. Final Report", 21425/03.55344 rev.1/C, NRG Petten
"Technology Implementation Plan. A Framework for the further development and exploitation of the results of EC RTD Projects", 21425/03.55418/C, NRG Petten
"Recommendations for the Dosimetry of Boron Neutron Capture Therapy (BNCT)", 1425/03.55339/C, NRG Petten



EUROPEAN NETWORK FOR MEDICAL RADIO-ISOTOPES AND BEAM RESEARCH - EMIR

Nuclear medicine and radiotherapy make a vital contribution to the diagnosis and treatment of major diseases. This role is likely to expand with new developments including availability of new medical isotopes. Building on HFR's position in the medical radioisotope production field, EMIR (European Network for Medical Radioisotopes and Beam Research) was initiated in 2001 by the JRC-IE to identify and solve difficulties that constrain nuclear medicine and radiotherapy development in Europe and facilitate closer interdisciplinary collaboration. Participating organisations include the main European associations of medical radiation specialists, radiopharmaceutical radioisotope producers, nuclear research reactor institutions, research organisations and the JRC. The steering committee established task groups focusing on eight key areas for development.

Further to the departure of the Project Leader in early 2002, the project functioned on a low level until mid-2003. At that point, work focussed in 2003 on preparing for the organisation of the 5th International Conference on Isotopes (5 ICI) and starting the radioisotope survey. In addition, a reflection took place internally on the most optimal approach to restart EMIR activities given the level of resources.

EMIR's task group on "Radioisotope Availability" decided in 2002 that a Survey on Radioisotopes was needed to complement and update information available from past surveys. The present survey should concentrate on isotopes for therapy, research, availability, capacity and identification of areas in Europe where shortages occur. On this topic, activities in 2003 focused on selecting a sub-contractor and defining the contract in a way allowing work to be performed with resources available. The contract was signed at the end of 2003 and work started with Ariadne Advice & Consultancy who proposed a set of questionnaires and an approach for having the survey ready by early 2005.

ICI is an international conference series focussing on the broad issue of isotopes at an international level, organised by an ad hoc committee every other year, independently from any formal body or organisation. During 4 ICI, EMIR made a successful bid to jointly host 5 ICI with ESTRO (European Society on Therapeutic Radiology and Oncology). 5 ICI will take place in April 2005 in Brussels and the number of foreseen attendants is around 350 people. Although most participants are expected to come from the scientific community to ensure the quality of the scientific programme, special effort is made to attract policy-makers at all levels to promote the issue of radioisotopes, consistently with EMIR's original mission. The success of 5 ICI, as well as work carried out for achieving this result, will be extremely useful if JRC is to decide in 2005 to maintain or expand the activities of EMIR.

Work on that matter in 2003 focussed on:

- Setting-up 5 ICI's IMSC (International Monitoring and Steering Committee), carefully ensuring international and industrial representation. The kick-off meeting took place in early December 2003.
- Planning the event (including IMSC approval)
- Making preliminary informal contacts at the level of policy-makers to enhance the awareness on the issue.
- Preparing the First Announcement text and layout, which have been approved with minor changes and which will be issued in early 2004.
- Gathering and centralising the contacts databases for the mailings; at the end of 2003, the contact database included more than 7000 contacts which will be useful, not only for 5 ICI but also for EMIR in the future
- Selecting and formally requesting the venue: EC's Charlemagne Building in Brussels

Simultaneously, a prioritisation exercise was carried out to assess how to combine EMIR's activities with its resource level. The prioritisation exercise led to the internal decision to re-orient EMIR activities along the following lines: until mid 2005, EMIR and its resources will be devoted to executing past commitments and keeping EMIR activities restricted to a Common Interest Group[1]. At that date and depending on results achieved, interest from industrial players and needs of the policy-makers, a strategic decision will be taken within JRC on the future of EMIR activities.

[1] A Common Interest Group is a network with activities restricted to information and discussion platform, as opposed to a fully-fledged network which, not only includes the above activities but also aims at co-ordinating R&D projects and setting-up / maintaining a reference laboratory.

MEDICAL RADIOISOTOPE PRODUCTION

The HFR once again confirmed its position as the most important reactor in Europe for the production of Medical and Industrial Isotopes. 2003 was a record year with an overall growth rate of approximately 20% for these critical materials. Growth was recorded in all areas of activity, but the major part of the growth was in the production of medical isotopes.

Both areas in the medical application of isotopes grew: diagnosis of disease such as cardiac failure and cancer, as well as therapeutic treatment of various disease states, in particular cancer, arthritis and in palliative (pain reduction) therapy. The world market need for these important medical procedures continues to grow steadily, especially for the related application Positron Emission Tomography (PET) that utilises short half-life isotopes produced in specialist cyclotron units. Conventional nuclear medicine and PET together continue to grow as this medical speciality broadens its areas of application as new carrier molecules are developed and introduced.

New development areas in nuclear medicine diagnosis include the identification and measurement of apoptosis, the process of so-called programmed cell death. Apoptosis is a natural phenomenon in healthy tissue, but has a special role in certain disease states and importantly in the reaction of diseased tissue to various therapies. Being able to visualise and track the mechanism of apoptosis prior and during therapy will adjust the clinical management of a number of important diseases.

In the area of medical therapy, the development of new targeting molecules continues to push forward the boundaries of this important application. Increased specificity and biological activity allows higher therapeutic doses to be given while reducing the risks of unwanted side effects. New data presented at the European Association of Nuclear Medicine (EANM) Annual Congress 2003 held in Amsterdam demonstrated that this research is moving forward quickly and with encouraging results.

Isotopes produced in the HFR in 2003 included an important number of irradiations of new potential products. These included the production of previously little used isotopes for initial clinical investigations as well as the production of some more well known isotopes in a number of new and novel formats. The continued development of new isotopes and existing isotopes in new forms and for new applications is an important seeding ground for the new technical developments that lead finally to clinical breakthroughs. The number and range of new products under investigation during 2003 was most encouraging.

