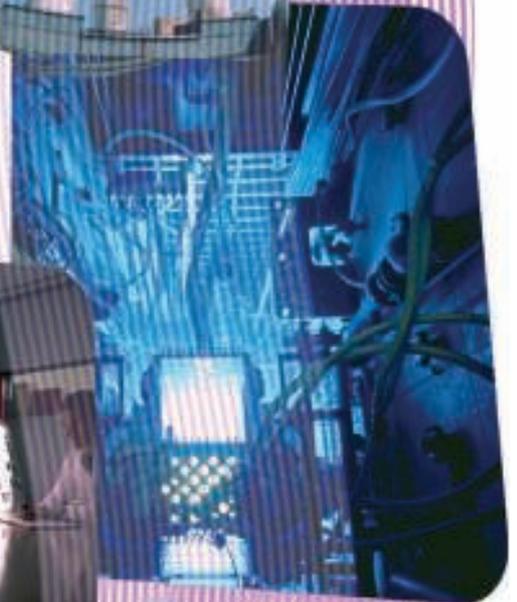


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ENERGY**

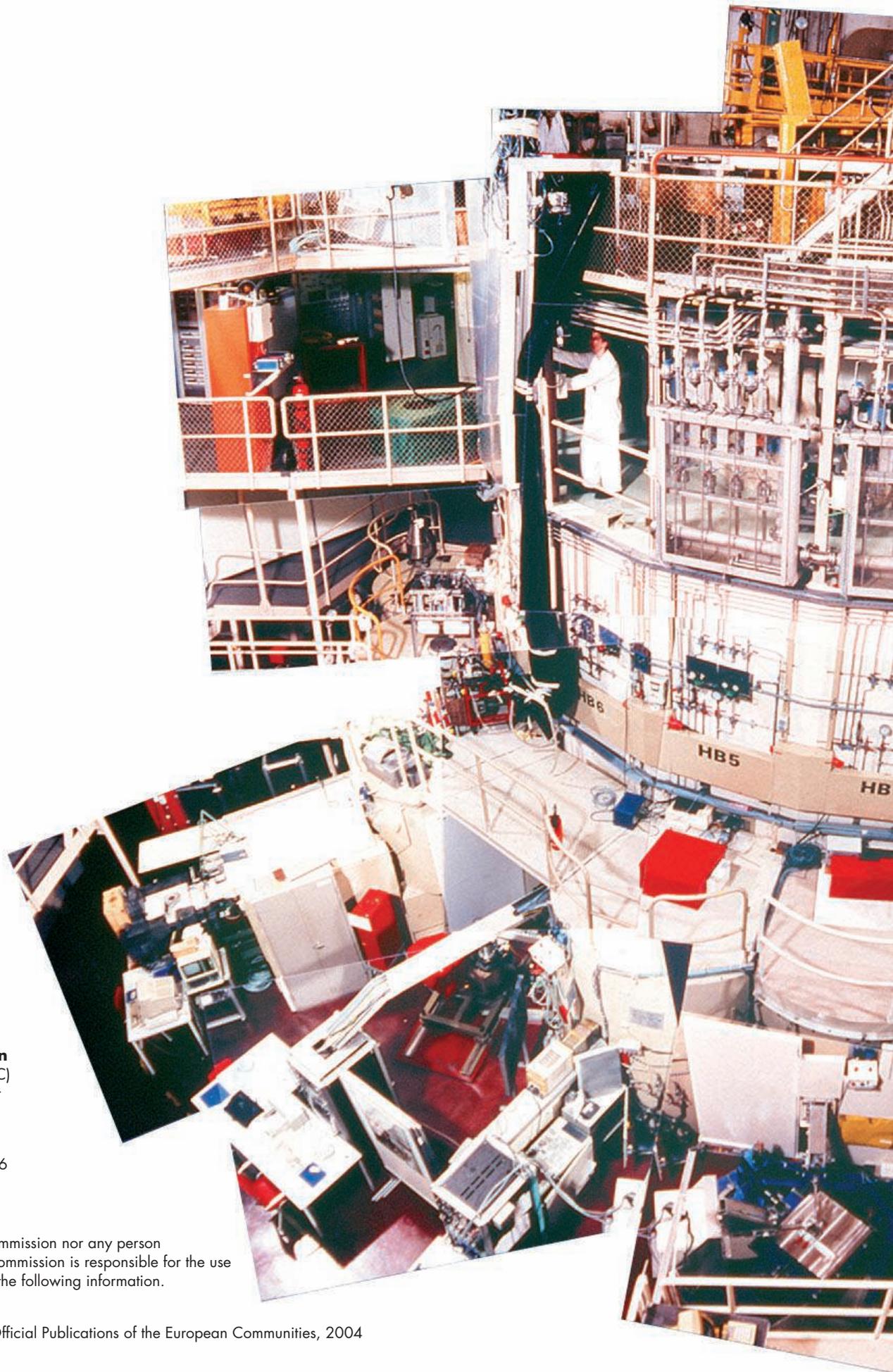


**ACTIVITY REPORT  
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EUROPEAN COMMISSION  
JOINT RESEARCH CENTRE

Report EUR 21298 EN



**European Commission**  
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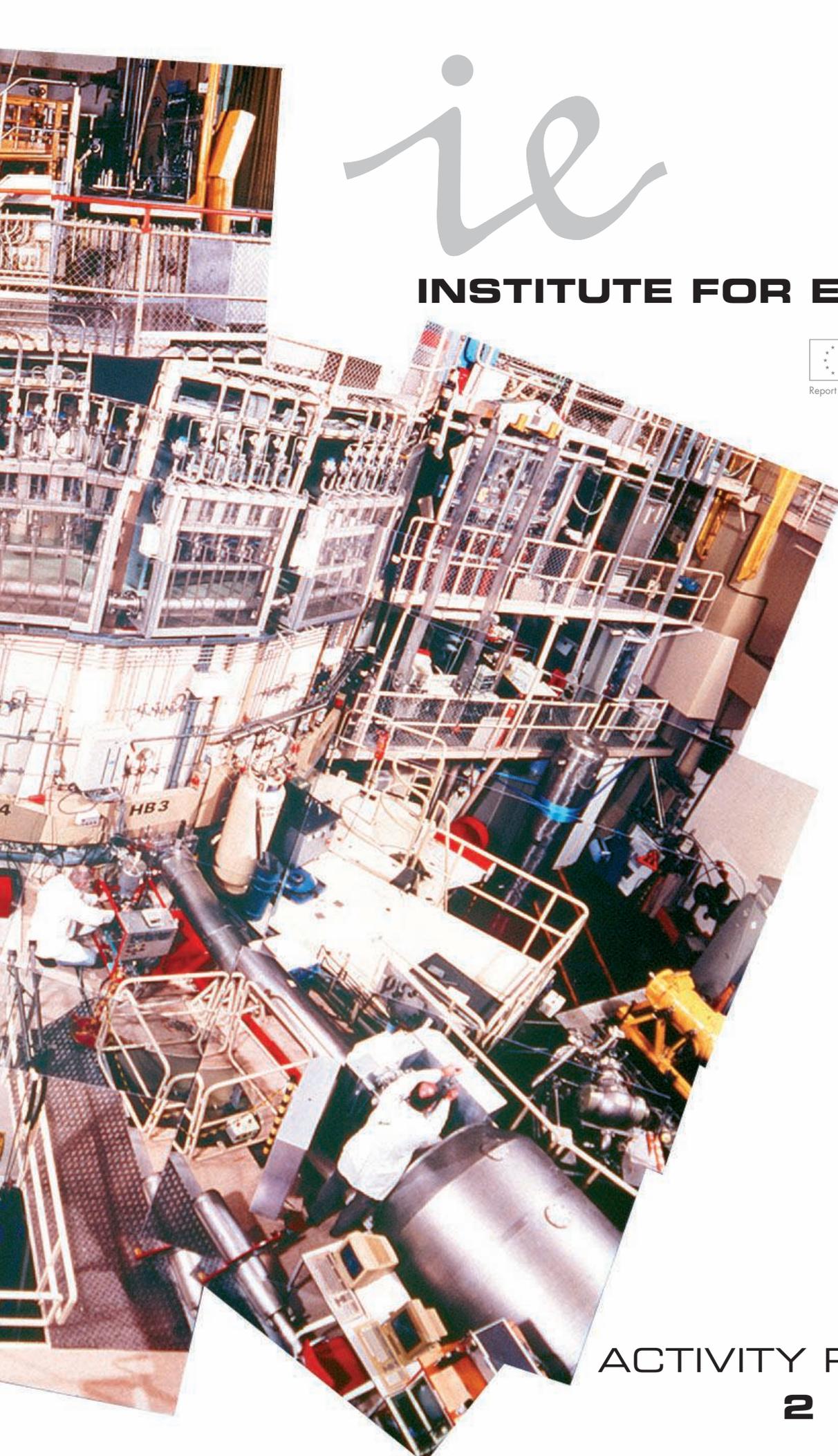
Luxembourg: Office for Official Publications of the European Communities, 2004

**ISBN 92-894-8194-3**

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Printed in the Netherlands, Aranea Offset B.V.



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**INSTITUTE FOR ENERGY**



EUROPEAN COMMISSION  
JOINT RESEARCH CENTRE

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**ACTIVITY REPORT  
2 0 0 3**

# Foreword

The year 2003 was the first year of the EC's Sixth Research Framework Programme and, as consequence, our project portfolio was largely renewed. In the nuclear safety area we integrated most of our institutional networks under the unique umbrella of the SAFELIFE action and we increased our activities towards safety of new reactor concepts. In addition, we also started a new project related to casks for nuclear waste, SAFECASK. In the cleaner energies area we launched two new projects related to hydrogen; one for hydrogen storage and one for fuel cell testing. Designs and planning for new state-of-the-art facilities in these two areas were completed and relevant licences applied for. We also succeeded in qualifying for major roles - memberships in the Advisory Council and various working groups as well as the scientific part of the secretariat - in the new European Hydrogen and Fuel Cell Technology Platform and in the implementation and liaison committee of the International Partnership for Hydrogen Economy. A new integrated scientific area *Sustainable Energy Technologies Reference & Information System* SETRIS, pulling together relevant activities from five different JRC institutes under our leadership, was also launched. Highlights of these activities are described further in the present report.

Our major tool in nuclear safety related research is the High Flux Reactor (HFR). We were able to utilise the reactor according to plans for a variety of research projects and medical applications as described in a separate Annual report that covers the activities of the HFR. In addition we also completed the action plan which stemmed from the IAEA review of 2002 and which addressed safety and safety culture issues. A new Supplementary Programme, funded by the Dutch and French Governments was approved by the Commission in December 2003 and by the Council in February 2004. Finally, in view of the fact that the current licence dates from 1962 and that the HFR will be converted from high-enriched uranium to low-enriched uranium fuel in 2006, it was deemed necessary to up-date the current licence. The preparatory work, which required three years of effort, was completed in the course of 2003 and the licence application was actually submitted to the authorities in December 2003.

The Institute also carries out research and support work outside the institutional programme. Cashed income from these activities was 9.3 M€, which is 31 % of the total budget of the Institute and more than twice the target value of the Institute. A large part of this income was related to the

support to DG AIDCO on the TACIS-PHARE nuclear safety programme.

Our Institute, as the rest of DG JRC, is committed to Total Quality Management, following the European Foundation of Quality Management concept. In 2003 a major improvement of our management systems and processes was achieved, leading to the granting of the ISO 9001(2000) certificate. We also completed the preparations of our environmental management system so as to fulfil the ISO 14001 standard (the certificate was granted in February 2004). This development was positively perceived by local and national Dutch authorities, who have recently put more emphasis on the importance of safety and environmental matters.

The year 2003 was a good year for the Institute. We succeeded to achieve our HFR related objectives, we were successful in initiating our new work programme, and we thrived in securing a key role in the hydrogen economy initiative. I want to thank all staff members, partners and stakeholders for their efforts and contributions which have allowed us to perform so well.



**Kari Törrönen**  
Director IE

A handwritten signature in black ink, appearing to be 'Kari Törrönen', written over a white background.

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# Introducing the Institute for Energy

## Overview

The Institute for Energy orients its efforts towards complying with the requirements of its customer Directorates-General (DGs) of the European Commission by providing a direct support to different stages of European policy-making in the energy area, on issues related to environmental protection, safety and security of the citizens, and sustainable development. The Institute provides high added value scientific and technological contributions where a European perspective and independence of commercial and national interests are essential.

## Mission Statement

*The Institute for Energy provides scientific and technical support for the conception, development, implementation and monitoring of community policies related to energy. Special emphasis is given to the security of energy supply and to sustainable and safe energy production.*

To implement its mission, IE has identified three main research themes with the following objectives:

### **nuclear activities:**

*To develop, provide and disseminate S&T knowledge in selected safety issues in support of EU policies and Commission Services on nuclear safety.*

### **non-nuclear activities:**

*To support the EU policy on the security of energy supply, with special emphasis on performance in terms of efficiency, safety, environmental compliance, and on hydrogen.*

### **nuclear medicine**

As a spin-off of the nuclear energy and safety related research projects, the Institute has built up expertise in the area of nuclear medicine, where the objective is:

*To support the EU public health policies through the development of high quality and safe medical applications of nuclear technologies and methodologies used for diagnosis and treatment.*

The Institute possesses internationally recognised state-of-the-art laboratories and facilities which form the basis for the generation of scientific output, thus providing reference results to the Commission services and contributing to scientific knowledge and understanding.

All activities involve networking in line with the Commission's initiative for a European Research Area (ERA). Through these networks, involving national R&D institutions, universities, international normative and standardisation organisations, regulatory bodies and European industries, the Institute acts as a gateway for Commission services to the world of energy-related science and technology.

Another important Institute activity is training of EU Member State and Candidate Country scientists, which is achieved by hosting and providing access to Institute facilities to grant holders, visiting scientists, or seconded national experts.

According to its Mission the Institute provides support to EU policies. This takes place both through direct support to policy Directorates General and supporting community policies related to Energy. An example of the first is the Institute's strong contribution to safety of Eastern nuclear reactors through DG AIDCO. In the latter case the Institute provided support for DG ENV in preparation of the Commission Communication published with a view towards the possible revision of the Waste Framework Directive, or in formulation of the Commission's position in signing the US-led international action "Carbon Sequestration Leadership Forum".



# Visits and Meeting Highlights 2003

## 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 "gemeentes" (municipalities). Each visit combined a series of short presentations on the role of the Institute, the HFR, and its programmes, and activi-

ties 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 hereunder). In addition, Mrs Gardeli, Director of the European School in Bergen, visited the facility on December 12.

| 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   | Mr. J.M. Staatsen             | 20                           |

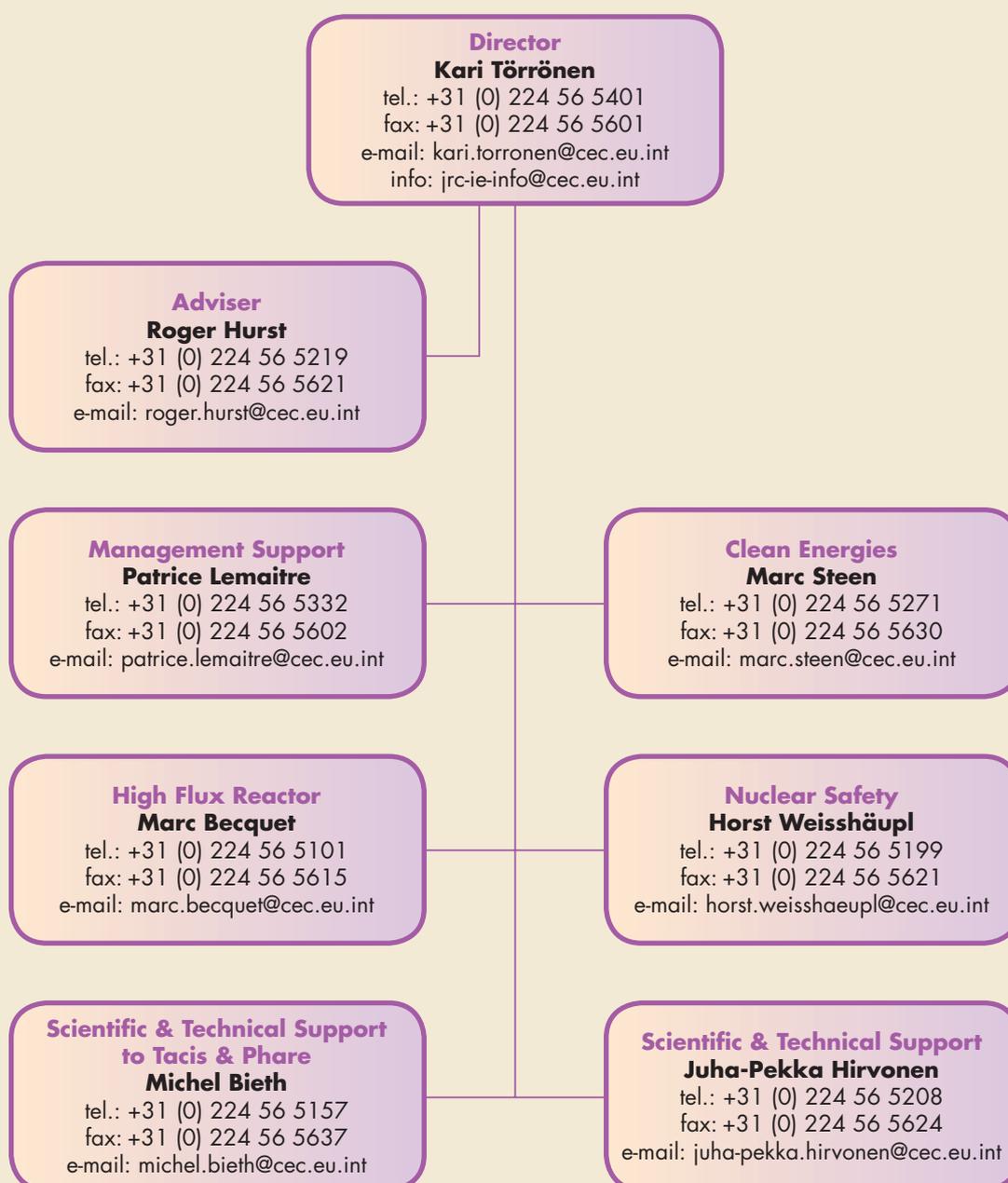
## "The year at a glance"

|                |       |   |
|----------------|-------|---|
| <b>January</b> | 22    | The ENIQ Task Group on Inspection Qualification on the 22nd.  |
| <b>March</b>   | 17-18 | The RIMAP Network (Risk Based Inspection and Maintenance Procedures for European Industry) conference in Petten.  |
|                | 25-28 | The Annual International Phebus FP Network meeting in Bergen on the 25th-28th March with 70 participants from the EU, candidate countries, USA, Canada, South Korea, Japan and Switzerland. |
| <b>April</b>   | 8     | The 16th EPERC Steering Committee in Petten.  |
| <b>May</b>     | 1     | Visit of VROM/KFD communication advisors to the HFR.  |
|                | 12-13 | The 24th ESReDA Seminar on SAFETY INVESTIGATION OF ACCIDENTS with 130 external participants.  |
|                | 12-16 | Key meetings in Moscow in the frame of the JRC technical assistance to AIDCO for the TACIS Nuclear Safety Programme with members of the IE TACIS Unit.                                      |
|                | 14-16 | The PREWIN Steering Committee and General Assembly Meeting in Prague with approximately 60 members.   |
|                | 16    | The kick-off meeting of the HFR International Safety Experts Team in Petten.  |



|                  |       |   |
|------------------|-------|---|
| <b>June</b>      | 2-3   | Training Workshop in Petten under the Madama Contract for customers and both Actual and Prospective RTD partners of the JRC-IE Alloys-DB and Corrosion-DB.  |
|                  | 11    | Successful operation to transport used fuel elements to special storage facility.   |
| <b>July</b>      | 9     | Visit of the Dutch member of the JRC Board of Governors, Mr. Kees VIJLBRIEF (Finance Ministry).   |
|                  | 15    | The JRC Working Group on Nuclear Activities in Petten.  |
| <b>September</b> | 15    | Vessel Inspection at the HFR.   |
|                  | 22-23 | International Seminar in Petten on JRC European Networks on Structural Integrity of Safety-Related Components for Nuclear Power Plants.   |
| <b>Sept/Oct</b>  | 30-01 | 9th Meeting of the JRC Decommissioning & Waste Management Expert Group in Petten.   |
| <b>October</b>   | 9-10  | The training workshop in Petten on "Safety, Efficiency & Performance of Innovative Hydrogen Storage Technologies for Road Transport" with 14-15 delegates from 10 EU enlargement countries.   |
|                  | 14    | The visit of two Members of the European Parliament, R. Linkohr and G. Adam, in Petten.   |
|                  | 21-22 | The special Marie Curie event for Grantholders in the Netherlands in Petten, organised by the European Commissions DG RTD and DG JRC-IE.  |
|                  | 23-24 | A Five-Year Assessment of Community research activities as required in accordance with decisions on the EC and Euratom 6th Framework Programs.  |
| <b>November</b>  | 5     | The visit of the State Secretary for Housing, Regional development and the Environment Mr. P. Van Geel (accompanied by 7 members of his ministry), the "Commissaris der Koningin" for North Holland Mr. H. Borghouts, and the Mayor of Gemeente Zijpe Mrs. A. Van Apeldoorn-Pruijt in Petten. |
|                  | 18-19 | The training workshop on "Nuclear Safety: Scientific and Technical Support to PHARE Countries" in Petten.   |
| <b>December</b>  | 9-10  | The two day workshop and information exchange in Petten on syngas production from waste and biomass.  |
|                  | 12    | Visit of Mrs. Gardeli, Director, and Mr. Schlabe, Deputy Director of the European School in Bergen to the HFR.  |

