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Institute for Energy

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EUROPEAN COMMISSION

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Institute for Energy

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IE Mission

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.

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Message from the Director

For the year 2006 energy issues continued to be a top priority on the political agenda, not only in EU but worldwide. The year saw concrete steps towards the development of an EU energy strategy. The Institute for Energy made significant technical contributions to this process. Indeed the importance of the role of the Institute was underlined during the visit to Petten of the EU Energy Commissioner, Mr. Piebalgs in January 2006. Our activities and resources were geared to support the overall establishment of EU energy policies, not only through our support to our main customer DG TREN, but also to DG ENV, DG ENTR, DG AGRI, DG RELEX and DG AIDCO.

Our activities were integrated with other JRC institutes working in the energy area through a new JRC-level integration concept called Priority Area Coordination (PAC) where the Institute took the lead in the Energy and Transport area. The international dimension included collaboration with IAEA, IEA, OECD/NEA and IPHE, to name but a few.

2006 was the final year of the EU 6th Research Framework Programme. Considerable effort was therefore dedicated to preparations of the Institute's action portfolio for the new 7th Research Framework Programme. In this context valuable advice and discussions with the Institute's Scientific Advisory Group – SAG – played a key role in ensuring the match between our competences and the needs of the EU program.

In the area of cleaner energy, our support to the European Hydrogen and Fuel Cell Technology Platform increased as did the support to other energy related Technology Platforms. The associated state-of-the art Fuel Cell Testing Facility was completed and the first experimental results were produced. Other experimental facilities related to hydrogen storage, and gasification of biomass activities saw considerable development and expansion.

In the nuclear safety area our activities focused on four main topics: safety of the ageing fleet of current nuclear power plants in EU and neighbouring countries; next generation (Generation 4) power plants; nuclear waste management; support to DG AIDCO in the TACIS Programme. In response to the request of some European Nuclear Regulators, we proposed a new activity – namely the Clearinghouse - The overall objective of the project, which will be known as the European Network on Operational Experience Feedback for Nuclear Power Plants, is to allow effective and efficient implementation of operational experience feedback for improvement of safety of the EU Nuclear Power Plants,

As regards our High Flux Reactor (HFR) another successful year from the operation and experimental output can be noted. Preparations were also made to establish a new legal entity within which the management and operation of the HFR - namely a joint undertaking. Our HFR activities are described in more depth in a specific HFR annual report 2006.

In line with our commitment to continuous development and total quality management, we renewed our certified quality and environment management systems fulfilling ISO9001(2000) and ISO14001(2004) requirements.

The site renovation proceeded according to plan. The state of the art IT facility and new workshop were completed and a small gym for staff members was opened. In preparation for the major building renovation in 309 a logistics operation involving the movement of 30% of the staff to temporary accommodation was successfully co-ordinated.

Internal communication also saw a marked improvement in 2006 with the introduction of an internal newsletter which was particularly beneficial for the integration of new staff.

Looking back on the year I think we can be proud of our achievements and progress. I believe this is due to the motivation and professionalism of all staff members, partners and stakeholders. I would like to acknowledge this and extend my appreciation for their efforts and contributions which made the year 2006 a success!

Kari Törrönen
Director IE

Introducing the Institute for Energy

The Institute for Energy in Petten is one of the seven Institutes of the Joint Research Centre (JRC), a Directorate General (DG) of the European Commission. The JRC functions as a reference centre of science and technology for the EU. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether commercial or national.

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 energy policy, with special emphasis on performance in terms of efficiency, safety, environmental compliance, and security of supply.

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 develop high quality and safe medical applications of nuclear technologies and methodologies used for diagnosis and treatment.

Support to EU Policies

The year 2006 has seen a surge in political interest at EU level in energy-related issues. At the December 2005 informal Hampton Court European Summit, the Council requested the Commission to put forward a proposal for an Energy Policy for Europe; the Russian Presidency of the G8 in 2006 proclaimed energy as one of its key priorities; the International Energy Agency was given a mandate under the G8 Gleneagles Action Plan to come forward with proposals on energy efficiency, clean energy technologies and on climate change policy. The Commission reacted to these requests by publishing a Green Paper on A European Strategy for Sustainable, Competitive and Secure Energy in March 2006. The Green Paper stated that the EU lacked a common policy and would therefore fail to meet key energy and climate change objectives. It proposed a number of areas for enhanced EU cooperation: energy savings and efficiency, larger use of renewable energy, investment in the energy supplies and energy technologies of the future and adoption of a common voice in international energy negotiations. The urgency of the latter was stressed by the Russia-Ukraine gas dispute in January 2006, which triggered the presentation to the June Council of a position paper by the European Commission and the High Representative for External Relations on an external policy to serve Europe's energy interests. The June Council also called upon the Commission to provide a prioritised Action Plan for a European Energy Policy to be adopted at the Council's 2007 spring meeting.