HFR: The Programmes

HFR as a Tool for Fission Reactor Technology

In 2003, several activities were performed at HFR in relation to fission R&D:

- Fuel irradiation for testing high temperatures and burn-ups, structural material out-of pile tests and data management for HTR applications
- Irradiation of innovative fuel for improvement of fuel cycles in Light Water Reactors (LWR), in particular with the objective of exploring the thorium cycle and of closing the uranium fuel cycle through the incineration of plutonium and minor actinides
- Testing of candidate window materials for Accelerator Driven Systems (ADS)

HIGH TEMPERATURE REACTOR R&D IN THE HFR

In the last few years, two new test reactors were built in Japan (High Temperature Test Reactor) and China (HTR-10). Significant progress was achieved in terms of fuel design and fuel cycle, structural materials, graphite and technology, and numerous other reactor concepts were developed worldwide. These use either compact fuel (US, Russia: Gas Turbine - Modular Helium Reactor, initially designed for degrading weapons-grade plutonium) or pebble fuel (South Africa: Pebble Bed Modular Reactor). Either concept can rely on strong similarities with the other for the power plant technology. Feasibility studies for several advanced conceptual designs are conducted in a number of research institutes and universities worldwide to optimise aspects such as safety, performance, sustainable use of fuel, minimization of waste or economy.

In Europe, significant efforts are dedicated to the recovery of the knowledge on the once fully mastered fuel fabrication and on the qualification of materials. The JRC-IE contribution is fully integrated in these EU projects through technical contributions in the fields of:

- Fuel & material irradiations
- Out-of-pile testing
- Data management

The strong on-site synergies between NRG and JRC installations are used and the long-term expertise in advanced materials development and irradiation testing in the HFR is maintained and constantly improved.

HTR Fuel Irradiations

Objectives

Three irradiation tests of low-enriched uranium fuel types in the HFR are under preparation to determine their limits with respect to radioactive fission product release with increasing burn-up and at increased fuel temperature. Pre- and post-irradiation examinations will be conducted to test the safety relevant quality and temperature limits of the irradiated fuel. The results of these experiments are expected to provide orientations for further improvement of fuel technology.

- HFR-EU1: Irradiation of pebble type fuel produced by NUKEM (Germany) and by the Institute of Nuclear Energy Technology (INET, China), with on-line fission gas release monitoring. Target burn-up is 21% Fissionable Heavy Metal Atoms (FIMA) for NUKEM pebbles and 16% FIMA for INET pebbles.
- HFR-EU1bis: Irradiation of pebble type fuel produced by NUKEM at increased temperature with simplified fission gas monitoring. Target burn-up is 16% FIMA.
- HFR-EU2: Irradiation of compact type fuel produced by General Atomics (USA) with on-line fission gas release monitoring. Target burn-up is 10% FIMA.

Achievements in 2003

For all three irradiation tests, the fabrication and assembly phase has started and was completed to different degrees. The assembly of the mechanical parts of the gas circuits for HFR-EU1 and HFR-EU2 was completed. For HFR-EU1bis, new thermal analyses and design modifications were performed to further increase the irradiation temperature and to make this test immediately relevant for the Generation IV system VHTR.

In the future, further irradiation tests of advanced MOX, plutonium or thorium fuel as well as specific fuel for the incineration of nuclear waste in gas-cooled reactors may be envisaged.

HTR: Structural Material Out-of Pile Tests

Objectives

These tests aim at investigating the out-of-pile properties of high-temperature materials to be used for an HTR, such as pressure vessel material, control rods or ancillary components. Later on, specimens of candidate materials will be irradiated at temperatures typical of their envisaged use in an HTR. Post-irradiation testing will focus on determining the mechanical properties.

Achievements in 2003

Significant out-of-pile material testing activities were prepared for the conventional part of an HTR power plant, in particular for high temperature helium turbines and helium-helium heat exchangers. The materials to be tested include metallic super-alloys or ceramic and fibre composite materials. The exposure in particular of the metals for longer periods to high temperatures and different helium chemistries may carburise or decarburise them, thus altering their mechanical properties which has to be quantified. The required installations were commissioned and the production of test specimens has started. For the future, irradiations of improved graphite carbon-based composites and reflector materials as well as alternative matrix materials and neutron poisons may be envisaged.

Development of an HTR Fuel Database

Objectives

Numerous irradiation tests of earlier HTR fuel types were already conducted some 30 years ago in the HFR and elsewhere. In this context, a database application (Fuel-DB) for experimental results was developed in order to recover, maintain and utilise a maximum of HTR fuel related information.

Achievements in 2003

The database structure was finalized in 2003 and fed with data from the various project partners. Due to the volume of the documents to be included and analysed, this feeding process is expected to continue for several years.
Future work on the HTR fuel database will concern essentially the maintenance and minor upgrades as required by the project.

FUEL IRRADIATIONS FOR THE IMPROVEMENT OF FUEL CYCLES

MICROMOX

Because of the intrinsic nature of MOX fuels – $(U,Pu)O_2$ – such as their neutronic properties, high burn-ups are technically more difficult to achieve than with standard UO_2 fuel elements. This is due to the large amount of fission gas that is produced and released, thus building-up higher internal rod pressure compared to conventional UO_2 fuels. These higher pressures reduce the experimental margins relative to safety criteria and lead to a strict burn-up limitation by the safety authorities for this type of fuel. Reduction of gas release or rod internal pressure is however possible by either increasing dramatically the free rod volume, which is actually not compatible with the current fuel and reactor design or by using a new generation of fuels with improved capabilities of gas retention.

Funded by the European Commission as a 5th Framework Programme SCA, the MICROMOX project in which BNFL, PSI, Belgonucléaire, NRG, JRC-ITU and JRC-IE participate, is aimed at studying various MOX fuels with enhanced capability of fission gas retention. Four different fuels are considered:

- Homogeneous MOX fuel with large grain size (40 µm), that is expected to exhibit a high gas retention capability,
- Homogeneous MOX fuel with standard grain size (20 µm),
- Heterogeneous MOX fuel fabricated with the Micronized Master Blend (MIMAS) process showing at micron size level irregular Pu distributions,
- A UO_2 fuel with standard grain size to be used as reference material.

The fuels are irradiated by pairs of rodlets; one rodlet of each pair is instrumented with a central thermocouple and a pressure transducer to allow for both temperature and pressure to be monitored during the irradiation.
In terms of irradiation, the objective of the MICROMOX project is to achieve a burn-up close to 60 GWd/tM after two years and then, at the end, to test the fuels in transient conditions.

Achievements in 2003

The Micromox assembly comprised many delicate operations in a glove box such as the mounting of the instrumented capsules and the sodium filling of the sample holder which were completed. The irradiation started on 23 October 2003. Because of the complex design of the experiment and its numerous instrumentation (28 thermocouples, 4 neutron flux detectors, 4 pressure transducers), the reactor power was slowly increased to 45 MW whilst the instrumentation reading was thoroughly followed. The start-up was a complete success and the experimental temperatures and pressures were as calculated in the Design and Safety Report.