# Organisation Chart





# Competencies

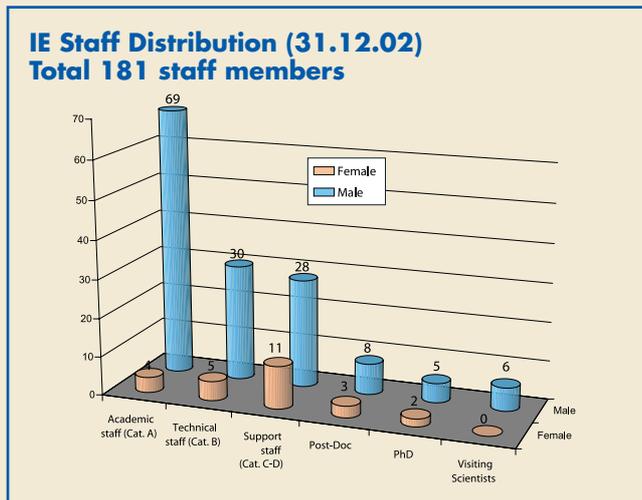
The areas of competence of IE lie in research areas where it has developed core aptitudes by know-how, expertise and understanding of issues. The table gives an overview of IE competencies.

|                                |   |
|--------------------------------|---|
| <b>Nuclear Reactor Safety</b>  | accident analysis and mitigation                    |
|                                | accident prevention and plant life management       |
|                                | advanced experimental techniques                    |
| <b>Cleaner Energies</b>        | new energy technologies especially hydrogen related |
|                                | energy recovery from waste and biomass              |
|                                | energy technology assessment                        |
| <b>Nuclear Medicine</b>        | new medical diagnostic and treatment methods        |
| <b>Support Activities</b>      | Irradiation services at HFR                         |
|                                | microstructural analysis                            |
|                                | modelling and numerical analysis                    |
|                                | data management                                     |
| <b>Networking</b>              | operation of expert networks                        |
| <b>Training of Researchers</b> | Doctoral and post-doctoral students                 |

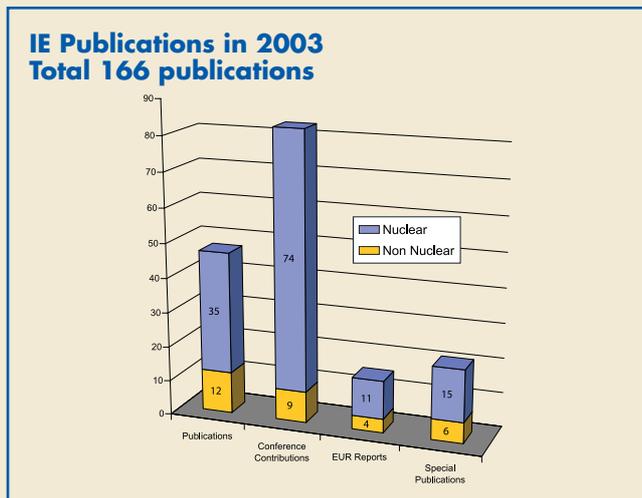


# Facts and Figures

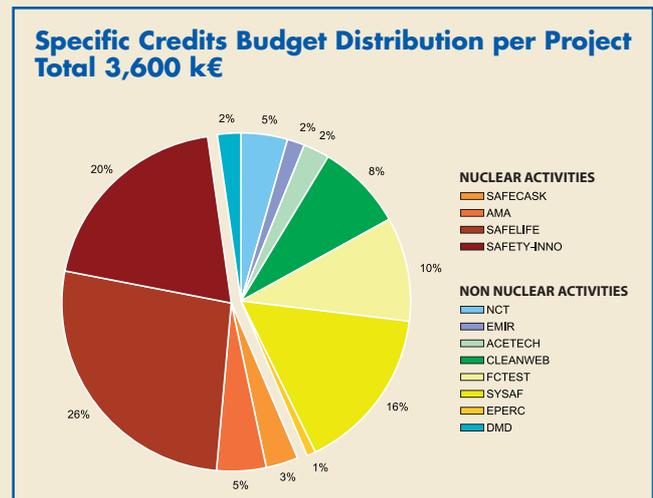
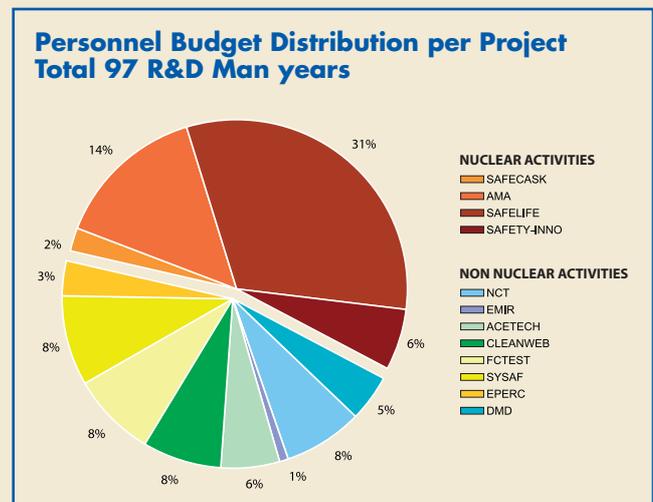
At the end of 2003, the Institute for Energy had 171 staff members, 147 permanent staff and 24 visiting staff, financed by the institutional programme, competitive activities, and a small fraction of the HFR supplementary programme.



The prime measure of the scientific productivity of the Institute is the number of scientific publications indicated in the column-chart below, where differentiation is made between publications from nuclear and non-nuclear projects. Reports on competitive activities and of third party work are not included. The complete publication list of IE can be found at <http://www.jrc.eu.int>



The Institute performs two major types of activities. The first are institutional projects which are carried out on behalf of the European Commission and are directly financed through the EC (non-nuclear) and Euratom (nuclear) Specific Programmes. The budgets for the various activities are schematically shown below. The second category of research projects are competitive activities, which cover work for third parties, shared cost actions, and work for other Directorates of the Commission cashed income for these activities was approximately was 9.3 M€, in 2003.





# Total Quality Management

The standards, rules and regulations of the Commission and the JRC set the minimum requirement for the management of the Institute for Energy. To exceed this minimum level, the Senior Management of IE has decided to use the principles of Total Quality Management (TQM) in all activities of the Institute. TQM comprises several activities which all aim at continuous improvement of the Institute's internal processes. The main activities of 2002 are presented in the following.

## **Quality management system**

IE has a certified Quality Management System (QMS) since 1999. During 2003, the upgrade of the QMS to meet the requirements of the process-based ISO 9001:2000 standard was completed. The activities of the IE are divided into four types of processes: management processes, support processes, scientific processes, and monitoring processes. Each process has an owner who is responsible for its monitoring and improvement.

The QMS was audited internally in the first half of the year 2003. Also a certification body audited the QMS, and the certification to the ISO 9001:2000 system was granted in September 2003.

## **EFQM Self assessment**

The performance of the IE processes is assessed every second year using the EFQM self-assessment method. In the year 2003, there was no self-assessment. The improvement needs that were identified in the previous year's assessment were reviewed and when possible a corrective action was planned and implemented.

## **Benchmarking**

IE is benchmarking its performance against that of other European research organisations. IE has a continual benchmarking activity with JRC-ITU, JRC-IPSC, and VTT (Finland). In 2003, the benchmarking activity included the completion of a questionnaire method with the aim to benchmark leadership processes. The benchmarking itself will take place in 2004.

## **Improvement cycle**

An improvement cycle has been defined in order to systematically collect and handle improvement proposals. The need for improvement can arise e.g. from staff suggestions, staff satisfaction surveys, customer satisfaction surveys, internal and external audits, self-assessments, and project evaluations. A management team reviews all the proposals on a regular basis.

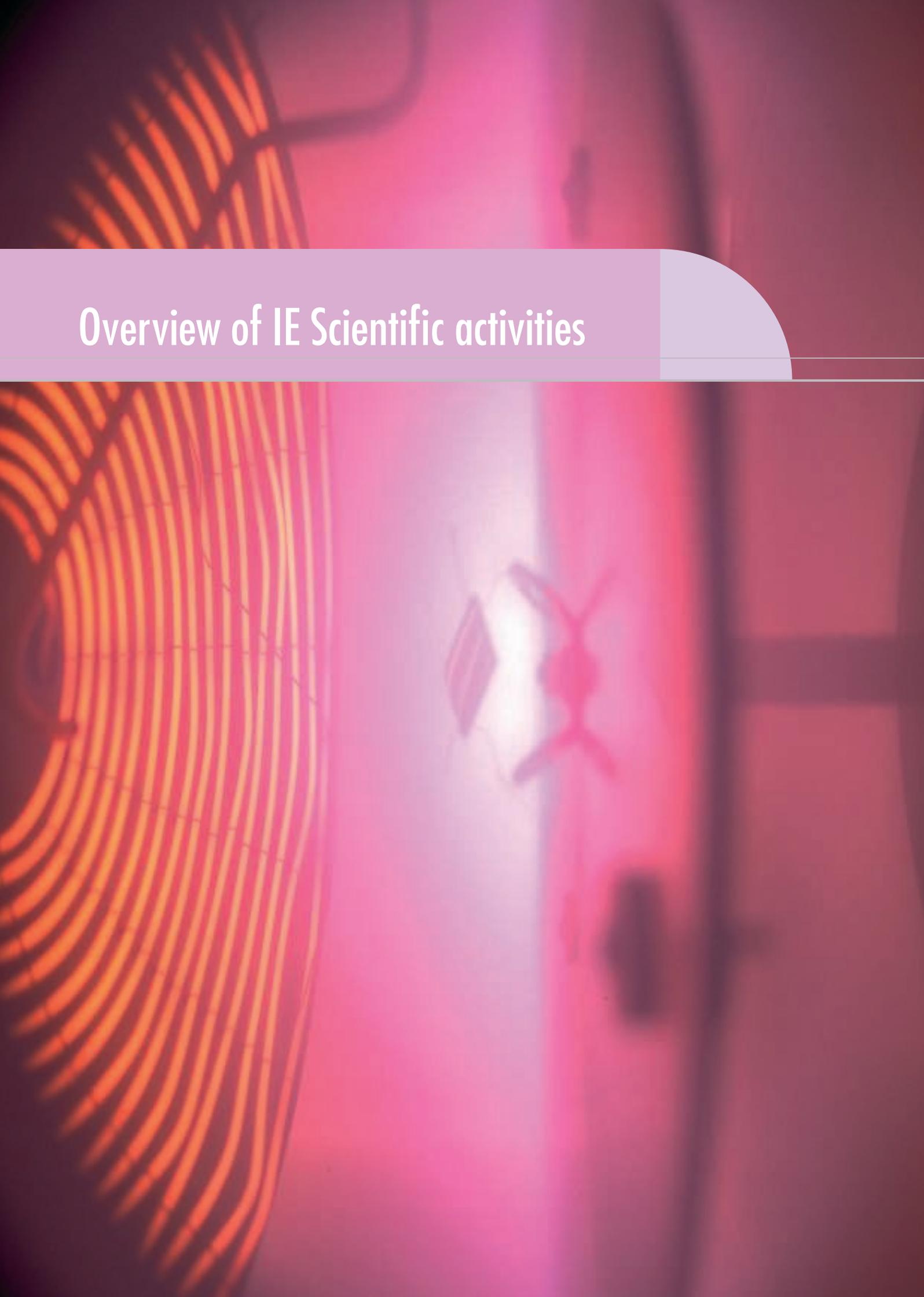
## **Environmental management**

The Senior Management decided in 2002 that the IE should develop an Environmental Management System (EMS) which would be based on ISO 14001 standard. The system development started in 2002, and it was finalised and implemented in 2003. The environmental policy was defined, annual and long-term objectives were established, and several environment related procedures and work instructions have been introduced. In addition, the IE has published an Annual Environmental Report since 2001. The EMS was audited internally at the end of 2003. The certification audit has been planned for January 2004.

## **Monitoring of performance**

The management of the IE defines for each year a number of objectives. The progress towards these objectives is followed through a set of Key Performance Indicators (KPI's). The indicators are set so that they describe the progress of the most critical processes. In each unit, the Unit Head has defined unit level objectives and indicators, which are in line with those of the Institute.

The progress towards the objectives is monitored in the Senior Management Meetings, and in the Institute level and Unit level Management Reviews

The background of the slide features a close-up, slightly blurred view of a microscope slide. On the left side, there is a prominent grid pattern, likely from a cover slip or a specialized slide. In the center, a small, dark, multi-segmented specimen, possibly a mite or a small insect, is visible on the slide. The overall color palette is dominated by warm, reddish-pink and orange tones, creating a scientific and focused atmosphere.

## Overview of IE Scientific activities

# Cleaner Energies

At the beginning of FP6, a refocussing of the activities took place in the Cleaner Energy chapter of the Institute research portfolio. One of these, CLEANWEB, has its roots back in FP5, whereas the other three, SYSAF, FCTEST and SETRIS-ACETECH started in January 2003.

As indicated in the Green Paper on Security of Energy Supply, current Commission efforts target the penetration of renewable energies and of alternative fuels, in addition to energy demand management measures among its goals. Additionally, the Commission is committed to removing the barriers for enabling the use in the longer term of hydrogen as an energy carrier for electricity, transport and heat applications. In line with these considerations, the experimental actions CLEANWEB, SYSAF and FCTEST increasingly focus on elements in the hydrogen chain from production to end-use, as schematically indicated in the figure below. Complying with the JRC mission statement, and in line with the subsidiarity principle, these actions do not aim to develop new production processes or new conversion technologies. Instead, they target the harmonisation and validation of methods and procedures for characterisation, performance and safety assessment of selected components in the hydrogen chain, such as sensors, storage methods and media, and fuel cells. They also address underpinning numerical simulation and modelling. Available experimental facilities are being converted to suit this focus, and new ones have either just been acquired, or are under construction.

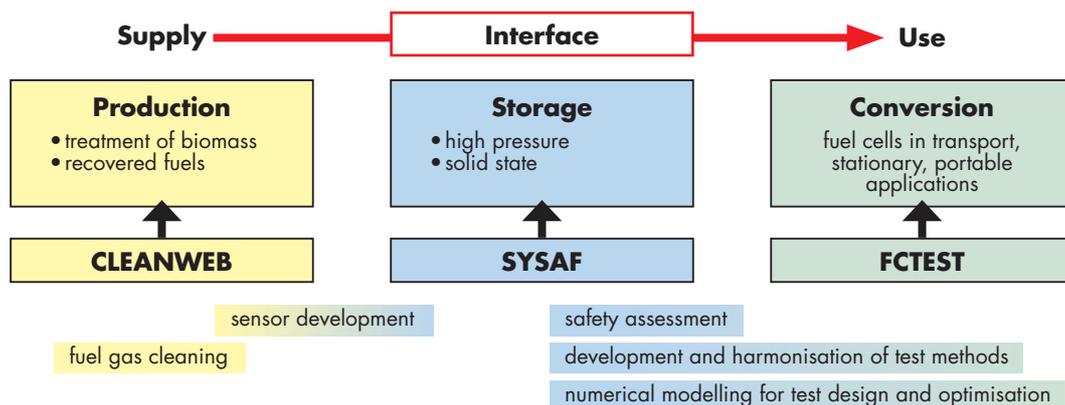
Through the networks (institutional or co-funded by DG RTD) in which IE is involved, European partners can be granted access to these facilities.

The fourth action, ACETECH, of a desk-top nature, constitutes a new type of activity for IE. It provides IE-lead and S&T contributions to the Integrated Scientific Area SETRIS, which brings together energy-related (aspects of) actions from JRC sister institutes IES, IPTS, IPSC and ITU. SETRIS aims at becoming the EC portal for energy issues through the operation of a Scientific Reference System (the JRC tool of choice for policy support within the European Research Area) on sustainable energy technologies.