THORIUM-CYCLE

The use of Thorium-based materials as nuclear fuel element offers an interesting option for waste reduction, both at the front-end and at the back-end of the cycle: at the front-end because thorium mining produces less waste than uranium mining and at the back-end because less waste is produced during irradiation than with conventional UO_2 fuels. Furthermore, very high consumption rates can be achieved when Th/Pu fuel elements are used.
The general objective of the Thorium-cycle experiment is to investigate the behaviour of this type of material at high burn-ups and to extract fundamental data from the Post Irradiation Examination that will be performed at NRG.
The Thorium-cycle experiment comprises four different capsules loaded with different thoria-based materials (Table 3) and instrumented with central thermocouples. Similarly to the Micromox experiment, the capsules are filled with bath for thermal bonding.

Table 3 **Loading of the Thorium Cycle Experiment**

Sample n°	Material	Fissile content
1	ThO_2	
2	UO_2	^{235}U = 11% of tot. U
3	$(U_{0.9}Pu_{0.1})O_2$	$^{239}Pu+^{241}Pu$ = 65% of tot. Pu
4	$(Th_{0.89}Pu_{0.11})O_2$	$^{239}Pu+^{241}Pu$ = 65% of tot. Pu

Achievements in 2003

In February 2003 the Thorium-cycle experiment completed 14 HFR cycles out of 25 when a sodium leak was suspected. The experiment was immediately withdrawn from the core and a complete investigation was started involving neutron-radiographic inspections and Finite Element Model (FEM) calculations. As the effect proved to be innocuous, the irradiation was resumed on 23 October 2003, together with Micromox in position H8 of the core. The end of the irradiation is scheduled for September 2004.

HELIOS

The Helios experiment is in its preparation stage and is expected to be funded through a 6th Framework Programme SCA. It consists in irradiating americium in various inert materials. This experiment follows the previous irradiations that have been performed since 1992 in the HFR for the transmutation of long-lived fission products and minor actinides in the frame of nuclear waste management. The start of the irradiation is foreseen for 2006.

Achievements in 2003
2003 was dedicated to the pre-design of this new experiment in collaboration with our scientific partners (CEA, NRG, JRC-ITU, BNFL, EdF).

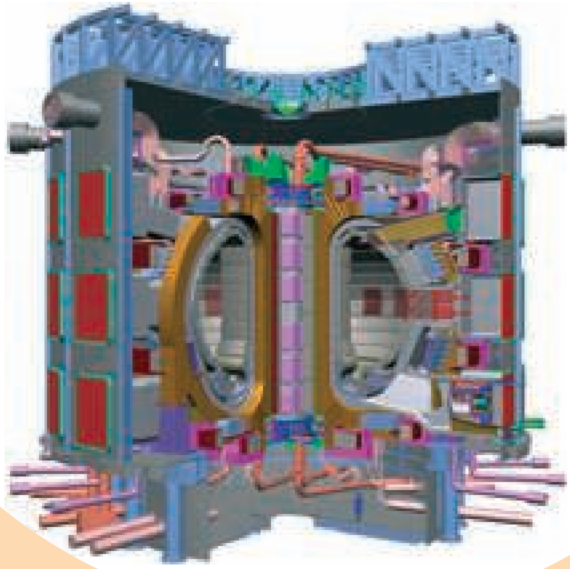
TRABANT

The first phase of this experiment, sponsored by FZK and JRC-ITU Karlsruhe, in which two mixed oxide fuel pins with a high Pu (40-45%) content and with the aim to assess the irradiation behaviour of such fuel pins up to medium burn-up, was completed in 2002.
The second phase, in which a third fuel pin, composed of 2 separate fuel pins, one on top of the other, both containing 0.9 g/cm3 of plutonium, incorporated into an yttria-stabilised zirconia phase, $(Zr,Y,Pu)O_2$-x, with one composite fuel type mixed with stainless steel powder acting as the fuel matrix, was planned to start during 2003.
However, due to delays in the manufacturing process as well as approval of the new Design and Safety Report, the second phase could not be started during 2003. A start in early 2004 is now anticipated. The irradiation will then continue for another 9 reactor cycles.

CASHIR (ADS)

The irradiation project CASHIR is carried out to test candidate window materials for ADS. The ADS window (interface between a high energy proton beam and a liquid heavy metal target for the generation of spallation neutrons) operates under extreme conditions with dose rates up to 100 dpa/year (displacement per atom/year) and high thermal stresses. The aim of this project was the experimental simulation of irradiation effects. The spectrum effects on the development of the microstructure evaluation, hardening and possible changes in fracture mechanisms and hence mechanical properties of ferritic-martensitic steels were investigated for the relevant neutron irradiation conditions. Moreover, the experiment addresses the influence of helium generated in the ferritic-martensitic steel.

The experiment comprises a cadmium shield to reduce the thermal fluence rate in the steel samples to about 2-7% of its unperturbed value. The original irradiation dose level target that had been set was 4-6 dpa. The specimens (84 mini charpy and 24 tensile) are made of EM10-ADS and BS-9Cr2WVTa and are irradiated at 250°C in liquid sodium.
The irradiation started in May 2001 and was, with the exception of a few interruptions imposed by reactor operation and minor technical incidents, continued throughout 2003. The irradiation will be finished in May 2004.



HFR: The Programmes

HFR as a Tool for Fusion Reactor Technology

Effort for the development of electricity generation from fusion started in the middle of the last century and aims at achieving industrial production of energy from fusion power plants in the middle of the 21st century. At the end of the 20th century the Joint European Torus (JET) experiment could produce tens of Megawatts during a short period of time. That amount of energy produced is tens of magnitude superior to results achieved through plasma experiments in the fifties. The next step for production of energy from fusion is the International Thermonuclear Experimental Reactor (ITER), which, using deuterium and tritium as fuel, is designed to produce 500 thermal Megawatts during pulses lasting at least 1000 seconds and expected to operate in the next decade.

To carry out the European effort on fusion technology development, national research centres have joined forces in the European Fusion Development Agreement (EFDA), which, along with Japanese and American partners supports ITER; Chinese and South Korean partners are expected to join the initiative in the near future. The important involvement of the EU (with a joint French-Spanish candidacy to host the reactor) in the ITER initiative is also reflected in the HFR programme: HFR's high versatility provides it with extremely relevant R&D capabilities for fusion power plant technology. The HFR contributes to the fusion technology development by providing experimental results utilising the HFR as the neutron source and the hot cell laboratory to perform post-irradiation testing. The main areas of interest are the ITER vacuum vessel, the blanket development and the development of the reduced activation materials: chromium steel and ceramic composites.