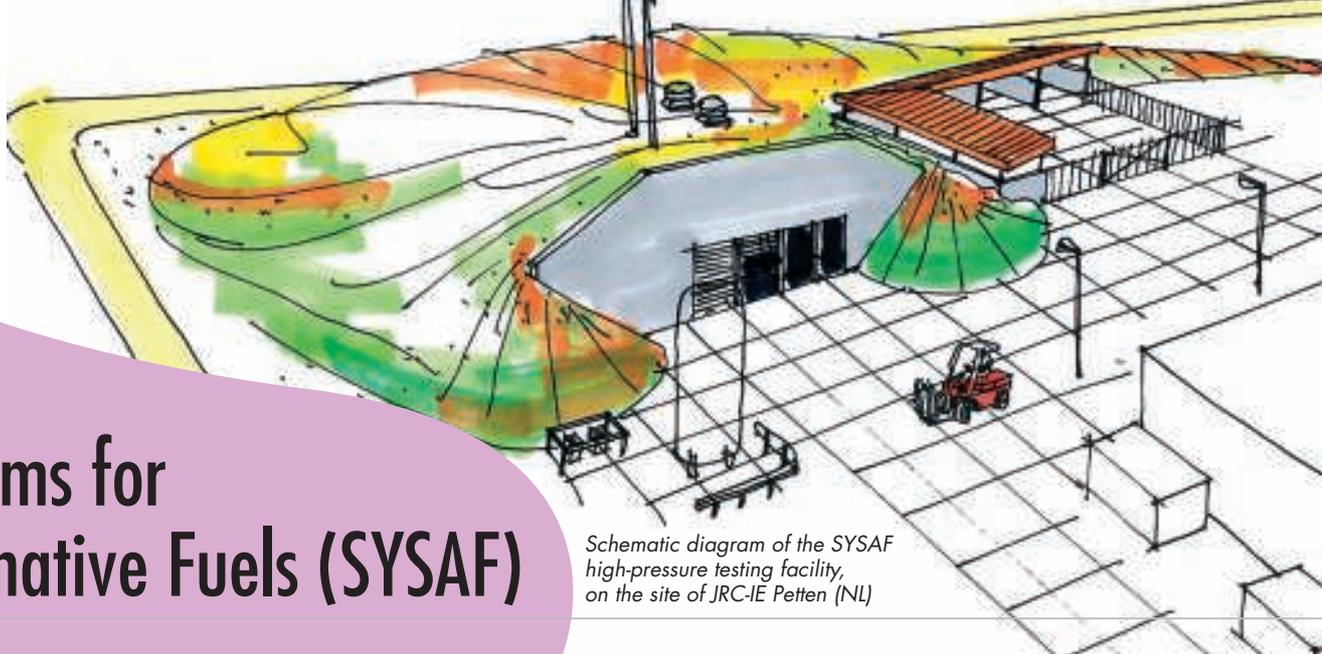
During 2003 the Clean Energies team enhanced its policy orientation through detachment of the ACETECH action leader to DG TREN. This contributed considerably to increased understanding of policy issues and their overall context, and to streamlining interaction for a smoother and more efficient policy support in the future.

Impelled by growing political awareness world-wide of the need for de-carbonising economic activity and the opportunities offered by developments in sustainable energy technologies, the JRC-IE is involved in and contributes at different levels to the EU Hydrogen and Fuel Cell Technology Platform, to the International Partnership for the Hydrogen Economy, as well as to other international partnerships.

## Elements of the H<sub>2</sub>-chain experimentally addressed at IE



# Systems for Alternative Fuels (SYSAF)



Schematic diagram of the SYSAF high-pressure testing facility, on the site of JRC-IE Petten (NL)

## Background

Air quality concerns, greenhouse gas emissions and the security of energy supply being the key drivers, alternative fuels attract considerable interest in the EU. The Green Paper "Towards a European Strategy for Energy supply" (COM (2000) 769) proposes an ambitious programme for the road transport sector. The use of alternative fuels is promoted, with the aim to have them accounting for 20% of the total fuel consumption by 2020 (COM (2001) 547). The action plan of the Commission now focuses on the promotion of biofuels, natural gas and hydrogen.

The development of alternative fuels calls for a major effort in terms of research and technological development. Through its action Systems for Alternative Fuels (SYSAF) IE focuses on the study and evaluation of fuel storage, of distribution and of safety sensor technologies providing the automotive and transport industry with reliable information on the design of on-board energy storage, upstream of the fuel cell or modified internal combustion engine. The fuels include natural gas and gaseous hydrogen stored under high pressure in lightweight tanks and hydrogen stored in solid-state systems.

Safety being a crucial issue, SYSAF supports, in collaboration with other EU stakeholders, the standardisation process by identifying best practices and establishing harmonised testing methods.

## Pressurised Gas Storage - Tank Testing Facility

In 2003, most of the effort of the high-pressure activity was devoted to the engineering of the new full-scale tank testing facility ("Safety Cell"). In parallel, the documentation required by the local authorities in the frame of the stringent environmental permit was finalised.

In order to establish partnerships with key players in the alternative fuels storage field, SYSAF participated in 2003 to the submission of a FP6 Network of Excellence proposal (Hysafe) and an Integrated Project proposal (StorHy). Both were successful and are due to start in March 2004.

The SYSAF task on high-pressure storage contributed to an Enlargement action workshop with a presentation on the state-of-the-art in high-pressure storage systems for vehicles. A first version of a report, to be finalised in 2004, is devoted to the identification of pre-normative R&D work needed for the safe and effective implementation of hydrogen (and natural gas) storage.

## Solid-State Storage

The experimental activities concentrate on underpinning research to assess the performance, efficiency and overall potential of solid-state materials as innovative hydrogen storage systems. Special attention is paid to benchmarking, harmonisation, validation and standardisation of data and necessary test methods/procedures for the performance characterisation and life-cycle stability of solid-state materials. As part of recent investments, testing facilities have been acquired. They are based on two of the most prominent methods for determining the hydrogen sorption/desorption capacity of hydrides and carbon structures and include a fully automated Gas Reaction Controller and a Gravimetric Analyser Unit able to conduct Pressure-Composition-Isotherms, dynamic, kinetic, and cycling measurements. Also undertaken within this Task, under the SETRIS-ACETECH umbrella, was the preparation of an EUR report on the state-of-the-art of hydrogen storage technologies and future perspective (EUR 20995EN).

## Hydrogen Safety Sensors

All energy carriers necessarily have safety systems built into their production, distribution, and use. Hydrogen production, storage and distribution facilities, fuel cells, hydrogen fuelled systems (e.g. H<sub>2</sub> fuelled vehicles), must be equipped with reliable and effective hydrogen sensors and automatic shut-off systems to protect from any leaks, and enhance



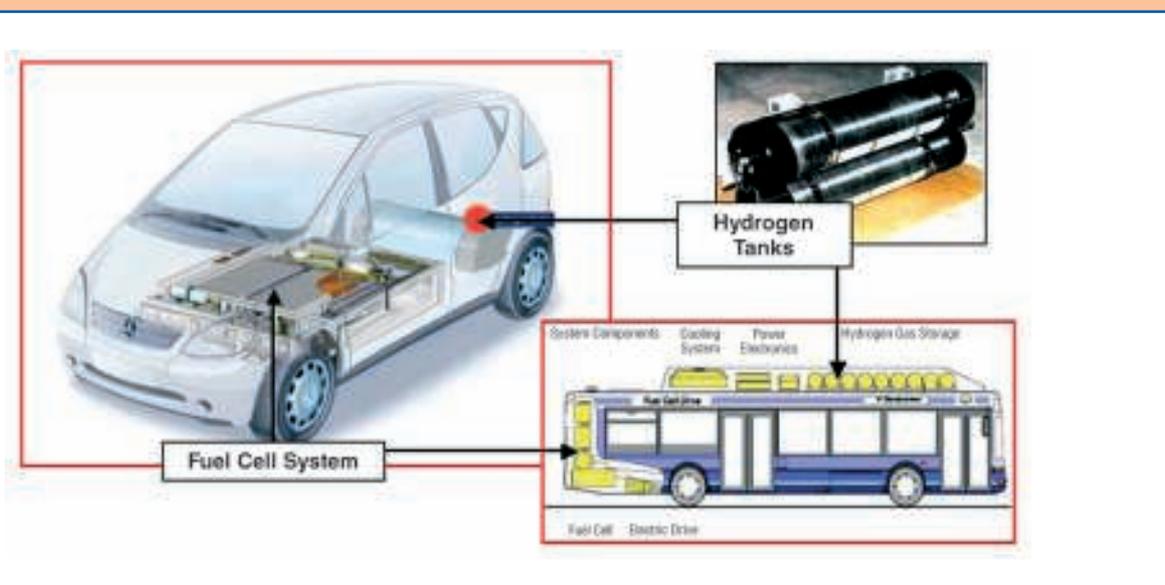


safe operation. For these reasons, SYSAF has started the establishment of a facility for testing and validating the performance of hydrogen safety sensors under a range of conditions. The activity, which is expected to produce the first experimental results by the end of 2004, has the following major objectives:

- To set up and develop, over 2004-2005, a facility to test the performance of hydrogen safety sensors under the influence of a range of environmental conditions representative of those expected in use;
- To use this facility to provide assistance to companies developing these devices in meeting stringent performance requirements demanded by users and certification bodies;
- In cooperation with manufacturers and users, to develop a standard procedure for testing the performance of these sensors in a controlled environment.

### Enlargement Activities

A two-day training workshop, "Safety, Efficiency & Performance of Innovative Hydrogen Storage Technologies for Road Transport", was held at Petten on 9-10 October 2003 as part of the JRC Enlargement Action. Fifteen delegates attended the workshop from 10 out of 13 EU Enlargement countries, namely Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia and Turkey. The workshop was targeted at young researchers (average age of the participants was 30 years), and aimed to illustrate the activities of IE in the field of hydrogen storage and safe use, mostly within the frame of the SYSAF Action. Presentations were given by IE researchers and covered hydrogen storage under pressure, in solids (nanotubes, hydrides, etc.), and hydrogen safety sensors. In cooperation with the SETRIS Action, the workshop was opened with an extended description of the role of hydrogen as an alternative fuel for transport.





# Clean and Efficient Energy from Waste and Biomass (CLEANWEB)

## Background

CLEANWEB is carried out in the frame of Community policy objectives related to waste management and to energy as presented in documents such as the Green Paper on "Security of Energy Supply" [COM(2000)769], the Communication "Promotion of Electricity from Renewables" [COM(2000)279] and the Community policy on Integrated Pollution Prevention and Control [96/61/EC]. The Action provides S&T expertise on a long-term basis to the Commission for policy development and implementation work, as well as to international organisations (International Energy Agency, International Solid Waste Association) and to relevant industrial partners both in the EU and in Candidate Countries. For the relevant waste and biomass industries, including both power and fuel (e.g. H<sub>2</sub>) production, and their support organisations, the Action facilitates direct scientific and technical collaboration, through the PREWIN<sup>1</sup> network and other consortia, for technical projects aimed at increasing plant and energy efficiencies and minimising emissions.

In 2003 the key areas of activity included direct support to policy at community level, underpinning research in collaboration with other research institutes and industry on subjects linked to energy efficiency and plant reliability, operation of the PREWIN network, assisting in the JRC Enlargement activity, training young researchers and expansion of the Action scope to include the production of alternative fuels from waste and biomass.

## Policy Support

Work included monitoring the implementation of the Waste Incineration Directive (2000/76/EC), provision of information for compilation of the Waste Incineration BREF, taking part in the formulation of the Environmental Technologies Action Plan (ETAP) and discussions on up-dating the documents related to the Waste Framework Directive (75/442/EEC).

<sup>1</sup> PREWIN European Network: Performance, Reliability and Emissions Reduction in Waste Incinerators

## PREWIN European Network

The network has continued to expand in terms of membership and activities. The current membership stands at 75 organizations from 15 EU, EU Candidate and non-EU countries. This year has seen increased membership from the Candidate Countries, particularly Poland, Czech Republic and Slovenia. Network members from Czech Republic and Germany hosted two General Assembly and Steering Committee meetings in May and November, respectively. The network continues to develop and up-date technical documents. A new document on Thermal Spray Repair Procedures has been produced. A technical paper has been written on N<sub>2</sub>O generation, emission and abatement. Laboratory and plant scale exposure testing continued on both existing alloys and coatings for boiler components as well as candidate replacement materials. PREWIN made a specific contribution to the waste incineration BREF on the subject of secondary combustion and the 850°C/2 second rule.



### Laboratory Studies

Underpinning research carried out in the Plant Simulation Test Laboratory (PSTL), partly in collaboration with partners of 7 Shared Cost Actions, resulted in the following main achievements:

- A miniaturized CO sensor, with cooling system (including phase change material) capable of maintaining a maximum temperature of 100°C while in the burning bed of a waste incinerator, was built and tested for eventual operation in a multi-sensor for modelling of grate combustion;
- From study of the effects of deposits in biomass boilers on the performance of heat exchangers a negative influence of CO<sub>2</sub> was identified, this finding having key relevance for CO<sub>2</sub> capture in combustion processes;
- The collection and validation of thermodynamic and corrosion data has enabled the building of a dynamic model for the prediction of component performance in waste and biomass combustion systems; the model should reduce the scale of future laboratory/plant programmes;
- Results of oxidation tests on thin foils has enabled the building of models for the prediction of the useful lifetime of components including particle filters and catalyst supports in flue gas cleaning systems.

*Components of a new CO sensor for operation on the grate of a waste incinerator*



- The PSTL has been used in an international project to determine a code for thermal cycling oxidation testing;
- Characterisation of a novel electrically conducting non-oxide ceramic has revealed the potential for use as an on-line oxidation probe in combustion processes;
- A new sensor for HCl, capable for on-line operation at elevated temperatures has been built and tested and the necessary proposal prepared for a patent application;
- A Research Training Network project started to evaluate protective coatings for enabling future higher thermal efficiency waste and biomass combustion.

### Enlargement Activities

The CLEANWEB Enlargement effort, started in 2001, was continued throughout 2003 and involved 2 workshops and the issue of 3 orders for small-study contracts on CLEANWEB-related topics. The two information workshops were:

1. Bled (Slovenia), November 4th & 5th 2003, "Waste & Biomass to Energy – Technical, Environmental and Social Considerations". The workshop was attended by representatives from, Croatia (1), Latvia (1), Malta (3), Poland (2), Romania (1), Slovakia (3), and Slovenia (14). Invited experts were from: Denmark (1), Ireland (1), Italy (1), The Netherlands (3) and the United Kingdom (1).
2. Bergen (Netherlands), December 9th & 10th 2003, "Recovered Fuels from Waste and Biomass; Methods of Syngas/Biogas Production and Cleaning; Fuel Utilisation for Energy Production". The workshop was attended by 9 participants from 7 Candidate Countries, Bulgaria (1), Hungary (1), Malta (1), Romania (3), Slovakia (1), Slovenia (1) & Turkey (1), one visitor from JRC-IES (Ispra) and 4 representatives from JRC-IE (Petten).

The subjects of the 3 small study contracts, for delivery in 2004, were: a) small-scale biomass plants for distributed power/heat generation, b) cleaning of syngas from waste or biomass gasification/pyrolysis for storage or direct use for energy production and c) novel flue gas cleaning systems for waste and biomass energy production plants.

### Training

During the year CLEANWEB hosted 2 PhD students, 4 post-docs and 1 visiting scientist, all of who contributed to various parts of the scientific work of the Action. Six out of the 7 visitors were from Candidate Countries.

# Fuel Cell Systems Performance Testing & Standardisation (FCTEST)

## Background

EC backing of the potential of Fuel Cells (FC) and of hydrogen as an important future energy carrier has been confirmed by President Prodi, Vice-president Mrs. De Palacio, and Commissioner Busquin during the launch of the High Level group on Hydrogen and Fuel Cells in October 2002. However, FC technology is not yet mature and needs to be further developed. For the rating of technology improvements commonly agreed measures for system efficiency, power density, dynamic behaviour and durability are indispensable. This requires the definition of harmonised testing procedures both for entire FC systems and for system components, and a large variety of parameters needs to be monitored resulting from different applications and stack technologies, various types of fuel, fuel quality, etc. Currently no standardised test procedures for FC cells, stacks and systems are available. Similarly, no standardised test procedures exist for the assessment of FC systems against user requirements for stationary, portable and transport applications. In practice many laboratories have developed their own test protocols to meet the needs of their own or national R&D programmes. The impartial role of the JRC-IE in the European Research Area (ERA) makes it ideally suited to embark upon these harmonisation tasks in compliance with the subsidiarity principle and the JRC-IE mission.

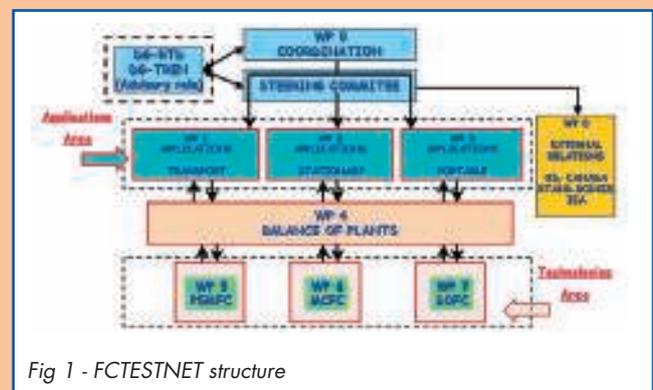


Fig 1 - FCTESTNET structure

## Achievements

The Fuel Cell systems performance TEsting & Standardisation (FCTEST) Action of IE started in January 2003. The action is structured around three major objectives:

- To set-up the Fuel Cell Testing Facility and assess the performance of Polymer (or Proton) Electrolyte (or Exchange) FC (PEMFC) stacks;
- To acquire and consolidate a position on the international scientific scene through networking / co-ordination of FCTESTNET (see below);
- To enhance scientific insight of FC performance through mathematical modelling of the complicated physical laws pertinent to FC to guide future testing activities;
- In 2003 the focus was to complete the testing facility, finalising its concept layout (see artistic impression above), the investment plan, and acquiring the necessary licenses. The state-of-the-art facility is equipped with:
  - Fuel Cell Automated Test Station for testing PEMFC stacks up to 100 kW;
  - Vibrating table with simultaneous control of six degrees of freedom;
  - Environmental chamber operating in the temperature range from -40°C up to +60°C, and relative humidity up to 95%;
  - Gas analysis equipment.

The FCTESTNET FP 5 thematic network was launched in January 2003 with 55 partners (see Fig.1) with JRC-IE as scientific coordinator. The main objectives of FCTESTNET are:

- To compile and harmonise existing and further develop testing procedures for FC, stacks and systems;



- To map FC testing competencies within EU;
- To establish links between EU and US, Japan, and international standardisation bodies in the frame of harmonising FC testing procedures.

Test procedures, standards and regulations play a key role in making FC technology accessible and the JRC-IE operated FCTESTNET has been accepted as the preferential exchange and co-operation platform between EU and US DoE in FC testing and standardisation.

FC performance under a given set of experimental conditions is influenced by a large variety of different parameters. Measuring all of these, as well as their inter-dependencies, quickly exceeds the experimental feasibility. Hence, to support future testing activities, the FCTEST action worked on mathematical modelling of the complicated physical laws pertinent to FC with the aim of identifying cell-limiting mechanisms. After experimental validation in the test facility, such cell models can subsequently be used to forecast cell performance in design, scale-up, and optimisation.

So far, well-specified 2-D numerical experiments have been performed to determine performance in terms of several factors. They simultaneously accounted for electrochemical kinetics and multi-component species transport, and considered different FC components (flow channels, gas diffusion layers, catalyst layers and the membrane). Fig. 2 shows the considered along-the-flow PEMFC model.

An exploratory research project was awarded to the action: SIMulation of transport phenomena in physico-chemical processes within porous structures using the LAttice-Boltzmann method (SIMLAB). This method represents an alternative to conventional finite element, finite difference and finite volume methods, and has its theoretical basis in statistical physics. The project aims at application and linkage of micro-structural analysis techniques and lattice-Boltzmann flow calculations, to yield a microstructure-based simulation tool. It is intended to use this tool initially for simulating the performance of Gas Diffusion Electrodes in PEMFC and Solid Oxide Fuel Cells (SOFC), and subsequently expand its use to simulation of overall FC performance.