The irradiation of the blanket sections with lithium ceramic pebbles is not limited to post-irradiation testing, but it includes the complete in-pile instrumentation for the operation of the helium extraction circuits of the module. In this way the HFR provides valuable in-pile process data for blanket operations in ITER.

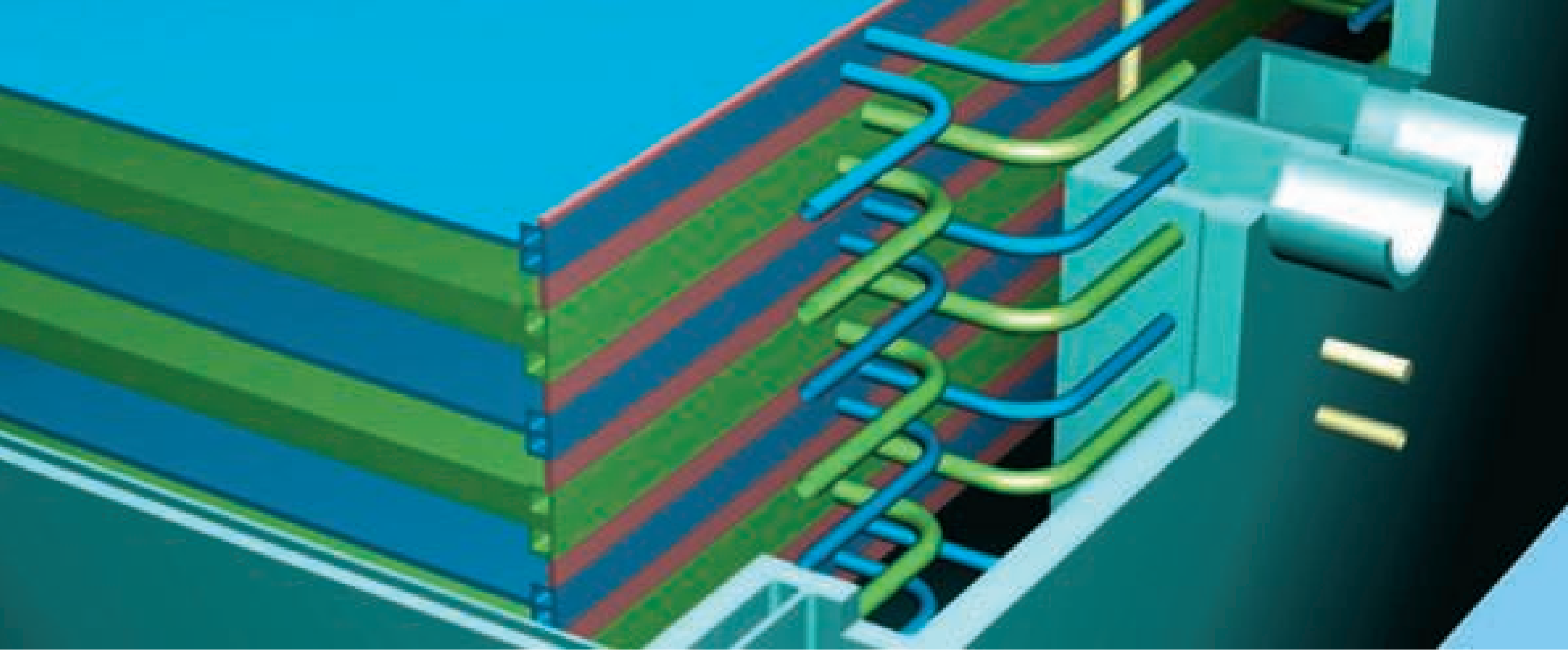
ITER Vacuum Vessel

It is anticipated that the segments of the vacuum vessel wall of ITER will have to be replaced or repaired. Welding of fresh segments to neutron-irradiated segments is then unavoidable. Post-irradiation welding following neutron irradiation in the HFR will provide designers with information on the potential of this approach and the resulting integrity of the welds.

In support of ITER re-welding activities, stainless steel specimens made of 5-10 mm thick plates were irradiated in HFR then welded under high constraint conditions and investigated for micro-structural features in the HFR hot-cell laboratories. Additional micro-structural analyses were performed to investigate the effects of various He content. This work followed on intermediate results of the Reweld Demonstration Feasibility Study for the ITER Vacuum Vessel.

The work will be continued for weld processes that require much less heat input. It has been observed that the lower the heat input the less effect helium has on the integrity of the irradiated plate.

Presently, design bolting of components to the back plate of the ITER main structure is envisaged. These bolts are exposed to weak neutron fluxes; such exposure might however be sufficiently strong to affect their pre-stressed condition. Post-irradiation testing was performed for high strength materials selected for bolting applications (such as Alloy 718, 625+ and Ph-13-08-Mo) and some reference structural materials (316L(N) IG, Eurofer-97). Specimens were pre-stressed bolts and bent strips, irradiated to 0.2 and 0.6 dpa at 300°C in HFR in 2003. Stress relaxation values for Alloy 718 were smaller for bolts as compared to strips, but showed larger scatter, probably due to the unstable microstructure. The strip values were comparable with the present ITER design curve. The residual bolt tensile behaviour was found to be consistent with earlier results. Stress relaxation for Alloy 625+ tensile bolts and bent strips were consistent, with a low scatter. The stress relaxation for Alloy 625+ and Ph-13-08-Mo was higher than expected at these low doses. Tensile testing showed irradiation softening for alloy 625+ and hardening for Ph-13-08-Mo. Results for the other materials showed larger scatter, as smaller deformations apply. Key issues for measuring irradiation stress relaxation behaviour have been solved in a combination of specimen down-sizing and economising irradiation volume, along with a more comprehensive post-irradiation testing campaign.

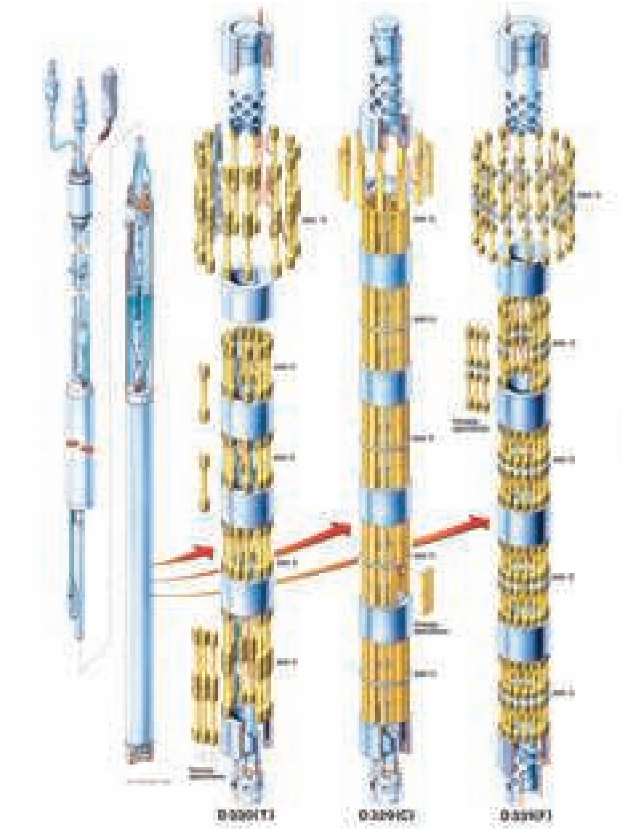


SPICE

The irradiation project SPICE is carried out in the frame of the European Long-term Fusion Materials Development Programme. The objectives are to evaluate the mechanical properties of Eurofer 97 samples after irradiation at doses of 15 dpa and at different irradiation temperatures (250/300/350/400/450°C).

The material was prepared and characterized by FZK (Germany). The instrumented sample holder contains 180 mini charpy, 91 tensile and 160 fatigue specimens.

The irradiation started in July 2001 and was, with the exception of a few interruptions imposed by reactor operation and minor technical incidents continued through 2003. The dpa target will be reached in May 2004.

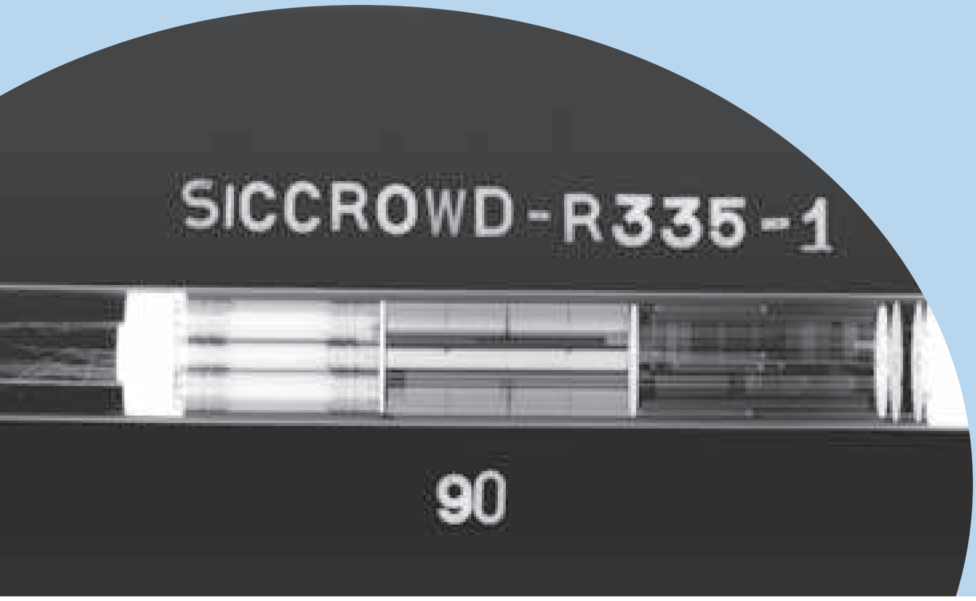


Helium Cooled Pebble Bed Sub-Module Operation

The nuclear reaction producing power in first generation fusion plants occurs between hot deuterium and tritium at sufficiently high pressure. Since free tritium is insufficiently available in nature, blankets near the fusion plasma are the source for half of the fuel (namely tritium). This fuel is produced by transmutation of lithium through neutrons generated in the plasma.

Present designs look at various forms of lithium in the blankets, such as liquid (e.g. lithium lead) or solid (e.g. pebbles of lithium ceramics). The primary cooling of the blankets is envisaged through the liquid lithium or, in the case of ceramic pebbles, through pressurised helium. Besides the lithium for the fuel, beryllium has to be mixed with the pebbles to act as a neutron multiplier. Tritium purge lines provide the connection to the tritium storage devices. Arranging lithium bearing compounds, beryllium multipliers, tritium purge lines, and cooling devices is quite complex, thereby justifying the experimental demonstration of the basic design parameters. ITER will serve as a test bed for Test Blanket Modules (TBM), which will provide input for the design of blankets for the Demonstration fusion reactor (DEMO) and for later fusion power plants. Such a TBM also closely needs to follow the design of blankets for DEMO and fusion power plants. It is essential to test ITER blanket sub-modules in materials test reactors.

The neutron spectrum in the HFR forms a realistic environment for the testing of blanket modules. Four helium-cooled pebble bed assemblies with lithium-silicates and lithium-titanates, closely following the major design for ITER's intended TBM, were tested during 2003 in the HFR. This irradiation campaign provides experimental data to verify and validate models used for predicting TBM behaviour. On-line process readings of temperatures, pressures and tritium production allowed detailed validation. Tests prior to irradiation contributed to understanding the thermo-mechanical behaviour of pebble bed assemblies. The experiment has already resulted in improvement of the nuclear and thermo-mechanical analyses. Continuation of the experiment into 2004 will help to improve the predictions of TBM behaviour and in particular, regarding beryllium creep.



Functional Fusion Blanket Materials

In the frame of the EXOTIC (EXtraction Of Tritium In Ceramics) series, the work on post-irradiation ceramography and tritium annealing tests has continued, improving the database for designers, scientists and materials engineers. The information chiefly concerns the ceramic tritium sources of primary interest for fusion power development, namely lithium silicates and titanates. The EXOTIC-9 irradiation, currently in the preparation stage, will include, for a special batch of meta-titanate pebbles obtained from CEA (France), the in-pile determination of characteristics of its tritium release. A limited size batch with 30% enriched lithium will be tested alongside the major test objects.