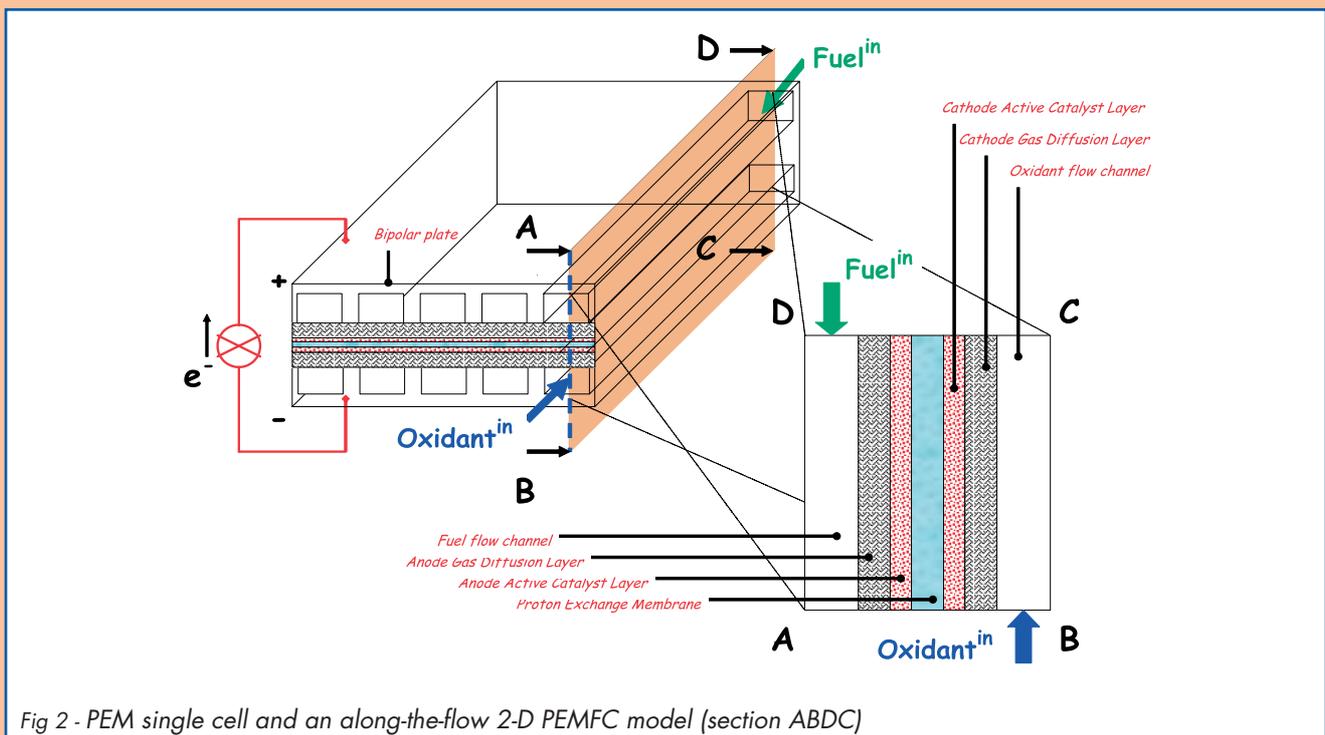


Fig 2 - PEM single cell and an along-the-flow 2-D PEMFC model (section ABDC)

# Sustainable Energy Technologies Reference and Information System (SETRIS)

## Background

The Sustainable Energy Technologies Reference and Information System (SETRIS) ISA (Integrated Scientific Area) responds to the needs of policy makers for a continuous flow of unbiased, accurate and validated scientific and technical information, data and assessments on energy technologies that are necessary for underpinning an effective sustainable energy policy. To achieve its mission, SETRIS draws upon the specific expertise and input of individual actions in the JRC Multi-annual Work Programme (MAWP) from a number of Institutes, namely IE, IPTS, IES, ITU and IPSC, facilitating the synergies between them and maximizing the effectiveness, breadth and depth of contributions (e.g. de-fragmenting expertise, sharing know-how and tools, and reinforcing coordination).

SETRIS operates both pro-actively and in response to specific requests from its partner policy DGs. Its primary functions include (i) techno-economic assessment of energy technologies, technology mapping, energy technology watch, (ii) modelling of energy systems, scenario building for energy outlooks, and (iii) collection, validation and harmonisation of information and data as necessitated to underline its other two functions. Ultimately, SETRIS strives to evolve into a credible and indispensable Scientific Reference System (SRS) on sustainable energy technologies and to become the main JRC entry point for requests from policy makers and the source for all related JRC outputs on such matters.



IE coordinates and leads the SETRIS Board and contributes to its function with a dedicated Action, the “New and clean energy technologies assessment system – ACETECH”. ACETECH focuses on selected energy technologies, namely hydrogen and natural gas technologies as well as on carbon management options (e.g. carbon sequestration). It also covers clean coal with regards to co-production of de-carbonised electricity and of alternative fuels, and technological options for distributed power generation.

## Achievements

In 2003 significant steps were made towards integrating and embedding working links between all JRC activities that are part of SETRIS, under the auspices of the SETRIS coordinator at IE. The SETRIS concept and its strategic orientations were discussed in the first JRC energy workshop (led by ACETECH), leading to the establishment of a steering board and drawing up the principles for a JRC strategy on energy. The links amongst institutes have been strengthened, as presently demonstrated by a number of ongoing collaborative projects. The established SRS on renewable energy and end-use efficiency, accepted as the model case to move forward, is fully supported by all pertinent JRC activities and is currently expanding at IE with the assistance of all related JRC actors, setting the foundations for a broader SRS on sustainable energy technologies and addressing at first instance the bio-energy pillar.

## Policy Support

SETRIS continued building strong links with customer DGs, primarily with DG TREN (where the SETRIS co-ordinator was detached for 8 months), as well with DG ENV and DG RTD.

SETRIS provided recognized input to a number of actions related to energy policy (including the use of energy in transport). More specifically, it supported the Commission’s work in the follow-up of its Communication on alternative fuels by contributing to the Alternative Fuels Contact Group (AFCG) by producing reports, making presentations, validating information and offering its expert opinion. In the context of assessing energy technologies, ACETECH produced a techno-economic assessment report on carbon sequestration. This report was used as the S&T reference for drafting the briefing papers for Vice President, Mme de Palacio and Commissioner Busquin, in preparation of the Commission’s position on joining the ‘Carbon Sequestration Leadership Forum’, a US-led initiative for international



cooperation on carbon sequestration. This report is also referenced in the final report of the AFCG. An additional techno-economic assessment report on hydrogen storage technologies was prepared in the frame of the Commission's hydrogen activities.

ACETECH participated and supported the Commission's efforts for advancing with the recommendations of the High Level Group on hydrogen and fuel cells, in setting up the European Hydrogen and Fuel Cells Technology Platform. Similarly it led the JRC contributions to the work of the Inter-Service project team of the Commission for hydrogen and supported the IPHE (International Partnership for the Hydrogen Economy) initiative by contributing to meetings and reviewing position papers. In the same context, ACETECH together with 2 other organizations prepared a successful proposal for a Specific Support Action call (FP6), to assume the Secretariat tasks of the Hydrogen and Fuel Cells Technology Platform.

In the course of 2003, SETRIS also contributed to other policy areas, including the 'follow-up' of the Green Paper on the security of energy supply by analyzing the evolving geopolitical scene as this may affect fuels and technologies of choice.

ACETECH contributed to the work of the Commission for sustainable aviation transport, functioning as the assigned EC Observer in the International Civil Aviation Organisation (ICAO) / Committee for Aviation Environmental Protection (CAEP) in the Working Group 3 "Technology and Emissions"; it participated in the negotiations for a new NOx standard in aviation and contributed on the role of technological innovation for stringency measures in environmental regulations.

### 2003 Output in short:

- 2 techno-economic assessments of energy technologies;
- 2 peer-reviewed publications submitted;
- 2 position papers;
- 3 external presentations and several in meetings organised within the Commission;
- Led the JRC review of 3 inter-service consultations on energy relevant issues;
- Acted as reviewer of 3 external studies commissioned by DG ENV and by DG TREN;
- 8 person-months of detachment to DG TREN/ Directorate D/ Clean Urban Transport;
- Initiator of forthcoming JRC energy strategy.



# European Pressure Equipment Research Council (EPERC)

## Background

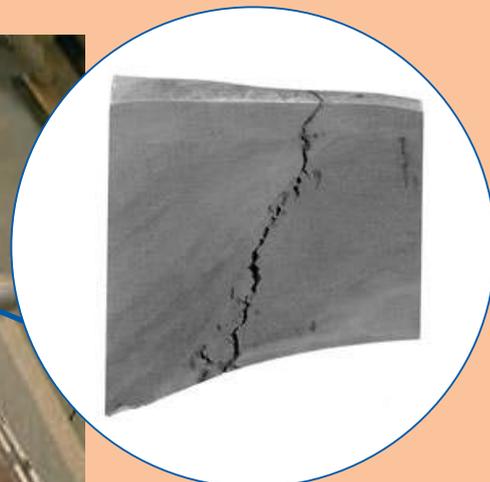
EPERC is carried out to support the pressure equipment industry and those sectors that rely on such equipment, in particular the energy and petrochemical sectors. It is carried out in support of the implementation of the EC Directive on Pressure Equipment (PED 97/23/EC) and other measures for the prevention of major industrial hazards associated with pressure equipment which require harmonised standards and best practices for equipment design, manufacture and safe operation. The Action provides S&T expertise to underpin the operation of the EPERC network which was founded in 1995 and currently numbers more than 200 participating organisations from numerous European countries. The Action helps to assemble its Reference Laboratories and contributes scientific expertise and research results to the various Technical Task Forces established within EPERC. The Action also covers responsibility for Technology transfer/dissemination of results through Technical Bulletins, newsletters, a dedicated web-site and seminars. It lends direct support to DG Enterprise regarding actions in support of the PED implementation and provides an input to the DG TREN Working Group on "Codes and Standards" in order to support harmonisation of safety requirements and construction rules in the nuclear power industry. In an international context the EU Enlargement action is supported through training, technology transfer, and monitoring of PED implementation whereas, further afield the implementation of a MoU between EPERC and the US and Japanese Pressure Vessel Research Councils is to be executed.

## Policy Support

In 2003, the action continued to support the implementation of the Pressure Equipment Directive (97/23/EC), which came into force in May 2002, through seminars and technology transfer to the Accession States and, in particular, through its input as advisor to DG ENTR concerning an external contract entitled Comparative Study of PE Design Codes. Through its invited membership of the International Advisory Board, advice could be offered to the Polish Centre of Excellence on Pressure Equipment, PRESAFE.

## EPERC Network

The network has continued to expand in terms of membership and activities. By the end of 2003 the membership had risen to 214 organisations from 23 EU Member and Accession States and EEA countries. This year has seen increased membership from the Candidate Countries, particularly Poland, Czech Republic and Slovenia. The first Steering committee meeting of the year took place at JRC Petten and the General Assembly and second Steering Committee meeting was hosted in Gent, Belgium in October. Both Steering Committees were of great importance for the future of EPERC, as a preliminary study of the economic viability of EPERC with its development into a self-standing organisation had been commissioned at the beginning of the year, as a result of the JRC giving an indication that it may, at some stage, withdraw from its role as network Operating Agent. In July a clear statement came from JRC as to its withdrawal at the end of 2003 and considerable effort was directed





*EPERC exhibition at the 10th International Conference on Pressure Vessels Technology*

to finding a suitable organisation to succeed it. Through a tendering system, a successor was found in BAM, Berlin and the decision ratified at the September Steering Committee meeting. A deadline for transferring all archives and instruments from JRC to BAM was set as the year end and was duly achieved.

In spite of this important matter, the EPERC Network has managed to continue to carry out its commitments to the FP5 projects, FITNET, RIMAP and INTEGRITY and also to prepare three new proposals for FP6. Two industrially relevant EPERC Technical Bulletins were issued on:

- Use of high strength steels in pressure vessels fabrication;
- Determination of gasket coefficients.

In addition, as an input to standards a Technical report on a Small Punch (SP) test method round robin exercise has been issued as a precursor to establishing a dedicated CEN activity in this area. The CEN Technical Groups, Design by Analysis and Creep, have also been supported by EPERC and JRC staff in making considerable progress allowing publication of a draft standard by the end of the year. Lastly, with regard to standards activities, a technical report on fatigue design has been passed on to the DG TREN Working Group on "Codes and Standards"

On the subject of external relations the Memorandum of Understanding with the American PVRC and the Japanese PVRC was finalised by agreement on technical co-operation and exchange of information in the three areas of Flanges & Gaskets, Repair, and Multiaxial Creep, with a meeting taking place in the United States to launch these co-operative activities in November 2003. JRC took on the responsibility for Multiaxial Creep preparing a position paper on the subject.

In order to strengthen EPERC PR, the JRC organised an EPERC exhibition at the 10th International Conference on Pressure Vessels Technology at the Technical University of Vienna in July 2003.

### **Laboratory Studies**

As the Action was to be terminated at the end of 2003, the laboratory studies were gradually run down. The main test campaign on behaviour and creep properties of petro-refinery steels in hydrogen environments was curtailed with the finalisation of a Ph.D. thesis and a conference presentation. A second sub-action directed towards standards for improved safety of high temperature pressure equipment for energy/petrochemical industries through the development of a Code of Practice on Small Punch (miniature creep specimen) Testing was limited to a contribution to the EPERC Round Robin Testing project. Publications were to be made in 2004 as a precursor to the launch of the CEN standard action. Additional experimental Small Punch Test studies related to assessment of hydrogen damage in petro-refinery steels were continued until the end of the year to enable the submission of a second Ph.D. thesis early in 2004.

With the decision to close down the unique component test facility the penultimate advanced verification test for component modelling for power plant components foreseen in the EPERC FP5 funded programme was completed on a large tee-piece, with a crack developing associated with the intersection weld. The design for the final test as a benchmark for combined bending load/internal pressure test on full scale pipe component was made for testing in 2004.



# Nuclear Safety

***“Nuclear power plant safety requires a continuing quest for excellence. All individuals concerned need constantly to be alert to opportunities to reduce risks to the lowest practicable level. The quest, however, is most likely to be fruitful if it is based on an understanding of the underlying objectives and principles of nuclear safety and the way in which its aspects are interrelated...”***

(International Nuclear Safety Advisory Group of IAEA, Basic Safety Principles of Nuclear Power Plants, INSAG-12)

The general objectives of the institute’s activity in the nuclear safety area are to develop and provide the scientific and technical knowledge on key issues of Nuclear Reactor Safety in support of EU policies and Commission Services through investigations on structural integrity, accident analysis, system interactions and risk assessment. Special emphasis is given to Enlargement related questions. A further objective is a broad and effective dissemination of related scientific results.

In the area of prevention of accidents the activity focuses on ensuring the structural integrity of components for the safe operation of nuclear facilities through:

- Material’s degradation research due to ageing;
- Qualification of inspection procedures;
- Investigations on the structural integrity of safety relevant components.

The output of the activity consists of unique materials evaluation and component testing tools for verifying advanced life assessment models and condition monitoring methods for operating power plant components.

In the area of mitigation of accidents, the emphasis lies on ensuring commonly validated and accepted code applications and on drawing conclusions for accident management measures through:

- Analysis of accidents by test interpretation, code verification and validation, selected bench-marking exercises on code applications;
- Development and inter-comparison of probabilistic and risk assessment methodologies;
- Support to the harmonisation of safety methodologies and procedures on selected safety issues.

In 2003, IE started an additional activity in the area of radioactive waste management, concentrating on the structural integrity aspects of waste canisters.



# Safety of Ageing Components in Nuclear Power Plants

## Background

Nuclear electricity accounts for more than one third of the total EU electricity production. The life distribution of current nuclear power plants is such that in 2005 more than 70% of them will have passed the 20-year lifetime and almost 30% the 30-year age limit. Hence from both the safety and security of supply viewpoints, ageing of these power plants is of increasing concern to the European policymakers, citizens and utilities, in particular also those from EU Candidate Countries. A policy of continuous R&D, plant life monitoring and surveillance is required to ensure that safety margins are maintained. JRC competencies are used to promote integration of fragmented R&D work, and to accelerate, through consensus, the harmonisation of European procedures and practices.

## Action description

SAFELIFE provides an integrated approach to R&D activities on critical issues for plant life management of ageing nuclear power installations. The focus is on establishing European best-practices for deterministic and risk-based structural integrity assessment of key components considering all nuclear power plant (NPP) designs both western and Russian-type. It exploits the IE's existing competence in characterisation of materials degradation, defect assessment, non-destructive testing, neutron methods and advanced modelling techniques for residual stress analysis, as well as developing appropriate new areas of expertise. The activities are organised as a series of major work packages addressing the key primary circuit components: Reactor Pressure Vessel (embrittlement models, ISI qualification, shallow flaw assessment), Primary piping (ISI, thermal fatigue, dissimilar pipe welds) and Internals (stress corrosion cracking).

A further series of work packages cover specific topics, namely: weld characterisation, maintenance methods, development of risk-based methods, NDE methods and testing, human factor influence, development of novel facilities, standardisation. Active components are not covered by dedicated R&D work at present, however they are included in the scope of the maintenance work package. SAFELIFE will continue to support European Networks and training activities within the frame of ERA.

The objectives and deliverables of the Action are summarised as follows:

- Develop and disseminate best practices, as a basis for harmonisation of European codes and standards on key primary components of light water reactors;
- Enhance JRC R&D competence and capabilities in nuclear safety technology, to support long-term EC policy needs on Plant Life Management (PLIM);
- Continue to exploit networks as a tool for integrating R&D efforts in line with ERA principles and for linking JRC R&D to utilities, manufacturers, R&D organisations and regulators. Further develop links to EC and international organisations;
- Implement an effective plan for training, mobility, dissemination and knowledge management and develop competitive activities complementing SAFELIFE objectives.

The action's partners are the members of the AMES, ENIQ, NESCS, NET, AMALIA & SENUF European Networks. The users are the involved DGs (DG-TREN, DG-RTD, DG-ELARG, DG AIDCO and DG RELEX) and outside the European Commission, the Utilities, Regulators, Network Member Organisations, IAEA, EPRI, OECD/NEA, NATO, CEN, ISO.

## Achievements in 2003

In its first year of operation, SAFELIFE Action has successfully carried-over a large number of co-ordinated tasks, clustered as follows: 17 scientific/technical tasks, 7 development tasks (facilities & competencies), 5 training and mobility tasks, 4 tasks on co-ordination with international organisations and 7 networking and competitive tasks co-ordination. The various tasks have allowed the successful integration of different FP5 projects into the new SAFELIFE Action and the progressive co-ordination of the 6 existing European Networks, See Figure 3.(in header)

The detailed technical achievements for 2003 are given grouped per competence in the following pages.

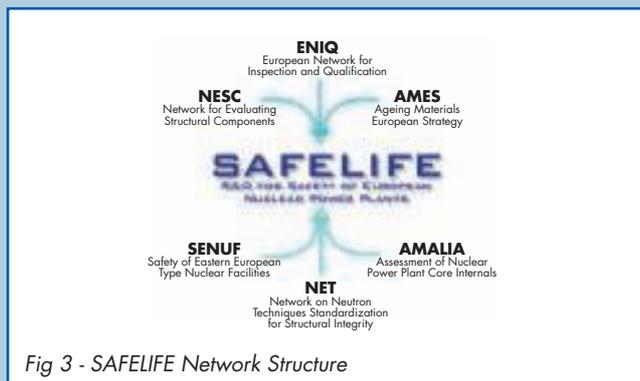


Fig 3 - SAFELIFE Network Structure

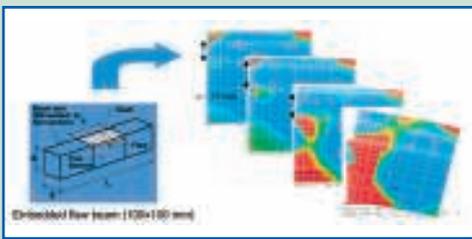


Fig 4 - Simulation of the fracture process in a bend test on a beam containing an embedded flaw

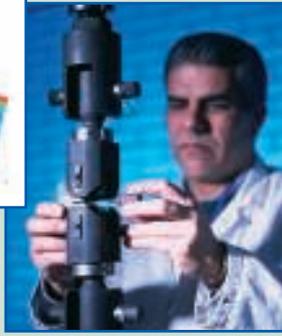


Fig 5 - Newly commissioned servo-hydraulic test facility allows precision fracture testing



Fig 6 - Preparation of the dissimilar weld assembly for blind trial on performance of non-destructive inspection for defects

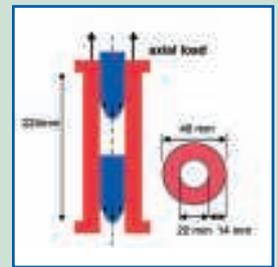


Fig 7 - Schematic of the thermal fatigue simulation technique, using pulses of cold water through a hot tube test piece

# Advanced Structural Integrity Techniques

As part of the SAFELIFE action a series of activities are carried out on the theme of advanced structural integrity assessment methods. These exploit the Institute's expertise in specialised mechanical testing techniques, computer-based modelling, non-destructive inspection and microstructural analysis. Several also support projects of the Network for Evaluating Structural Components (NESC), for which IE is the co-ordinator.

## Fracture of Shallow Flaws in Reactor Pressure Vessel Steels

Finite element software is used to perform detailed numerical simulations of the behaviour of structure subjected to thermal and mechanical loads. Figure. 4 shows such a simulation of a fracture test on a heavy section beam designed to simulate a shallow sub-surface defect in the wall of a reactor pressure vessel. The analysis confirmed that use of standard laboratory fracture toughness data (Figure. 5), to predict the fracture load, would be overly conservative in this case. The use, however, of additional "constraint" parameters can improve the accuracy of the assessment.

## Dissimilar Welds

Welds joining ferritic and austenitic pipe sections continue to provide a challenge for structural integrity assessment. As part of the NESC-III project the JRC is organising an international blind trial for assessing the performance of ultrasonic inspection techniques to detect and size flaws. A special welded pipe assembly has been prepared with implanted defects. Their exact details are kept secret from the participants and special measures have been taken to ensure no unauthorised X-rays are made (Figure. 6). Three European teams inspected the assembly in 2003, and the trials will be completed and reported in 2004. A further aspect of the Institute's support to NESC-III concerns the evaluation of the significant residual stresses present at these welds. Simulations of the full welding process have been made using finite element software, and the results are being benchmarked against those of other project participants, as well as neutron diffraction measurements made at the HFR

## Thermal Fatigue

Damage due to thermal fatigue remains an important issue for coolant lines in ageing reactors. A dedicated rig has been developed to simulate this type of cracking under controlled conditions for tubular test pieces in 316 L(N) stainless steel (Figure. 7). Under the applied down-shocks ( $\Delta T_{max} = 375^{\circ}\text{C}$ , frequency = 0.02 Hz) a network of

cracks initiates at the inner surface of the test component. An ultrasonic time of flight diffraction technique has been developed to measure the distribution and crack depths in the range 0.5 to 5 mm. In parallel, a coupled thermal-stress finite element analysis was used to simulate the local stresses and plastic strains. The predicted values of cycles to initiate cracking are in good agreement with the test results available to date. A further level of analysis sophistication is being explored using a crystal plasticity model to simulate a set of 212 crystal grains of random size and shape. The feasibility of introducing a short surface crack into this type of model has been demonstrated.

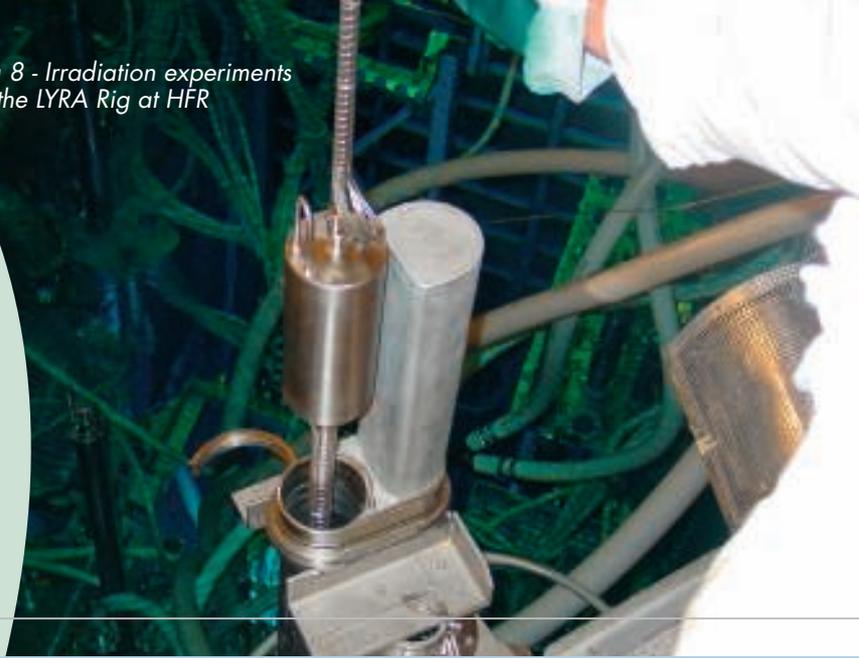
## Support to the HFR

The structural integrity assessment team also provided support to the HFR, in particular to the Weld 22 Action Plan. Results of in-service inspections, materials testing on the 5154-O aluminium alloy, weld residual stress distributions and finite element stress analysis were combined in an integrity assessment. This demonstrated that safe operation of the weld could be assured until the foreseen end-of-life in 2012. A probabilistic fracture study was also made for a section of the coolant piping.

## NESC Network

NESC brings together a group of 24 organisations to perform R&D projects designed to verify structural integrity assessment procedures using large-scale experimental projects and produce consensus recommendations for best practices. Two projects were on-going in 2003. NESC-III addresses integrity of dissimilar welds and is focussed on a large-scale test, which was successfully performed by EDF in July 2003. NESC-IV is an experimental/analytical programme to develop validated analysis methods for transferring fracture toughness data generated on standard test specimens to shallow flaws in reactor pressure vessel welds subject to biaxial loading in the lower-transition temperature region. The bulk of the post-test analyses as completed in 2004 and the final report is now in preparation. A new initiative for the network was the launch of the NESC-Thermal Fatigue project, which aims to develop a European Methodology for assessing thermal fatigue in LWR components. Further information on the NESC activities and reports is available on the web site (<http://safelife.jrc.nl/nesc/>) and the JRC's On-line Data Information Site (<http://odin.jrc.nl/ne/>).

Fig 8 - Irradiation experiments in the LYRA Rig at HFR



# Ageing of Reactor Materials

Within the SAFELIFE Action a series of activities are carried out on the evaluation and study of the issues related to materials and components ageing, neutron embrittlement and irradiation studies. These exploit the Institute's expertise in specialised irradiation technology in HFR, mechanical testing techniques, modelling, non-destructive inspection and micro-structural analysis.

The achievements of 2003, summarised in several published works in peer reviewed journals and international conferences are covering mainly the issues of:

- Understanding irradiation damage of RPV materials and the role of neutron fluence, chemical composition, material structure, irradiation temperature, neutron field parameters, etc.;
- Improving forecasting and use of RPV surveillance data;
- Predicting RPV materials behaviour after annealing;
- Qualifying NDE techniques to complement destructive methods;
- Irradiation experiments in the LYRA Rig at HFR, see Figure 8.

Western and Russian-type materials are involved in the various activities which are undertaken as international co-operation projects with key players in the EU, Candidate Countries and NIS countries. In particular for the Enlargement Countries especial emphasis is given in Workshop Trainings for young scientists, see Figure 9. Technical tasks to support IAEA are carried out.

## AMES European Network

The AMES (Ageing Materials European Strategy) European network started its activity in 1993 with the aim of studying ageing mechanisms and remedial procedures for structural materials used for nuclear reactor components. Operated by JRC-IE, it has been supporting the co-ordination of the project cluster throughout the 4th and 5th EURATOM Framework

Programs, carrying out partnership projects with plant life management implications. Among them we can list the development of non-destructive techniques applied to thermal ageing and neutron embrittlement monitoring (AMES-NDT and GRETE), improved surveillance for VVER 440 reactors (COBRA), dosimetry (AMES-DOSIMETRY, MADAM and REDOS), chemical composition effects on neutron embrittlement (PISA) and advanced fracture mechanics for integrity assessment (FRAME). AMES brings together the key organisations in Europe dealing with radiation embrittlement issues in RPV's.

In 2003 the AMES European Network focused its attention to carry out its ATHENA Concerted Action and to launch the new projects on model steels and realistic welds. The Work-Packages constituting ATHENA are as follows:

- Linking AMES strategy with Eastern Europe;
- Master Curve;
- Annealing and re-embrittlement;
- Radiation embrittlement understanding;
- Ageing mechanisms.

Further information on ATHENA is available on the web site (<http://safelife.jrc.nl/ames/projects/athena/athena.php>).

Further information on the AMES activities and reports is available on the web site (<http://safelife.jrc.nl/ames/>)



Fig 9 - Workshop Trainings for young scientists



# Nuclear Component Inspection and Qualification

The work towards European harmonisation of the utility approach on Risk-Informed In-service Inspection (RI-ISI) progressed with the drafting of a Framework document for RI-ISI best practice (in co-operation with network partners). JRC, in conjunction with the European Network on Inspection and Qualification (ENIQ) replied to the Nuclear Reactor Working Group (NRWG) invitation to discuss key regulatory concerns in the application of RI-ISI in a meeting at DG TREN. The institute also developed a basic program for probabilistic structural integrity assessments and performed an initial study of how to extract quantitative NDE information (probability of detection) from the qualitative inspection qualification process, to be used in the RI-ISI process.

The ENIQ 2nd pilot study, designed to explore and develop the use of technical justifications in Inspection Qualification, went ahead with the completion of the inspection procedure. A major milestone in the ENIQ 2nd Pilot study was the completion of a 5 tonne boiling water reactor nozzle qualification mock-up, with simulated cracks and defects manufactured by the SAFELIFE Reference Laboratory. JRC also developed an experimental procedure to measure the influence of cladding on the ultrasonic sound field and performed computer modelling of defect responses.



JRC was visited by Japanese delegations from TEPCO and JNES, interested in non-destructive testing and the ENIQ methodology for Inspection Qualification. A meeting was held with EPRI to discuss nuclear safety research, especially risk-informed decision making/RI-ISI.

As invited speaker to the IAEA meeting "Progress in ISI Qualification, Paks NPP (HU), the ENIQ manager gave support to Candidate Countries (CCs) in the field of Inspection Qualification, as was done via active participation of CC organisations in ENIQ network meetings and the Shared Cost Actions, SPIQNAR and NURBIM.

## Support to HFR

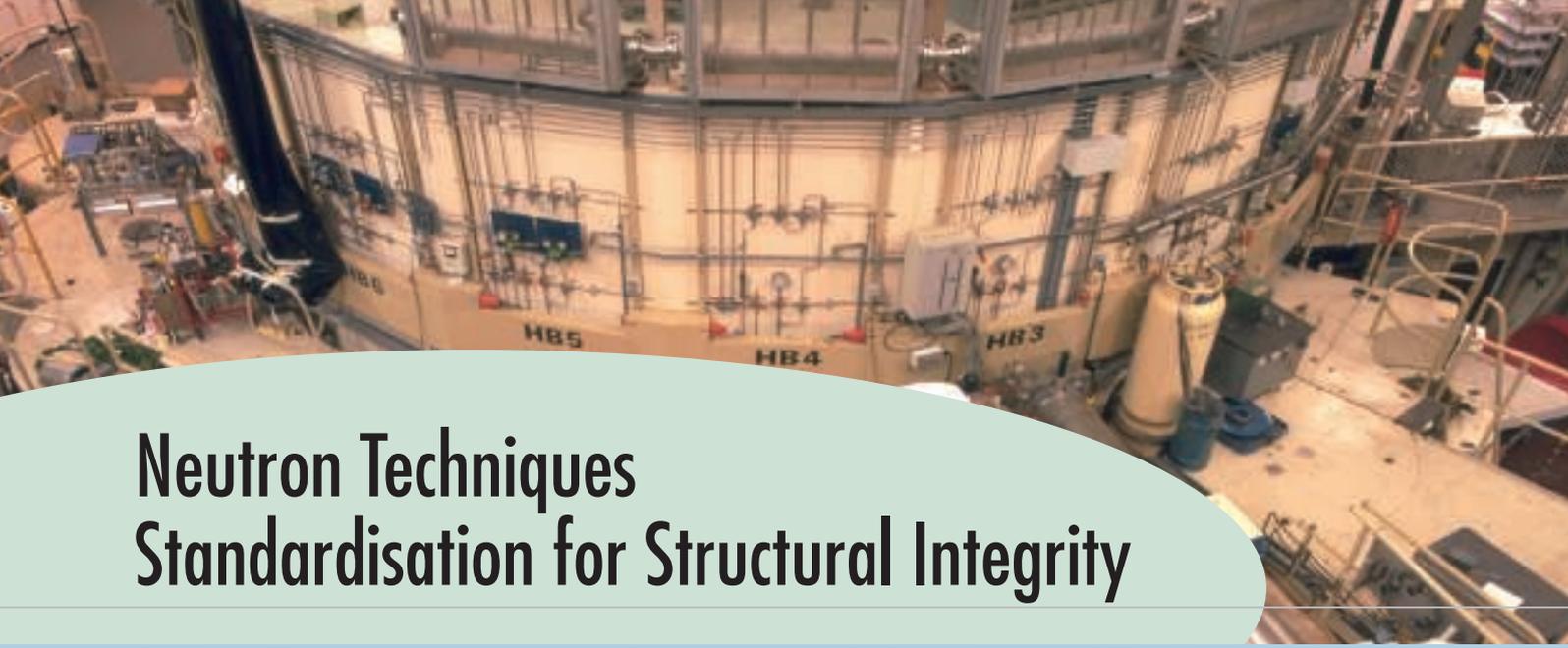
The Inspection Management team gave substantial support to the safe operation of HFR.

- Support to the HFR Weld 22 Life Management Project: work on the implementation of the ISI, including project management, technical investigations in support of the vendors NDT technique development, meetings with vendor, qualification body and regulator, design and manufacturing of qualification blocks in aluminium and qualification of the manipulator on the spare vessel;
- Regular participation to the Petten Reactor Safety Committee;
- Support to the Human Performance enhancement program; participation to the HFR Safety Culture Group, organisation of Self-Assessment Workshop for HFR Safety Culture, SWOT analysis based on Self-Assessment and interviews with HFR staff.

A web based database with information on European test pieces for inspection qualification was launched, in co-operation with IAEA, and the SAFELIFE related web pages were developed with a more coherent design and structure for Network and projects homepages.

JRC finalised the proceedings for the "Joint EC-IAEA Technical Meeting on Improvements in In-Service Inspection Effectiveness (EUR20690EN), organised by JRC in Petten, November 2002 and contributed to the finalisation of the IAEA TECDOC: Criteria and Recommendations for In-service Inspection Effectiveness Improvement.

A successful proposal for a FP6 specific support action called GAIN - Gap analysis for long-term inspection needs for NPPs - was submitted with two partners (contract negotiation completed April 2004).



# Neutron Techniques Standardisation for Structural Integrity

This action supports progress toward improved performance and safety of European energy production systems. The state of the art in assessing internal stresses, micro-structure and defects in welded nuclear components - as well as their evolution due to operational loads and irradiation exposure - needs to be improved before relevant structural integrity assessment code requirements can safely become less conservative. This is valid for both experimental characterisation techniques and predictive numerical algorithms. To address this need, 35 major industrial and research/academic organisations have joined forces, under JRC-IE co-ordination, to launch a dedicated European network, NET, in May 2002, representing major nuclear industries and most European neutron facilities from 7 EU states and 5 Candidate Countries. During 2003 the NET Steering Committee met twice and significant progress has been made on fine tuning the work programme of the network three Task Groups (TG).

## **TG1. Residual stress analysis on a single bead weld on a steel plate**

- *Specimen preparation and material characterisation:*  
Four specimens have been supplied and are currently used for NDT round robins and for destructive testing. Welding conditions, temperatures and back-face transient strains have been fully monitored. Neutron diffraction testing has shown that the specimens do not pose grain size problems. Specimens have also been manufactured for tensile measurements of parent material and weld beads deposited on off-cuts, and have already been tested for mechanical property characterisation.
- *Neutron and X-ray diffraction round robins:*  
Based on the finalised experimental protocol, the non-destructive stress measurement round robins have commenced. Up to now three facilities have performed neutron diffraction tests and two, X-ray diffraction testing.
- *Numerical modelling round robin:*  
It was decided that the initial FE analysis protocol for the NET-TG1 Computational Round Robin should be revised and issued in 2 parts, due to lack of mechanical properties data. Part 1 of the protocol will refer to the thermal analysis alone, whereas part 2 to the mechanical analysis.





### **TG2. Stress relief heat treatments in welded steel plates**

- *Specimen preparation and materials characterisation:*  
The agreed specimens have been recently manufactured and characterisation is expected to commence in early 2004.
- *Neutron diffraction testing:*  
The experimental protocol will be finalised as soon as required data (ELIXIR Project) become available.
- *Numerical modelling:*  
A preliminary problem definition document has been distributed to the partners for comments, which will be finalised with ELIXIR data. The issue of the level of modelling detail to be used in the CRR has been raised and both a simplified model and a detailed one have been proposed.

### **TG3. SANS investigation of thermal ageing effects on cast duplex stainless steels**

- *Harmonisation of data treatment:*  
It was suggested that a FeCu alloy could be used for that purpose. However at the present time no samples are easily available.
- *Harmonisation of experimental procedures:*  
This task is carried out on duplex stainless steel samples. Four facilities have already performed SANS testing on these specimens.

Other activities of the neutron techniques team have been directed towards an International Standard for "residual stress determination based on neutron diffraction" which has been drafted by an international group of experts and submitted to CEN & ISO by the NET Manager for the 2-month inquiry. This work started in 2001 and the final Standard is expected to be adopted by end 2004.

During 2003 the team has been engaged in four FP5 funded Shared Cost Actions (ADIMEW, ENPOWER, HITHEX, INTERWELD) dealing respectively with structural integrity of dissimilar metal welds, assessment of novel repair weld techniques, development of CMCs for high temperature applications, investigation of irradiation effects on RPV internal welds. ADIMEW has been completed and the IE/HFR results on residual stress analysis in dissimilar metal welds (DMW) based on novel neutron diffraction techniques have been recognised by EDF and FRAMATOME as a solid basis for the calibration of relevant computational models. Finally, a Marie-Curie individual fellowship has been granted by DG RTD, which has enabled contributions to the NET actions through the enhancement of the HFR neutron scattering facilities.

Further information on the NET network activities is available on <http://www.jrc.nl/net>



## Assessment of Nuclear Power Plants Core Internals

Stress corrosion cracking has in recent years started to affect core internals of pressurised water reactors, which were considered less sensitive than boiling water reactors to this type of problem. The corrosion of a vessel head penetration nozzle in Davis-Besse PWR in USA is a recent famous example. The possible enhancement of corrosion by neutron irradiation (IASCC) mechanisms is still not understood, despite large international programmes mainly based on post-irradiation tests.

To start studies on this NPP ageing aspect, IE has built, in 2003, a new rig consisting of an autoclave with fracture toughness testing equipment and a water chemistry preparation loop. The autoclave is equipped with a pneumatic loading device for bending tests of mini and standard Charpy test specimens.