Preparation of the HICU experiment (High-fluence Irradiation of breeder Ceramics), aimed at long-term (up to two years) irradiation of ceramic pebbles, is still underway. Conflicting requirements and design complexity have generated difficulties to consolidate a finalised design. In particular, cadmium shielding (required for neutron spectrum adjustment) is hard to combine with high power densities produced by the enriched-lithium ceramics; thermo-mechanical behaviour of ceramic pebble stacks generates another design uncertainty. It is expected that data from other experiments (e.g. the Helium cooled pebble bed sub-module) will help in sufficiently resolving remaining uncertainties. Pre-testing and X-Ray tomography of pebble stacks before irradiation will be necessary to improve the quality of the results (which are expected in two years). In the light of these issues and despite the delays, the test matrix and sample selection are finalised and the irradiation is expected to start in 2004.

In the frame of the International Energy Agency (IEA) implementing agreement on Radiation Damage Effects in Fusion Materials, beryllium pebble stacks will also be irradiated in the HFR for a two-year period. Partners in the EU, Japan and the Russian Federation provide different grades of beryllium pebbles to be tested in HFR's HIDOBE (High Dose Beryllium Irradiation) rig in order to quantify their long-term behaviour and validate their model descriptions. Most of the pre-tests have been completed satisfactorily; the rig irradiation will start early 2004.

Coatings for Corrosion Prevention and as Barrier

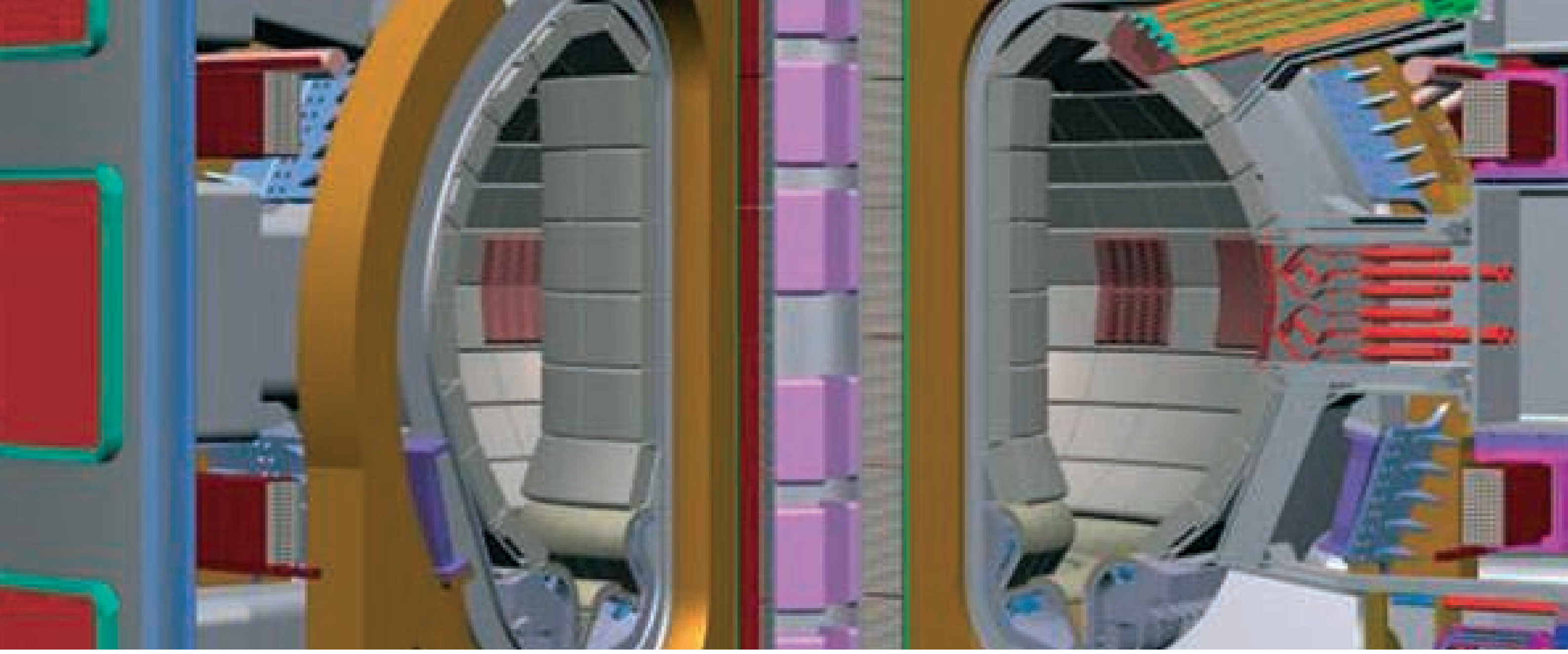
Several design approaches use coatings on the structural materials or the piping of fusion blanket components. Coatings have several functions:

- Prevention or reduction of coolant attack on the structural material
- Electrical insulation of the metallic component from the metallic coolant
- Barrier to tritium transport

Experiments including coated materials have been part of the EXOTIC irradiations in the HFR. Major results of tests on double walled tubes and materials with coatings to reduce permeation have been reported: the function of a copper barrier layer remains unchanged after irradiation; alumina coating is not affected by irradiation in a neutron field up to 2 dpa.

The qualification of the double walled tubes with a copper barrier includes the measurement of the crack propagation in the copper layer. A method by potential difference, used for reference testing, turns out to be feasible for post-irradiation testing of multi-layered sandwich assemblies. The solution proposed for testing the crack propagation in hot-cells will be based on the measurement of sample stiffness under a four point bending test. In addition it is proposed to perform impact tests on sandwiched material in order to obtain information on the copper layer integrity under high velocity loading.

Additionally, a neutron irradiation of pre-oxidised Eurofer97 is foreseen in order to determine the effect on the integrity and permeation properties of the steel's oxide layer. However, further irradiation experiments with alternative types of coatings are hampered by the lack of supply of stable coatings.



Structural Steel for ITER Test Blankets

Austenitic stainless steel is widely used in fission reactor components. The environmental conditions of fusion applications make such steels less attractive because of high swelling rates and helium embrittlement properties[1]. Conversely, with a micro-structural behaviour preventing high swelling rates or helium embrittlement, ferritic martensitic steels have become the reference structural steel for blankets. Another advantage of such steels is that, providing the impurity level can be controlled, they can be made with alloying elements that allow re-processing after less than 100 years. Manufacture of such alloys has been successfully demonstrated by the Japanese and EU steel industry. This class of steels is called Reduced Activation Ferritic Martensitic (RAFM) steel.

A whole set of irradiation projects with post-irradiation testing is necessary to qualify this steel for application in blankets. The first target is the justification for its use in the ITER test blanket modules. In the HFR a large programme is underway to contribute to the quantification of neutron irradiation effects up to 12 dpa, on RAFM steels. The main investigation of the toughness reduction of different kinds of product forms was completed in 2003. The major results have been reported during ICFRM-11 in Kyoto stating that considerable hardening and reduction of toughness has been observed, but that this latter parameter did not impair the operation of the blanket module.

In 2003 the irradiation of RAFM steel samples has been prepared and started with a view to quantify irradiation effects on fatigue endurance of blanket modules in ITER. The modules are subjected to fatigue from the intermittent operation of the ITER plasma.

Silicon Carbide Ceramic Structural Material

Providing that the oxide dispersion strengthening of next generation steels is effective, blankets based on steels will allow operational temperatures up to 650°C; another 100°C can be further gained through the use of nano-microstructure stabilisation. However, given that the upper operating temperature of steel will be reached at around 750°C and that high thermal efficiency can be obtained at operating temperatures over 1000°C, interest is growing in structural materials allowing such operating temperatures, such as silicon carbide ceramic composites. These materials, which present attractive strength properties up to 1000°C, also display some drawbacks that need to be eliminated:

- Low heat conductivity after neutron irradiation
- Strength reduction by neutron irradiation
- Low toughness
- Limited leak tightness

The SICCROWD irradiation up to 950°C and Post–Irradiation Examinations (PIE) aims at addressing the major issues related to neutron radiation. Materials from suppliers in the EU, Japan and the US were irradiated in the rig up to 4.4 dpa in SiC (equivalent to 2.3 dpa in steel) and the PIE is underway.

Although no final conclusion can yet be drawn, preliminary observations have shown that physical and mechanical properties depend very much on the manufacturing process. Differences in factors 5 to 10 have been observed. On the basis of results of the PIE, some materials will be eliminated from further investigations whilst others will provide promising potential for improvement. The landscape of silicon carbide ceramic composites is still more or less unexplored with respect to its post-irradiation behaviour. Many future experiments aiming at the validation of improvements are foreseen, but one must bear in mind the inherent low toughness of silicon carbide ceramic composites. A hybrid design using steel girders with large parts made from silicon carbide will also present a further avenue to explore for fusion power plant blankets.

[1] High swelling rates are a consequence of displacement damage due to high energy neutrons, combined with high operating temperatures; helium embrittlement is due to bubbles formed by helium, resulting from transmutation reactions.

HFR: The Programmes
HFR as a Tool for Research

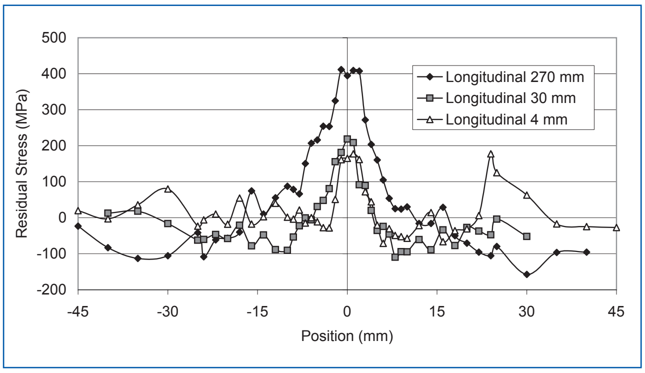
Neutron Beam Research

In 2003 significant efforts were undertaken to upgrade and revitalize several HFR neutron beam facilities and a large number of neutron diffraction testing campaigns were executed aiming at supporting structural integrity assessment investigations of primarily RPV and primary piping welded components.

The combined powder and stress diffractometer (CPSDF) at beam line HB5 was re-commissioned after installation of a position sensitive detector. Together with the Large Component Neutron Diffraction Facility (LCNDF) at HB4 there are now two operating diffractometers for residual stress investigations. A furnace for neutron diffraction analysis at elevated temperatures (up to 1600°C) has been developed, and procurement of a shielded container for handling and neutron diffraction testing of irradiated specimens is underway.

Six major testing campaigns were executed throughout 2003 based on the HFR LCNDF & CPSDF:

- 3-D mapping of residual stresses in 51 mm thick piping DMW was completed (ADIMEW)
- Strain/stress measurements on an "edge welded" beam specimen were completed (ENPOWER)
- Strain/stress measurements on two large reactor pressure vessel wall mock-ups containing a proposed sub-clad crack repair weld were completed; results will be used for calibration of numerical models (ENPOWER)
- Residual stress measurements in various short C/C-SiC tubular specimens at room temperature were completed; Testing at high temperature was started and will be completed in 2004 (HITHEX)
- Measurements of residual stresses in non-irradiated test pieces were completed (see Figure); irradiated specimens will be tested in 2004 (INTERWELD)
- Mapping of stresses in a single weld bead on steel plate in the context of a NET-TG1 round robin was completed; results will be used for calibration of numerical models which will be developed for detailed simulation of multi-pass repair welding processes (NET-TG2)



Progress has been made in upgrading the neutron radiography facility at beam tube HB8. The procurement of new equipment for evacuating and cooling the filter units is underway; the development of digital Data Acquisition (DAQ) and processing is foreseen in the course of 2004.

The Small Angle Neutron Scattering (SANS) facility at beam tube HB3b has been serviced and upgraded significantly during 2003. Its filter unit has been repaired, the electronics for DAQ have been serviced and the settings have been readjusted and new software and hardware for DAQ have been installed. The first neutrons have been captured by the detector at the end of 2003. A first testing campaign is envisaged in 2004 for the investigation of thermal ageing effects in steel alloys aiming at performance harmonization for European SANS facilities (NET-TG3). Toward end 2003, a feasibility study has been initiated for the development and installation of a cold neutron source at HB3. Preliminary findings suggest that such neutron sources could result in boosting neutron intensity by about a factor 50, at the neutron wavelength range appropriate for defects studies. The envisaged upgrading of the SANS facility performance should allow for the investigation of defects in a large class of cases, including irradiated material specimens. This capability, coupled with the HFR irradiation facilities and the new LCNDF version for neutron diffraction on irradiated specimens will result in a unique and autonomous Combined HFR Laboratory for RPV welded internals characterization within Europe.

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A list of HFR scientific publications mentioned in this Annual Report can be obtained upon request to the contact person.