The water temperature and pressure ranges, as well as the chemistry control enable carrying out reference fracture mechanics tests of Light Water Reactor core internals materials. The limited dimensions of the bellow-based testing equipment make it suitable for in-pile application, fitting into an HFR irradiation capsule.

This option under study at IE for the HFR would constitute the only rig in the world able to perform this particular type of fracture toughness tests on small specimens. This would complement the results obtained in other interesting rigs existing in the world (Halden, Mol, Rez), which are designed to carry out tensile, fatigue of fracture toughness on larger CT specimens tests (only some of them in controlled LWR water chemistry conditions).

The essential preparation was made to ensure that a dedicated network, to be called AMALIA, could be launched early in 2004.





# Safety of Eastern Design Nuclear Facilities

## Background

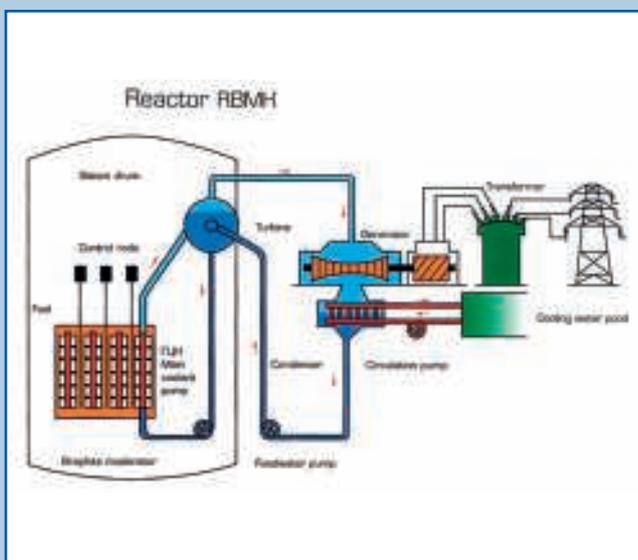
Since 1997, JRC-IE is providing, under the framework of Administrative Agreements, DG EuropeAid Co-operation Office, DG External Relations and DG Enlargement with technical and scientific support for the TACIS and PHARE programmes on nuclear safety. The activity covers Design Safety and Off-Site Emergency, On-Site Assistance, Waste and Decommissioning, as well as support to Safety Authorities and their technical support organisations for Russian designed Nuclear Power Plants and other Nuclear Facilities. These actions allow the JRC to assist the EC services during all preparation and implementation phases of the TACIS and PHARE programmes in nuclear safety, to assess the results of the individual projects for the Beneficiaries and to report the project feedback. For the TACIS and PHARE projects, the main actors are spread in several countries whereas the Nuclear Power Plants (NPPs) are of the same design (VVER and RBMK) and the safety related topics/issues are generic. The creation of a horizontal and integrated network concerning Nuclear Safety of NPPs in Eastern Europe is the best solution to bring together all stakeholders: the Beneficiaries, End Users, Eastern and Western nuclear industries, and therefore, to favour fruitful technical exchanges and feedback of experience. The specific objective for 2003 was to initiate the Working Group on Nuclear Power Plant Maintenance, as a first contribution to the improvement of their operational safety level.

## Achievements

### Support to DGs

The activity of the TSSTP unit is to support DGs External Relations, EuropeAid Cooperation Office and Enlargement in the preparation of the nuclear safety programmes and their implementation (see Support to Tacis/Phare Nuclear Programmes). Specific staff skills and experience are dedicated to these activities. The JRC-IE is regularly participating in the planning meetings of the IAEA RER projects, dedicated to the Eastern European Nuclear Power Plant Safety. A major concern in the TACIS and PHARE assistance in Nuclear Safety for CIS (Community of Independent States) and CEEC (Central and Eastern European Countries) is to avoid overlapping with other international programmes, in order to get the optimum effectiveness in the nuclear safety upgrading for the operating power plants. JRC-IE is also participating as observers with DG RELEX in the Steering Committee of the recently launched Extra-Budgetary Programme on Safe Operation of Long Term Operation of PWRs within the IAEA. A broader participation in all technical Working Groups is planned.

In the area of maintenance of Eastern European nuclear power plants, two state of the art reports have been prepared, one on "Maintenance Optimisation Methods in use in CIS & CEEC NPPs" and one on "Plant Life Management Procedures in use in CIS & CEEC NPPs". Publication should follow in 2004 after review by the SENUF WG members. SENUF is also participating to the deliverables related to Eastern European-type power plants in the existing nuclear safety related JRC networks (AMES, NESC, ENIQ), and contributing to the understanding of urgent needs to improve the nuclear safety in candidate countries. In particular, a contribution is given to signal processing and improved qualification for non-destructive testing of ageing reactors.





### Scientific Output

SENUF first Steering Committee took place at Petten (27 & 28 November 2003). 9 (7 from the CEEC and 2 EU) external organisations representing 8 Countries are full members since they have signed the collaboration agreement. Four to five others are expected to sign in 2004. A Chairman and a Vice-Chairman have been elected and JRC-IE is involved as Action Leader and in Network Management.

The work plan for 2004 for the Working Group on "Maintenance Optimisation of NPPs" has been fixed. The activity will start with the elaboration of a status report on "Advanced Maintenance Strategies" and a database for "Sharing the utilities' experience and the availability of specific and advanced tools and devices, materials and processes".

### Enlargement

The PECO Training Workshop on "Technical and Scientific Support to PHARE Countries on Nuclear Safety" was held in Petten (18 & 19 November) with the broad objective to familiarise the participants with the main achievements of selected TACIS and PHARE nuclear safety projects in the perspective of further harmonisation of the safety cultures within the Enlarged European Union and the wider Europe. The workshop covered the following areas: Probabilistic Safety Assessment, Severe Accident Analysis, Fire Safety and Risk Analysis, Reactor Pressure Vessel embrittlement, Leak-Before-Break concept, In-Service Inspection and NDE, Nuclear Power Plant Maintenance, Steam Generator performance, Radioactive Waste Management, and TACIS/PHARE project results dissemination. A technical visit to the ageing, fracture mechanics and NDE laboratories was organised.

17 participants from Bulgaria, Czech Republic, Hungary, Lithuania, Romania and Slovakia attended. The group has shown a broad variety in background education and was formed from people having various appointments (Nuclear Regulatory Authorities, Academic Research and Technical Support Institutes as well as Nuclear Power Plants) and responsibilities..

### Information Communication and Dissemination

Presentations on the state-of-the-Art on RPV embrittlement of VVERs and the main objectives to be achieved by TACIS projects have been given on several occasions (11th ICONÉ at Washington DC, "Structural Strength of Materials and Life of NPP Equipment at Kyiv, M.L. DAVIES Memorial Meeting at St Petersburg).

Two of those papers are considered for publication in Scientific Journals. An additional paper, presenting the TSSTP activities has been published in the Journal of the Finnish Nuclear Society.



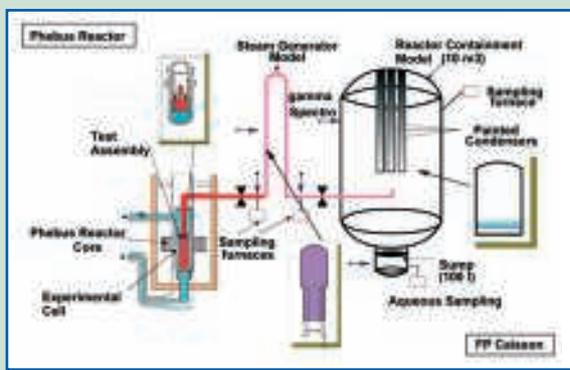


Fig 10 - Schematic scheme of the Phebus Test Facility

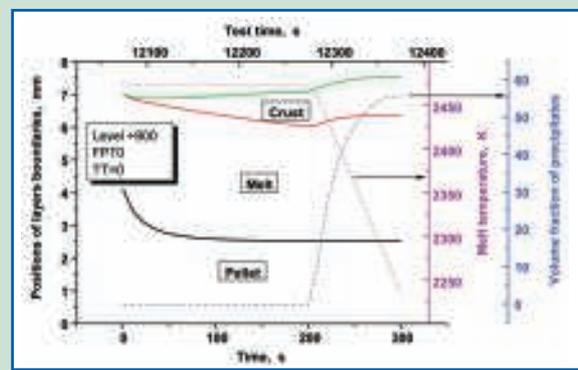


Fig 11 - Evolution of oxidised local molten pool layers in the upper zone (900mm) of the FPTO bundle after Zry melting

# Accident Management and Analysis (AMA)

## Phebus

Within the Phebus Network JRC-IE played a leading role in the Programme Committee and Steering Committee as well as in the organisation of the 5th Technical Phebus Seminar held in Aix-en-Provence. Numerous scientific workshops were co-ordinated to promote European and international co-operation in the field of severe accidents. The Phebus programme itself is jointly managed by the EC and IRSN/CEA with contributions from Switzerland, USA, Canada, South Korea and Japan. Especially in the scientific workshops, the test conditions of future Phebus tests were discussed as well as the pre- and post-test analyses performed with computer codes.

Over the last eleven years, four experiments were performed in the driver core of the Phebus reactor (see Figure 10). Due to the established proto-typical reactor conditions the physical processes in a light water reactor during a severe accident were simulated. In three of the experiments the test device consisted of a 21-rod bundle whereas in one test a debris bed with  $UO_2$  and  $ZrO_2$  particles was inserted in the experimental cell in order to study the formation of a molten pool and the fission product release. In the bundle tests the degradation of bundle components, the release of fission products and their transport in the circuit as aerosols, vapours or as gases were examined. Furthermore, the aerosol behaviour and the iodine chemistry in the containment were examined. In 2003, mainly the Phebus FPT3 test scheduled to take place in October 2004 was prepared. In this test a boron-carbide control rod will be inserted in the bundle to study its impact on the bundle degradation and fission product chemistry.

## Interpretation of the Phebus experimental Data and Validation of Severe Accident Codes

In one of the scientific workshops JRC-IE has launched benchmark studies related to three Phebus tests where severe accident codes have been applied by the international partner organisations. In these studies the bundle degradation and fission product release have been examined in order to stimulate the discussion, to achieve a common understanding of the physical processes and a profound interpretation of the experimental data. Due to the proto-typical reactor conditions, the validation of severe accident codes by using the measured experimental data will lead to enhancement of the extrapolation capability of the codes to plant situations. JRC-IE has also co-ordinated and participated in three shared cost actions (SCAs) including the OECD International Standard Problem 46.

At JRC-IE a remarkable progress in the modelling of the melt formation was made. With the new oxidation and dissolution model a consistent interpretation of the findings of the Phebus post-test analyses was worked out, e.g. the melt formation in Phebus FPTO at upper bundle positions as well as the formation of precipitates in the melt can be explained (see Figure 11).

Within the SCAs substantial contributions to the interpretation and analyses of Phebus FPTO and FPT1 tests were also carried out. Therefore a broad dissemination to the code developers is guaranteed and information for guidance to the end-users such as designers and regulators is available. Furthermore, assessment criteria for integral codes as used in the plant analyses have been developed and applied. In the frame of International Standard Problem 46, JRC-IE has contributed by applying the European Integral Code ASTEC (Accident Source Term Evaluation Code) to analyse the processes during the degradation and aerosol phase of the Phebus FPT1 test, considering the physical processes in the bundle, circuit and containment. Detailed separate analyses were performed with IMPAIR-3 on the iodine behaviour during the chemistry phase in the gas space and in the sump of the containment as well as with SOPHAEROS on the behaviour and transport of fission products in the circuit.

## Hydrogen Safety

In case of a severe nuclear accident, the interaction of the hot core with cooling water generates hydrogen. A hydrogen explosion could threaten the containment integrity, with the potential consequence of releasing radioactive material into the environment. The Computational Fluid Dynamics (CFD) code, REACFLOW, has been developed at JRC originally with the purpose of simulating hydrogen combustion in nuclear environments in order to predict the consequences of such hydrogen explosions. As a unique feature, REACFLOW has the capability to adapt its resolution to the solution. This increases accuracy as well as reduces the overall computational efforts. Also REACFLOW could be run in parallel on High-Performance-Computing cluster. The numerical modelling and computer resources at JRC reached, in recent times, such an advanced level that it became feasible to run complex and challenging numerical simulations in real-scale containment.

After some preliminary calculations of hydrogen combustion in a simplified European Pressurized Water Reactor (EPR)

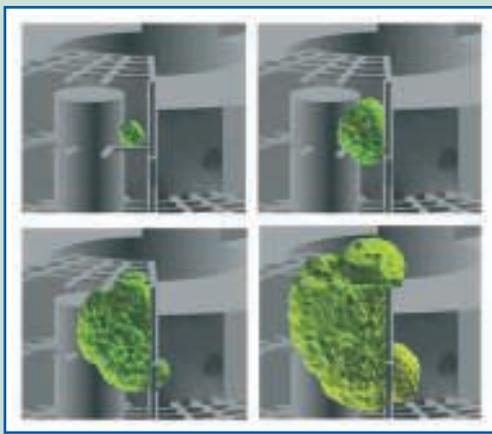


Fig 12 - REACFLOW simulation of the flame acceleration in the duct of the reactor pump room and the steam generator rooms in the early phase of an assumed hydrogen explosion in the containment of the EPR.

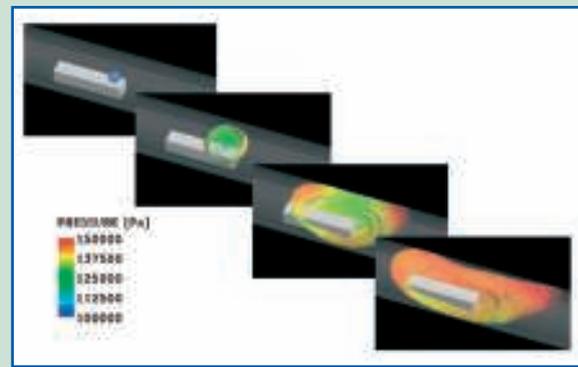


Fig 13 - Hydrogen explosion in a tunnel, following a release of hydrogen from a bus tank at 350 bars. The isosurface is a temperature surface (350 k) that shows the propagation of the flame. The colour on the surface describes the pressure, according to the values in the legend.

containment in 2002, in 2003 the work was continued applying CFD methods to investigate the effect of different geometrical internal layouts on the propagation of the flame and on the corresponding pressure loads. Vents, between rooms, are an essential feature in order to decrease the effects of the pressure difference between compartments during an explosion. By means of CFD simulations, the effects of the number, size and location of vents between rooms, on the generated overpressure peaks and overpressure oscillations in an EPR containment were analysed. In the analysis, different position of the ignition point and multiple and single ignition points were also taken into account. In Figure 12, the propagation of the flame across a vent between the pump room and the steam generator room of an EPR is illustrated.

As a spin off of the activities in the nuclear programme and as a contribution to the JRC's SYSAF activity, the same methods and tools were also applied to the safe use of hydrogen as an energy carrier. As an energy carrier hydrogen may potentially provide a solution for issues such as secure energy supply, climate change and air pollution, especially if hydrogen is produced with renewable energy sources. Hydrogen safety is a pillar of the future hydrogen economy. In this general context, evaluation of accident consequences as part of safety studies of hydrogen re-fuelling stations were performed, using the same CFD methodology that was applied in the containment analysis. In the first stage of the analysis, accident scenarios were identified. Those scenarios were investigated from the numerical point of view with the CFD code REACFLOW, providing valuable information about accident consequences.

A similar analysis was carried out for hydrogen commercial vehicles in comparison with more conventional compressed natural gas (CNG) driven busses. Different storage pressures and different pressure relief cases were investigated in order to evaluate the safer configurations for the tank system. Overpressures generated by the flame and the flame sizes were taken into account in the study.

Figure 13 shows the initial stages of the flame propagation in a hydrogen explosion after a hydrogen release from the tank system of a bus in a tunnel. Because of the relatively high level of confinement, the tunnel is a particularly severe configuration for a gas-explosion.

standards and regulations on vehicles with compressed gaseous hydrogen (CGH<sub>2</sub>) onboard storage systems and to draft standard documents on *Gaseous Hydrogen Vehicle Refuelling Stations* for submission to ISO TC197 WG 11. The work has proven CFD modelling techniques to be a useful tool for investigating the consequences of hydrogen explosions in real world situations in order to increase the understanding of hydrogen combustion and to improve the hydrogen safety standards.

### Probabilistic Safety Assessment

There is general agreement nowadays that risk informed decision making significantly contributes towards maintaining and improving nuclear safety and energy technologies in general. It complements the traditional deterministic approach to safety and maintains the concepts of defence in depth and adequate safety margins. Risk informed decision making uses the results of Probabilistic Safety Assessment (PSA) as one input to the decision making process, but allows for consideration of other factors, in particular aspects of safety management and safety culture. At present these aspects are included in PSA only to the extent that they are reflected in the plant specific data used, but they are not explicitly modelled in PSAs. Risk informed decision making can be successful only if all stakeholders understand the process and the results obtained. The general public is an important stakeholder and it is therefore necessary to find ways of communicating the results of risk informed decision making to them. JRC-IE has contributed in the following ways to these objectives

A large International Conference was organised in May 2003 in Petten on cross-comparison of practices of safety investigation of technological incidents/accidents in the energy and other technological sectors, resulting in a best practice document for use by all stakeholders, including policy services such as DG TREN. The need for a consistent comparative approach in benchmarking of different risk elements in current safety assessment practices has been identified, leading to the formation of the international Network RISKREG in which JRC-IE is co-ordinator for the energy sector.

This Network, consisting of leading European and US Universities and research institutes specialised in risk assessment, addresses the question as to how the systems and cultures of risk informed decision making in selected European countries and in the USA cope with the challenges

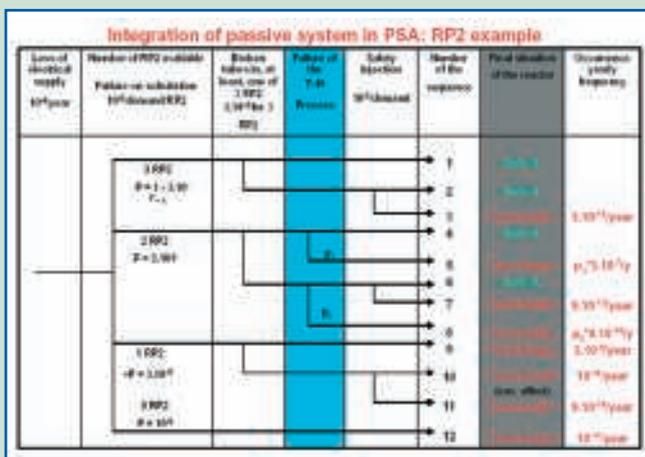


Fig 14 - Simplified event tree for loss of electrical power supply including passive systems



of risk governance with respect to present and future technological risks. The normative emphasis is on the development and evaluation of risk management options with the main goal to assist the European Commission on its way towards harmonised risk governance frameworks.

As risk impacts of technology should not be judged in isolation from the benefits to society, balancing risks and benefits is fundamental to any consistent decision making process. Risk-based methods provide measures that can significantly support consistent decision-making and enhance public understanding. With consistent data collections on accidents in specific, well-defined sectors, such as the energy sector, comparative assessment of accidental risks within a sector (e.g. nuclear and non-nuclear energies) can be performed on a consistent basis. Such comparative studies can be used effectively for informing all stakeholders on specific risks in a consistent way and for benchmarking the risks related to new technologies, such as application of hydrogen compared with existing ones (e.g. fossil).