Glossary

ADIMEW	Analysis of Dissimilar Metal Welds
ADS	Accelerator Driven Systems
AHG	Ad-Hoc-Group
ALARA	As Low As Reasonably Acceptable
AMES	Ageing Materials Evaluation Studies
BIMET	Structural Integrity of Bimetallic components
BNCT	Boron Neutron Capture Therapy
BNFL	British Nuclear Fuels plc.
BPA	Boron compound for BNCT
BSH	Boron compound for BNCT
BWR	Boiling Water Reactor
CASHIR	Cadmium-Shielded Steel Irradiation Experiment
CEA	Commissariat à l'Energie Atomique
CEN	The European Committee for Standardization
CFC	Carbon Fibre Compound
CMC	Ceramic Matrix Composite
COVRA	Centrale Organisatie Voor Radioactief Afval
CPSDF	Combined Powder and Stress Diffractometer
CT	Compact Tension
DAQ	Data Acquisition
DEMO	Demonstration Fusion Reactor
DG RTD	Directorate General Research (Technology Demonstration)
DG	Directorate General
DMW	Dissimilar Metal Welds
dpa	displacements per atom
EANM	European Association of Nuclear Medicine
EC	European Commission
ECN	Energieonderzoek Centrum Nederland
EdF	Electricité de France
EFDA	European Fusion Development Agreement
EMIR	European Network for Medical Radioisotopes and Beam Research
ENPOWER	Nuclear Plant Operation by Optimising Weld Repairs
EORTC	European Organisation for Research and Treatment of Cancer
ESTRO	European Society for Therapeutic Radiology and Oncology
EXOTIC	EXtraction Of Tritium In Ceramics
EXTREMAT	New Materials for Extreme Environments
FEM	Finite Element Model
FIMA	Fissionable (Heavy) Metallic Atoms
FLUX	Fluence Rate
FP or FWP	Framework Programme
FZJ	ForschungsZentrum Jülich
FZK	ForschungsZentrum Karlsruhe
GCR MINWASTE	Gas-Cooled Reactors-Minimization of Waste
GIF	Generation IV International Forum
GKN	Gemeenschappelijke Kernenergiecentrale Nederland
GWd/EM	
HABOG	Hoogradioactief Afval Behandelings- en Opslag Gebouw
HAZ	Heat Affected Zones
HB	HFR Beam Tube
HELIOS	Helium in Oxide Structure
HEU	High Enriched Uranium
HFR	High Flux Reactor
HICU	High Fluence Irradiation of Breeder Ceramics
HIDOBE	High Dose Beryllium Irradiation Rig
HITHEX	High Temperature Heat Exchanger
HT	High Temperature
HTGR	High Temperature Gas Cooled Reactor
HTR	High Temperature Reactor
IAEA	International Atomic Energy Agency
ICI	International Conference on Isotopes
ICRU	International Commission on Radiation Units and Measurements
IE	JRC Institute for Energy, Petten (NL)
IHCP	JRC Institute for Health and Consumer Protection
IMSC	International Monitoring and Steering Committee
INET	Institute of Nuclear Energy Technology (of the Tsinghua University)
INNO-HYP	Innovative Hydrogen Production
INRNE	Institute for Nuclear Research and Nuclear Energy, Sofia
INSARR	Integrated Safety Assessment of Research Reactors
INTERWELD	Irradiation effects on the evolution of the microstructure, properties and residual stresses in the heat affected zone of stainless steel welds
IP	Integrated Project

IRI-Delft	Interfaculty Reactor Institute, University of Technology Delft (NL)
ISI	In-Service Inspection
ISO	International Organization for Standardization
ISTC	International Science and Technology Centre
ITER	International Thermonuclear Experimental Reactor
ITU	JRC Institute for Transuranium Elements, Karlsruhe (D)
JET	Joint European Torus
JRC	Joint Research Centre
KFD	Kernfysische Dienst
LCNDF	Large Component Neutron Diffraction Facility
LEU	Low Enriched Uranium
LWR	Light Water Reactor
LYRA	Irradiation faciLitY for European network foR AMES
MCNP	Monte Carlo Neutron Photon
MEP	Member of the European Parliament
MICROMOX	Mixed Oxide (MOX) Fuel with Improved Microstructure
MIMAS	Micronized Master Blend
MIT	Massachusetts Institute of Technology
MOX	Mixed Oxide
MPA	Staatliche Materialprüfungsanstalt Universität Stuttgart
NAS	Near Accession States
NCT	Neutron Capture Therapy
NCTPlan	Neutron Capture Therapy Treatment Planning
NESC	Network for Evaluating Structural Components
NET	Network on NEutron Techniques Standardisation for Structural Integrity
NRG	Nuclear Research and consultancy Group
NRG-MMI	NRG Materials Monitoring & Inspection Group
PET	Position Emission Tomography
PIE	Post Irradiation Examination
PISA	Phosphorus Influence on Steel Ageing
PSF	Pool Side Facility
PSI	Paul Scherrer Institute (Villigen, Switzerland)
PWR	Pressurized Water Reactor
R&D	Research and Development
RAFM	Reduced Activation Ferritic Martensitic (steel)
RESTAND	Residual Stress Standard using Neutron Diffraction
RLB	Reference Licensing Basis
RPV	Reactor Pressure Vessel
SAFELIFE	Safety of Aging Components in Nuclear Power Plants
SANS	Small Angle Neutron Scattering
SCA	Shared Cost Action
SCK-CEN	Studieventrum voor Kernenergie - Centre d'Etudes de l'energie Nucléaire
SCWG	Safety Culture Working Group
SOP	Standard Operating Procedures
SPICE	Sample Holder for Irradiation of Miniaturized Steel Specimens
SURP	Surveillance Programme
TBM	Test Blanket Modules
TC	Technical Committee
TG	Task Group
TN	Technology Network
TRABANT	TRAnsmutation and Burning of ActiNides in a TRIOX
US	United States
VHTR	Very High Temperature Reactor
VU Amsterdam	Vrije Universiteit Amsterdam
WGNA	Working Group on Nuclear Activities

European Commission

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Abstract

The High Flux Reactor (HFR) of Petten is managed by the Institute for Energy (IE) of the EC – DG JRC and operated by NRG who are also responsible for the commercial activities.

The HFR, operated at 45 MW, is of the tank-in-pool type, light water cooled and moderated. It is one of the most powerful multi-purpose materials testing reactors in the world and one of the world leaders in target irradiation for the production medical radioisotopes.

2003 was the last year of the 2000-2003 Supplementary Programme; as such, it was a very busy year at the High Flux Reactor in Petten, during which a new Supplementary Programme was prepared and negotiated with the stakeholders. Other 2003 highlights include:
- *285 full-power operation days*
- *153 visits, including representatives from the neighbouring municipalities*
- *4 European Networks managed*
- *Various fusion and fission related irradiation experiments carried out*

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