Consequently, as a contribution to JRC's SETRIS activity, JRC-IE initiated the Energy Risks Monitor (ERMON) Project in 2003, which aims at mapping the available end results of any published energy risk assessment and incident/accident statistics into common standard metrics. ERMON, which will be developed together with US-DOE and European industry associations, such as MARCOGAZ., will allow fair results comparison on accidental risks from different energy systems.

In its more traditional competencies, new methods in PSA for nuclear power plants have been developed by JRC-IE, especially in relation to estimating the reliability of passive safety systems in advanced plant designs. The treatment of passive systems in PSA models is a difficult and challenging task. No commonly accepted practices exist so far on how to estimate reliability of passive systems. The main challenge arises from the nature of passive systems whose main operating principles are based not on active components, but on physical phenomena.

JRC-IE has developed with European partners a new methodology of passive system function reliability to produce probabilistic estimates of a specific passive safety system. The methodology is based on phenomenological processes (e.g. natural circulation), and its integration in plant-specific PSA's.

Applications of the new method were performed on three examples of passive systems:

- Isolation Condenser System of BWR reactors;
- Residual Passive heat Removal system on Primary circuit (RP2) of PWR reactors;
- Hydro-Accumulator (HA) system of PWR, VVER type of reactors.

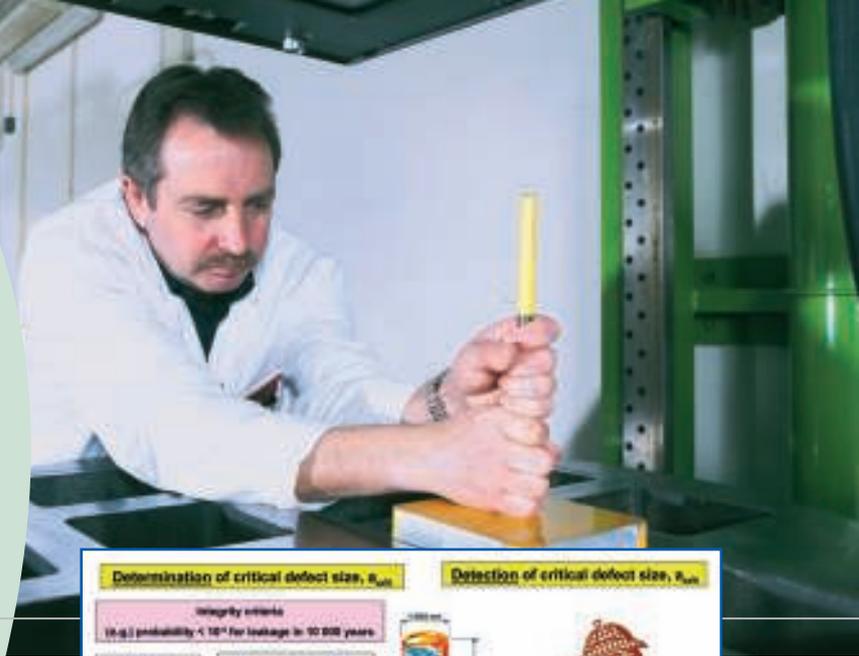
Figure 14 AMA6 shows the results of applying the new reliability assessment method for the case of a total loss of power supplies where the control of the reactor is ensured by the RP2 passive system and the safety injection by accumulators, regarding the residual power removal and the reactor cooling. As can be seen from the accident sequence probabilities, each core melt sequence is in the order or below 10<sup>-10</sup>/year with failure probabilities of the passive safety system function being very small, but not "zero".

Further, in its activities to contribute to international harmonisation of PSA practices and methods, JRC-IE concluded a major European benchmark exercise on Safety Evaluation of Computer Based Systems. From benchmarking the current practices in France, Germany and Finland, it was concluded that, although all regulatory requirements applied in the assessments are based on the IEC 60880 standard, the methodological requirements on national level are conceptually different. As an example, although quantitative software reliability analysis is recognised to represent a useful analysis item that could also be used in plant-specific PSA studies, in only one country such an approach is followed and several areas for improvement have been suggested.

JRC-IE also contributed to the establishment of an international IAEA Guide for Quality of PSA for different applications. The guide is expected to be published within the next 1-2 years.

All results including those from previous PSA related activities have been integrated into an Internet-based knowledge dissemination platform at [www.energyrisks.jrc.nl](http://www.energyrisks.jrc.nl).

# Casks for High-Level Nuclear Waste (SAFECASK)



Design of nuclear waste packages for transport, storage and geological disposal is an essential part of nuclear waste management. A totally new project, Casks for High-Level Nuclear Waste, SAFECASK, was started in 2003 with the objective to develop design and acceptance criteria for nuclear waste packages. A close collaboration was established with SKB in Sweden during the first year to develop a probabilistically based methodology for the Swedish/Finnish copper/cast iron canisters for geological disposal of spent fuel. The work performed by IE included:

- Planning and performing a test programme to determine statistical distributions of mechanical properties of canister inserts;
- Radiographic and fractographic investigations to determine distribution and type of defects of in the canister insert;
- The development of a first probabilistic fracture mechanics model that uses the defect distributions as input to predict corresponding variations in material properties;
- Design of a pressure test of and mock-up of a complete canister used in the test.

The general methodology is outlined in Figure 15. The results can be used to compute failure probabilities under the design load cases of a material with given properties or to determine acceptance criteria for manufacturing defects in canisters that ensures that the failure probability of a canister is below a prescribed (and extremely) low value. Although, 2003 was seen as a pilot year, significant progress was done in understanding how defects affect the long-term integrity of the canisters and models that integrate elasto-plastic fracture mechanics, statistical methods and experimental data were developed. Figure 16A shows the computed failure strain versus defect size together with some measured data whereas Figure 16B shows the measured and computed distribution of elongation at fracture in tensile tests of the cast iron. In the design of canisters it is necessary to specify material requirements and in the manufacturing it is important to have methods to determine whether the component fulfills the material requirements and no critical defects are present. The results shown in Figure 16A & 16B can be used in such an assessment; From Figure 16A a relation between critical defect size and elongation can be established whereas the probability for failure of a component can be deduced from the density distribution in Figure 16B.

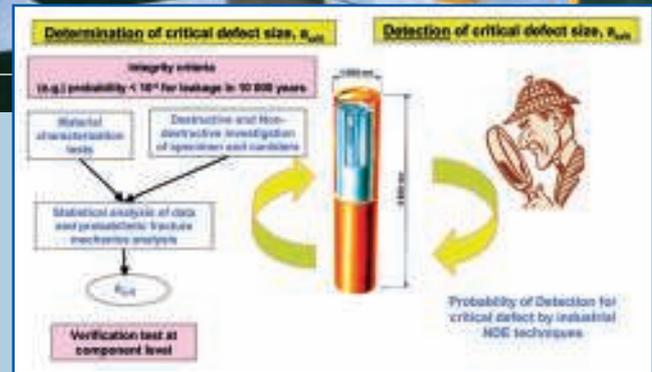


Fig 15 - Illustration of the multidisciplinary approach where a critical defect size associated with integrity criteria is computed from analysis and testing and where this defect size is used as acceptance criterion in manufacturing.

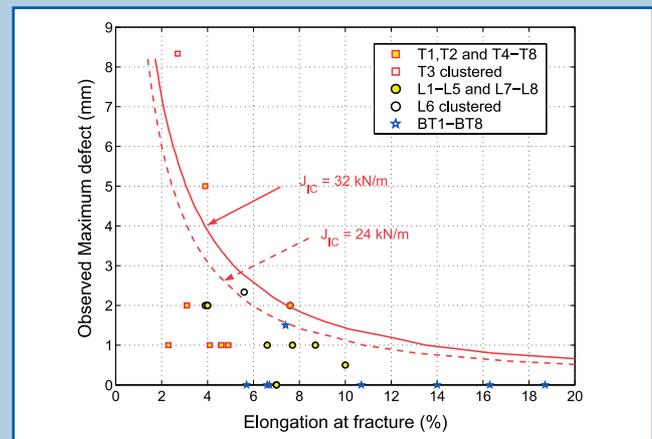


Fig 16A - Computed elongation versus defect size for measured fracture toughness (mean value  $J_{IC}=32 \text{ kN/m}$  and mean value minus two standard deviations  $J_{IC}=24 \text{ kN/m}$ ) together with measured data where the defects were sized by radiography.

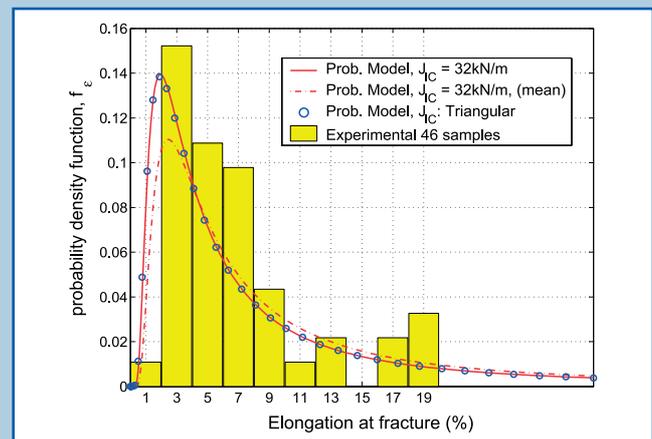


Fig 16B - Computed and measured probability density function of elongation.

# Data Management and Dissemination (DMD)



To realise a new platform independent, on-line database portal - ODIN (Online Data Information Network) - DMD (Data Management & Dissemination) has installed a SUN fire machine as a central server for the storage of data and document databases in the area of nuclear and conventional energy. The ODIN web portal is based on ORACLE and will integrate various databases within a central registration and login procedure.

The following two objectives of the ODIN mosaic were already fulfilled:

1. Transfer of NuCoC - an extensive information system on Nuclear Competence Centres in Europe – from LOTUS notes into ODIN;
2. Implementation of a new web-enabled Alloys-DB prototype containing experimentally measured mechanical properties data (see figure 17).

The already existing ODIN document dissemination sites for nuclear and conventional energy have been examined and upgraded to the needs of the DMD customers. Multiple data and documents of European projects & networks were uploaded into the ODIN databases. An annual training workshop for the engineering databases was held at JRC Petten on June 2nd and 3rd 2003. The European customers from industry and research were informed about the new upgrades, updates and further developments of the PC and client/server applications and trained in using the new database tools. A new ODIN-PM site was set up together with the institutional Project Management team.

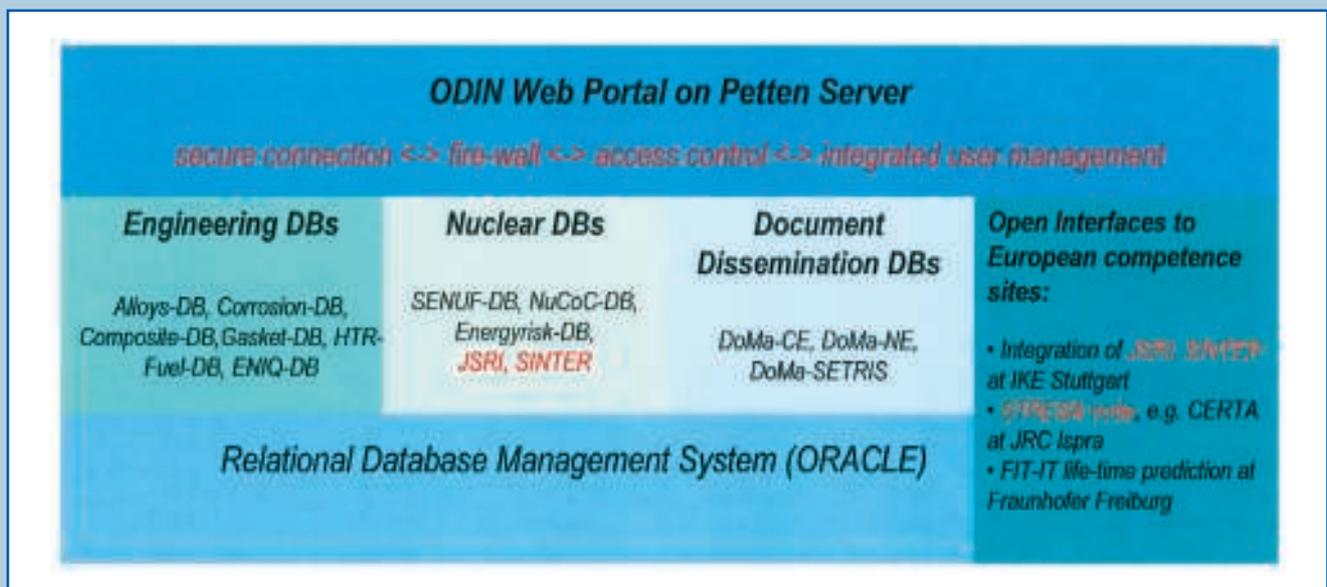


Fig 17 - The ODIN web portal.



# Support to TACIS/PHARE Nuclear Programmes

JRC provides Technical and Scientific expertise in the TACIS and PHARE nuclear safety programmes devoted to the improvement of nuclear facilities safety in Eastern Europe, Russia, Ukraine, Armenia and Kazakhstan. This expertise supports DGs External Relations, Europe Aid Cooperation Office and Enlargement, The policy of JRC support to these DGs has been underlined in the Commission Communication on Nuclear Safety assistance to CEEC and NIS to the Parliament and Council (6.9.2000, COM(2000) 493).

The Institute for Energy is involved in all the areas on which the TACIS and PHARE nuclear safety programmes have focused:

- On-site assistance and operational safety;
- Design safety, off-site emergency preparedness, in particular embrittlement of VVER reactor pressure vessels issues;
- Dissemination of TACIS and PHARE projects results;
- Regulatory authorities and their technical support organisations;
- Industrial Waste Management, including control of nuclear materials and decommissioning.

Further Administrative Agreements have been signed between AidCo-A & JRC-F to ensure for continuous support in On-Site Assistance and Design Safety activities.

The TACIS On-Site Assistance to Nuclear Power Plants in Armenia, Russia, Ukraine and Kazakhstan aims to improve the operational safety and includes the conditions of operation and surveillance of the installations, and equipment supplies. Since 1998, the programme focuses on a limited number of large-scale projects named Plant Improvement Projects. Plant Improvement Projects are based on a range of activities from the assessment of the safety relevance to procurement of modernisation equipment (about 10 to 15 M€) including licensing, installation, and adaptation of operational procedures.

The JRC technical expertise for On Site Assistance to the 14 TACIS Nuclear Power Plants in Russia, Ukraine, Armenia and Kazakhstan comprises:

- Participation of JRC experts in all procurement processes for safety related equipment
- Expert visits to nuclear power plants to assess and facilitate the implementation of TACIS projects.

The nuclear power plants concerned are located in:

- Russia: Balakovo, Beloyarsk, Bilibino, Kalinin, Kola, Leningrad, Novovoronezh, Smolensk
- Ukraine: Kmelnitsky, Rovno, South Ukraine, Zaporozhie
- Armenia: Medzamor
- Kazakhstan: Aktau





Since July 1999, the JRC carried out more than 800 reviews of technical specifications for about 120 projects. Assessment missions took place at almost all TACIS NPP sites including Chernobyl. Since the beginning, JRC participated in more than 90 evaluation committees for equipment supply and service contracts, including some dealing with very large projects, e.g. the implementation of the Chernobyl Industrial Complex for the Radioactive Waste Management. 32 evaluations have been carried out in 2003. Among those, JRC has participated in the evaluation of the tenders for large modernisation projects for Balakovo and Novovoronezh NPPs, aiming to upgrade the Reactor Protection Systems. These Plant Improvement Projects (PIP), each worth about 10 M€ on average, are now being implemented. It is also worth mentioning that a specific project, aiming to assess the applicability of the LBB concept for the primary circuit of Medzamor 2, has been launched after successful evaluation of the tender in 2003.

In Design Safety, the JRC-IE has been involved in the preparation of the TACIS 2003 Annual Programme through the review of Project Description Sheets, has developed extended Project Description Sheets for the 2002 TACIS Projects and started to develop the corresponding Terms of Reference (RPV internals, VVER 1000 Power Tilt Accident Analysis, RBMK Accident scenario assessment, Equipment of Off-Site Emergency Centres & Safety Related Equipment Qualification programmes). Projects on Qualification of the Kola NPP configuration of the Bubble Condenser, Experimental assessment of the consequences of a RBMK Pressure Tube Rupture as well as on Experimental validation of VVER 1000 Accident Management procedure and the Development of a Code System for Severe Accident Analysis for RBMK have been implemented. The JRC-IE is involved in advising AidCo-A5 on a case-by-case basis. The TAREG project on RPV integrity aiming to upgrade the safety margin assessment of the VVER 1000 & VVER 440/213 units has been implemented. As a first technical target, a consensus point of view upon the present state of the art and the remaining open issues, shall be built up with Eastern and Western Senior Experts within the Senior Advisory Group. This shall form the basis of the complementary industrial project, which is planned to be implemented late 2004.

The dissemination of the TACIS & PHARE project results is still a key objective for respectively AidCo and ELARG, respectively. Therefore, the current website displaying actually a limited number of updated Russian projects data, will be

complemented in the future for Russia, Ukraine and PHARE projects. In 2003, significant progress has been achieved by implementation of a second Administrative Agreement for Russia and the preparation of two others. Early 2004, an Administrative Agreement shall be implemented for PHARE projects.

TACIS Regulatory Assistance to Regulators and their Technical Safety Organisations has the objective to transfer regulatory methodology including the formulation of legislation and regulatory documents. It provides support in conducting licensing assessments for specific Plant Improvement Projects under the "2+2 approach": EU and TACIS Regulators + EU and TACIS utilities. Assistance is also provided for the overall safety assessment of specific installations.

The storage of spent nuclear fuel and radioactive waste in North-West Russia is a cause for concern. The TACIS programme is supporting projects related to the management of spent nuclear fuel and radioactive waste from the nuclear submarines of the Northern Fleet, such as Lepse defuelling and the Gremikha feasibility study.

The TACIS programme is contributing to support the installation of new and additional radioactive waste facilities, aiming to improve the present situation at Chernobyl NPP regarding the safety of waste treatment and storage. In Kazakhstan, the TACIS programme has been providing On-Site Assistance to the Aktau fast breeder reactor since 1995. The Aktau decommissioning plan has been submitted to IAEA for peer review, in which JRC is contributing.

The technical assistance provided by the JRC in Regulatory Assistance and industrial waste management for TACIS concerns the implementation and execution of specific projects, by checking the Projection Description Sheets and Terms of Reference, making the technical follow-up and assessing project results.

In conclusion, The actions described allow JRC to contribute to the safety improvement of operating NPPs from Russian design by assisting the European Commission' General Directorates in charge of the TACIS nuclear safety programme, during all phases from project preparation until completion.

# The High Flux Reactor, and Reactor Applications

2003 was a very busy year at the High Flux Reactor 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, it is expected that the Council will adopt 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 JRC and NRG to the licensing authorities. The main reason for a new licence was dictated by the decision to convert from High Enriched Uranium fuel to Low Enriched Uranium 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, JRC 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.

A more in-depth review of the operation and utilisation of the HFR can be found in the HFR Annual Report 2003 (EUR 21175).





# Safety of Innovative Reactor Designs (SAFETY INNO)

The institutional action Safety of Innovative Reactor Designs (SAFETY-INNO) carries out R&D related to future nuclear power plants for the medium and the long term including several FP5 competitive actions. The tasks focused on the safety analysis and safety optimisation of reactors, fuels and materials with improved sustainability and waste management features. In 2003, the action comprised the following activities:

- Activities related to the High Temperature Reactor Technology Network;
- High Temperature Reactor Fuel Irradiations;
- Development of an HTR fuel database;
- HTR Structural material out-of-pile tests;
- Safety and feasibility studies on other innovative reactor concepts.

## HTR-TN (High Temperature Reactor Technology Network)

**Background:** In response to growing interest in HTRs worldwide and on the initiative of JRC, HTR-TN was established in April 2000 to recover, maintain and develop HTR technology from Europe and elsewhere. The ultimate goal is the development of advanced HTR technologies thus supporting industry in the design of power plants, which comply with stringent requirements in terms 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 organisation of specialist meetings, seminars and conferences. Further information can be found at [www.jrc.nl/htr-tn](http://www.jrc.nl/htr-tn).

**Achievements:** JRC-IE continued operating this network, contributed to the co-ordination of related projects and provided technical input which is detailed below through both institutional and competitive actions. HTR-TN is driven by currently 21 partners and observers from research and industry with an additional partner and an observer joining in 2003.

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.

HTR-TN has gained further momentum thanks to the Euratom participation in the Generation IV International Forum (GIF) in July 2003. Much of the network's technical achievements

can indeed 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.

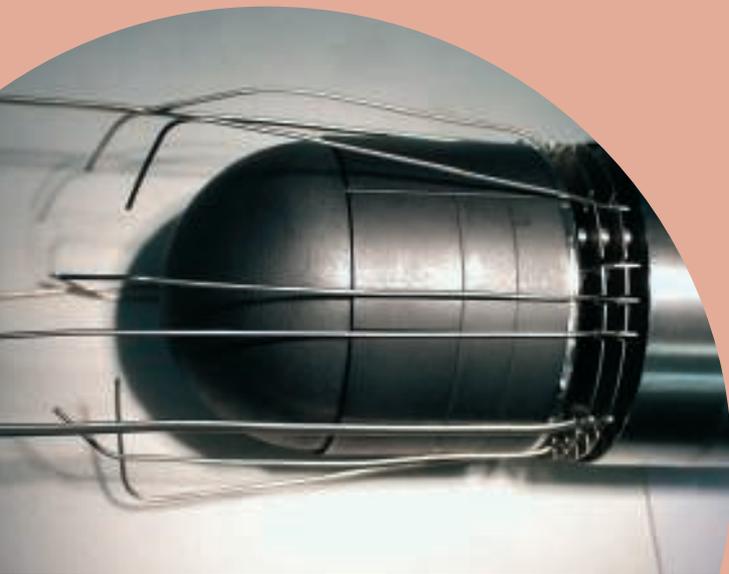
## High Temperature Reactor Fuel Irradiations in the HFR

**Background:** Three irradiation tests of low-enriched uranium fuel types in the HFR were further prepared 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.

- Irradiation of pebble type fuel produced by NUKEM, Germany and by INET, China, codename HFR-EU1 with on-line fission gas release monitoring. Target burn-up 21% FIMA for NUKEM pebbles and 16% FIMA for INET pebbles;
- Irradiation of pebble type fuel produced by NUKEM, Germany at increased temperature, codename HFR-EU1bis with simplified fission gas monitoring. Target burn-up 16% FIMA;
- Irradiation of compact type fuel produced by General Atomics, USA, codename HFR-EU2 with on-line fission gas release monitoring. Target burn-up 10% FIMA.

**Achievements:** 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 and commissioning has started. 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 (Very High Temperature Reactor).

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.



### Development of an HTR fuel database

**Background:** 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 utilize a maximum of HTR fuel related information.

**Achievements:** The database structure was finalised 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.

### HTR: Structural material out-of pile tests

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

**Achievements:** 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.

### Safety and feasibility studies on other other innovative reactor concepts

In parallel to the Generation IV initiative, the IAEA conducts the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) with different criteria due to the requirements of the participating countries. JRC-IE has contributed to establish the selection criteria for innovative reactors (IAEA-TECDOC-1362).

Further work concerned the set-up, test and application of codes for accident analysis (EAC-2), thermal-hydraulics (STAR -CD CFD code) and neutronics (HEXNODYN) for different reactor types.

Loss-of-Flow, Loss-of-Heat Sink and Total Loss of Power safety calculations were performed for both Pb-Bi and gas-cooled accelerator-driven waste burner designs. This was part of the JRC-IE contribution to the PDS / XADS FP5 shared cost action.

A conceptual design and specifications for an experiment in the KALLA facility at FZK was proposed. A contract was established with FZK to investigate whether Pb-Bi dissolves fission products such as caesium and iodine released by a failed fuel pin.

At the Global'03 conference a JRC-IE paper on the pros and cons of Lead Cooled Fast Reactors was chosen as the lead-in paper of the two sessions on LFR's.

Two patent applications related to reactor safety were prepared: one for a thermally triggered electrical fuse for use in different reactor systems or electrical devices, the other concerning design modifications of liquid metal-cooled fast and molten salt reactors.



## HFR as a Tool for Medical Applications

# Boron Neutron Capture Therapy (BNCT)

### Background

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  $^{10}\text{B}$  to capture thermal neutrons to produce two highly energetic particles, namely a helium ( $\alpha$ ) 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 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).

### 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 the 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, presented to and approved by the Reactor Safety Committee.

Under dosimetry, the main activities, involving an extensive measurement and calculation exercise, were performed as part of the validation of the treatment planning code NCT-Plan, as described below under EORTC Protocol 11011. Furthermore, a feasibility study for the treatment of other cancers has also been discussed (liver) in the same section.

### Participation in Shared Cost Actions

#### EORTC Protocol 11961:

*Clinical Trial of BNCT for Glioblastoma*

The last patient in this trial, namely patient number 6 in cohort 4, was treated in 2002. The analysis of the results during 2003, led to the general conclusion 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 these analyses, it was recommended that a 5th cohort should be treated.

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

*$^{10}\text{B}$ -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, a feasibility study, based on calculations only, has been started using the neutronics code MCNP.



### **EORTC Protocol 11011**

*Early phase II study on BNCT in metastatic malignant melanoma using the boron carrier BPA*

This trial looks at treating brain metastases of malignant melanoma using the boron compound, BPA. The trial will be prepared in common with the EORTC BNCT Group, the EORTC Melanoma Co-operative 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. 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.

### **“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. Contributions and work performed by JRC form part of the reports. The final co-ordination 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 world-wide.



# HFR as a Tool for Other Applications

## Neutron Beams Research



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

The combined powder and stress diffractometer at beam line HB5 (CPSDF) 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 completed (ADIMEW);
- Strain/stress measurements on an "edge welded" beam specimen completed (ENPOWER);
- Strain/stress measurements on two large reactor pressure vessel wall mock-ups containing a proposed sub-clad crack repair weld completed; results to 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 temperatures started, to be completed in 2004 (HITHEX);
- Measurements of residual stresses in non-irradiated test pieces were completed (Fig. 18); irradiated specimens to 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 completed; results to be used for calibration of numerical models to 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. Procurement of new equipment for evacuating and cooling the filter units has been initiated and for 2004 the development of digital DAQ and processing is foreseen.

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 soft-and hardware for DAQ have been installed. The first neutrons have been captured by the detector at the end of 2003. First testing campaign is envisaged for 2004 for the investigation of thermal ageing effects in steel alloys aiming at the harmonisation of European SANS facilities performance (NET-TG3). Toward year-end a feasibility study has been initiated for the development and installation of a cold neutron source at HB3. Preliminary findings suggest that such a cold neutron source could result in boosting neutron intensity by about 50 times, at the neutron wavelength range that is appropriate for defects studies.

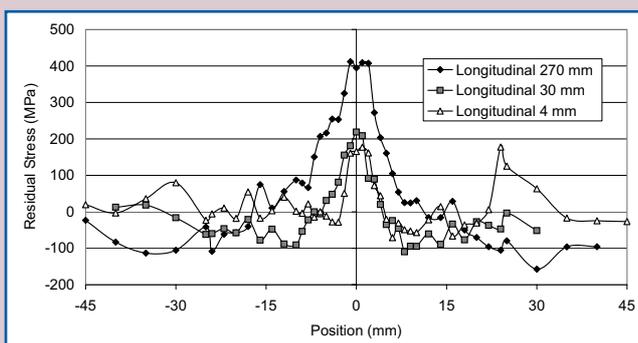
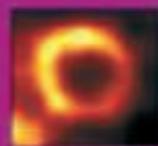
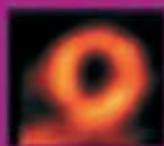


Fig 18

NH<sub>3</sub>



FDG



# European Network for Medical Radioisotopes and Beam Research (EMIR)

## Background

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 existing surveys on available facilities, PET (Positron Emission Tomography), and ESTRO (European Society for Therapeutic Radiology and Oncology) survey on certain radioisotopes. The present survey should concentrate on isotopes for therapy and research, their availability and 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 the 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 as opposed to the IIS (International Isotope Society) which is more focused on developed countries. During 4 ICI, EMIR's former project leader made a successful bid by EMIR 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 participants foreseen is around 350. 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, consistent 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 to be issued early in 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 with activities restricted to those of an information / discussion platform. 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.

# Glossary and acronyms

|          |  |           |  |
|----------|--|-----------|--|
| 2DMD     | On line Data Management and Dissemination  | EMIR      | The European Network on Nuclear Medicine                             |
| ACETECH  | New and Clean Energy Assessment System   | EMIR      | European Network for Medical Radioisotopes and Beam Research         |
| ADIMEW   | Analysis of Dissimilar Metal Welds   | EMS       | Environmental Management System                                      |
| AFCG     | Alternative Fuels Contact Group  | ENIQ      | European Network for Inspection and Qualification                    |
| AMA      | Accident Management and Analysis   | ENPOWER   | Nuclear Plant Operation by Optimising Weld Repairs                   |
| AMALIA   | Ageing of MAterials under the effect of Load and Irradiation-Assisted stress-corrosion cracking  | EORTC     | European Organisation for Research and Treatment of Cancer           |
| AMES     | Ageing Materials European Strategies   | EPERC     | European Pressure Equipment Research Council                         |
| ASTEC    | Name of nuclear safety code  | EPR       | European Pressurised Reactor   |
| ATHENA   | AMES THEmatic Network on Ageing  | EPRI      | Electric Power Research Institute (US)                               |
| BNCT     | Boron Neutron Capture Therapy  | ERA       | European Research Area   |
| BPA      | Boron compound for BNCT  | ERMON     | Energy Risks Monitor   |
| BREF     | Bat REference Document   | ESReDA    | European Safety and Reliability Data Association                     |
| BSH      | Boronated Drug   | ESTRO     | European Society for Therapeutic Radiology and Oncology              |
| BWR      | Boiling Water Reactor  | ETAP      | Environmental Technologies Action Plan                               |
| CAEP     | Committee for Aviation Environmental Protection  | FC        | Fuel Cell  |
| CC's     | Candidate Countries  | FCTESTNET | Fuel Cell TESTING and Standardisation Network                        |
| CEA      | Commissariat à l'Énergie Atomique  | FIMA      | Fissionable (Heavy) Metallic Atoms                                   |
| CEEC     | Central and Eastern European Countries   | FP6       | 6th Framework Programme  |
| CEN      | Comité Européen de Normalisation   | FRAME     | FRacture Mechanics   |
| CFD      | Computational Fluid Dynamics   | FZK       | ForschungsZentrum Karlsruhe  |
| CIS      | Community of Independent States  | GAIN      | Gap analysis for long-term inspection                                |
| CLEANWEB | Clean and efficient waste incineration, Waste-to-Energy and Biomass combustion   | GDE       | Gas Diffusion Electrode  |
| CMC's    | Carbon Matrix Composites   | GIF       | Generation IV International Forum                                    |
| CNG      | Compressed Natural Gas   | HA        | Hydro-Accumulator  |
| CO       | Carbon Monoxide  | HB        | HFR Beam Tube  |
| COBRA    | Consolidation of Scientific and Technological Expertise to Assess the Reliability of Reactor Pressure Vessel Embrittlement Prediction in particular for the Artic area plant | HFR       | High Flux Reactor  |
| CRR      | Co-ordinated Research Programme  | HITHEX    | High Temperature Heat Exchanger                                      |
| CT       | Compact Tension  | HTR-TN    | High Temperature Reactor-Thematic Network                            |
| DB       | Data Base  | Hysafe    | Safety of Hydrogen as Energy Carrier                                 |
| DG AIDCO | Directorate General Europe AID-CO-operation Office   | IAEA      | International Atomic Energy Agency                                   |
| DG ENTR  | Directorate General Europe Enterprice  | IASCC     | Irradiation Assisted Stress Corrosion Cracking                       |
| DG ENV   | Directorate General Europe ENVironment   | ICAO      | International Civil Aviation Organisation                            |
| DG INFSO | Directorate General Europe INFOrmation Society   | ICI       | International Conference on Isotopes                                 |
| DG RTD   | Directorate General Europe Research  | ICONE     | International Conference on Nuclear Engineering                      |
| DG TREN  | Directorate General Europe TRansport & ENergy  | ICRU      | International Commission on Radiation Units and Measurements         |
| DG ELARG | Directorate General Europe Enlargement   | IEA       | International Energy Agency  |
| DG's     | Directorates General Europe  | IES       | Institute for Environment and Sustainability                         |
| DMD      | Data Management and Dissemination  | IMPAIR    | name of nuclear safety Code  |
| DMW      | Dissimilar Metal Welds   | IMSC      | International Monitoring and Steering Committee                      |
| EAC      | Codes for Accident Analysis  | INET      | Manufacturer of Pebble Type Fuel, (China)                            |
| EC       | European Commission  | INPRO     | International Project on Innovative Nuclear Reactors and Fuel Cycles |
| ECN      | Energy Centrum Nederland   | INSAG     | International Nuclear Safety Advisory Group                          |
| EFQM     | European Foundation for Quality Management   | INSARR    | INternational Safety Assessment for Research Reactors                |
| ELIXIR   | EXtending plant Life through Improved fabrication and advanced Repair methodology (Project of EC 5th Framework Programme Project   |           |  |

|           |  |             |  |
|-----------|--|-------------|--|
| INTERWELD | Irradiation effects on the evolution of the microstructure, properties and residual stresses in the heat affected zone of stainless steel welds Integrated Project | PREWIN      | Performance, Reliability, and Emissions Reductions in Waste Incinerators Network   |
| IPHE      | International Partnership for the Hydrogen Economy   | PSA         | Probabilistic Safety Assessment  |
| IPTS      | Institute for Prospective and Technological Studies  | PSTL        | Plant Simulation Test Laboratory   |
| IRSN      | Institut de Radioprotection et de Sûreté Nucléaire   | PWR         | Pressurised Water Reactor  |
| ISA       | Integrated Scientific Area   | QMS         | Quality Management System  |
| ISI       | In Service Inspection  | RBMK        | Reactor Bolshoi Moshchnosti Kanalny (Graphite moderated, pressure-tube type reactor designed and built in the former Soviet Union) |
| ISO       | International Standards Organisation   | REACFLOW    | name of nuclear safety Code  |
| ITU       | Institute for Transuranium Elements  | REDOS       | Reactor Dosimetry (5th FWP project)  |
| JNES      | Japan Nuclear Energy Safety Organization   | RIMAP       | Risk Based Inspection and Maintenance Procedures for European Industry   |
| KFD       | Kern Fysische Dienst (Dutch Safety Authority)  | RPV         | Reactor Pressure Vessel  |
| KPI       | Key Performance Indicators   | S & T       | Scientific & Technical   |
| LBB       | Leak Before Break  | SAFECASK    | Casks for High Level Nuclear Waste Project   |
| LWR       | Light Water Reactor  | SAFELIFE    | Safety of Ageing Components in Nuclear Power Plants Project  |
| MADAM     | Conversion table of MATERIAL DAMAGE indexes (Project of EC 4th Framework Programme)  | SAFETY-INNO | Safety of Innovative Reactor Design  |
| MARCOGAZ  | Technical Association of the European Natural Gas Industry   | SANS        | Small Angle Neutron Scattering   |
| MAWP      | Multi-annual Work Programme  | SCA         | Shared Cost Actions  |
| MCNP      | Monte Carlo Neutron Photon   | SENUF       | Safety of Eastern Nuclear Facilities   |
| MOX       | Mixed OXides   | SETRIS      | The Sustainable Energy Technologies Reference and Information Systems  |
| NATO      | North Atlantic Treaty Organisation   | SIMLAB      | SIMulation if transport phenomena in physico-chemical processes within porous structures using the Lattice Boltzman method         |
| NCTPlan   | Nuclear Capture Treatment Plan   | SKB         | Svensk Kärnbränslehantering AB   |
| NDE       | Non Destructive Evaluation   | SOFC        | Solid Oxide Fuel Cells   |
| NDT       | Non Destructive Testing  | SOP         | Standard Operating Procedures  |
| NEA       | Nuclear Engineering Agency   | SOPHAEROS   | name of nuclear safety Code  |
| NESC      | Network for Evaluating Structural Components   | SPEECH      | Safety of Pressure Equipment Containing Hydrogen   |
| NET       | Network on Neutron Techniques Standardisation for Structural Integrity   | SPIGNAR     | Signal Processing and Improved Qualification for Non Destructive Testing of Ageing Reactors  |
| NIS       | New Independent States   | SRS         | Scientific Reference System  |
| NPP's     | Nuclear Power Plants   | STRESA      | STorage of REactor Safety Analysis   |
| NRG       | Nuclear Research and Consultancy Group   | SWOT        | Strength Weaknesses Opportunities and Threats  |
| NRWG      | Nuclear Regulators Working Group   | SYSAF       | Systems for Alternative Fuels  |
| NUKEM     | Manufacturer of Pebble Type Fuel, (Germany)  | TACIS       | Technical Assistance to the Commonwealth of Independent States and Georgia and Mongolia  |
| NURBIM    | Nuclear Risk-Based Inspection Methodology for Passive Components   | TAREG       | TACIS-Regional Programme   |
| ODIN      | On Line Data and Information Network   | TEPCO       | Tokyo Electric Power Company   |
| ODIN-PM   | On Line Data and Information Network Project Management  | TG          | Task Groups  |
| OECD      | Organisation for Economic Co-operation and Development   | TQM         | Total Quality Mangement  |
| PECO      | Pais d'Europe Central et Oriental  | TRIGA-MkII  | Training Reactor Isotopes General Atomics  |
| PEMFC     | Polymer (or Proton) Electrolyte (or Exchange) Fuel Cell  | US DoE      | United States Departement of Energy  |
| PET       | Positron Emission Tomography   | VHTR        | Very High Temperature Reactor  |
| PHARE     | Pologne, Hongarije; Aide a la Reconstruction Economique  | VROM        | Dutch Ministry of Volkshuisvesting Ruimtelijke Ordening en Milieu  |
| PIP       | Plant Improvement Projects   | VTT         | Technical Research Centre of Finland   |
| PISA      | Phosphorus Influence on Steel Ageing   | WP          | Work Programme   |
| PLIM      | Plant Life Management  |             |  |

European Commission

**EUR 21298 EN - Institute for Energy - Activity Report 2003**

Luxembourg: Office for Official Publications of the European Communities

2004 - 48 pp. - 21 x 29.7 cm

Scientific and Technical Research series

ISBN 92-894-8194-3

**Editing, design and co-ordination**

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**Abstract**

Report on the activities, accomplishments and resources related to the JRC's Institute for Energy for work carried out in 2003. In the first section of the report an overview is given of organisational issues, visits, fact and figures, competencies and quality. In the second half of the report the Institute's scientific activities are described.

The mission of the Joint Research Centre is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of European Union policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Community. Close to the policy-making process, it serves the common interest of the Member States, while being independent of commercial or national interests.