The JRC, mainly but not exclusively through the IE, has provided input to the above policy documents and has reacted to the energy policy "hype" by stepping up its interaction with the European policy makers, both Commission and Parliament. Together with Directorates-General TREN, ENV, ECFIN, COMP, ENTR, RTD and others, experts from a number of JRC Institutes under the coordination by IE have been heavily involved in the Commission's "integrated energy and climate change package to cut emissions for the 21st century" submitted to the Commission in December 2006. The topics with JRC involvement included an energy efficiency action plan, low-CO2 fossil power generation, a progress report on biofuels, a renewable energy road map, prioritised actions for strengthening the EU's energy infrastructure, a European approach to nuclear power, safety and security, the outline of a Strategic Energy Technology Plan for the EU. The type of involvement ranged from participation to interservice group meetings, over conducting impact assessments and evaluation of public consultation documents, to chairing of dedicated task groups, e.g. on carbon capture and storage technologies, and to co-drafting of sections in documents of the "package".

The rise of the energy topic on the EU policy agenda has also led to JRC playing a part in a number of energy-related European Technology Platforms (hydrogen and fuel cells, zero-emission fossil fuel power generation, electricity networks of the future, biofuels, photovoltaics, and safety of nuclear fission). The ETPs bring together all stakeholders (policy-makers, scientists, regulators, NGOs, ..) to formulate and implement a strategic research agenda and associated implementation plan on energy topics deemed of crucial EU importance and for which the necessary financial means may only be mobilised through public-private partnerships. In this way, JRC has established a cross-link between the energy policy (security of supply, sustainability and competitiveness) and the "knowledge triangle" (education, research and innovation).

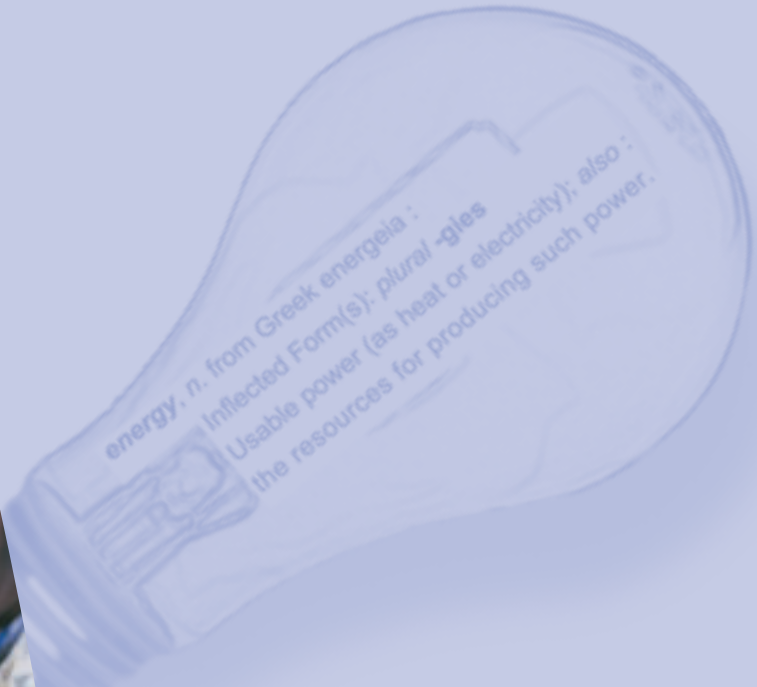
As detailed later in the individual action contributions, the IE has not only been involved in supporting energy related policies but also the more politically driven policies in relation to nuclear safety in neighbouring countries. In fact in terms of effort and resulting direct income, the support to TACIS/PHARE projects involving DG's RELEX and AIDCO remains a major element in the IE policy support.

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.

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

Overview of IE Scientific activities



Cleaner Energies

Sustainable Energy at the Institute for Energy
JRC-IE contribution to an Integrated Energy Policy for Europe

Uninterrupted access to affordable energy is an absolute prerequisite for the high quality of life enjoyed by Europeans and an essential ingredient of economic prosperity. In this respect, the European Union has to face the increasing challenge of meeting the continuously growing energy demand resulting from economic growth in EU member states while curtailing the disturbingly increasing dependence on imports and the adverse effects of energy production and use on the environment, the ecosystem, and human well-being. The interruption of gas supply from Russia in January 2006 has raised concerns about the EU's energy security even more and has accelerated the Commission efforts for formulating an integrated EU energy policy. This has resulted in the Green Paper on A European Strategy for Sustainable, Competitive and Secure Energy (COM(2006)105) of March 2006 and the publication of the so-called "Energy Package" consisting of a suite of Communications and Staff Working Documents under the heading of two major Communications on An Energy Policy for Europe (COM(2007)1) and Limiting Global Climate Change to 2 Degrees Celsius – The Way Ahead for 2020 and Beyond (COM(2007)2).

During 2006 the Institute for Energy has been continuously involved in providing scientific and technical support to the drafting of the aforementioned policy documents. It has actively contributed to a considerable number of impact assessments accompanying the Communications in line with the Commission approach towards "Better Regulation". Most notably among these are the ones related to the Communication on Sustainable Power Generation from Fossil Fuels (COM(2006)843) and the Renewable Energy Road Map (COM(2006)848). Additionally, IE has been involved right from the outset as an equal partner to DG TREN and DG RTD in the drafting of the Communication Towards a European Strategic Energy Technology Plan (COM(2006)847), which was added to the Energy Package at a very late stage by direct intervention of Commission President Barroso. The involvement of IE in the Energy Package is illustrated in figure 1 below.

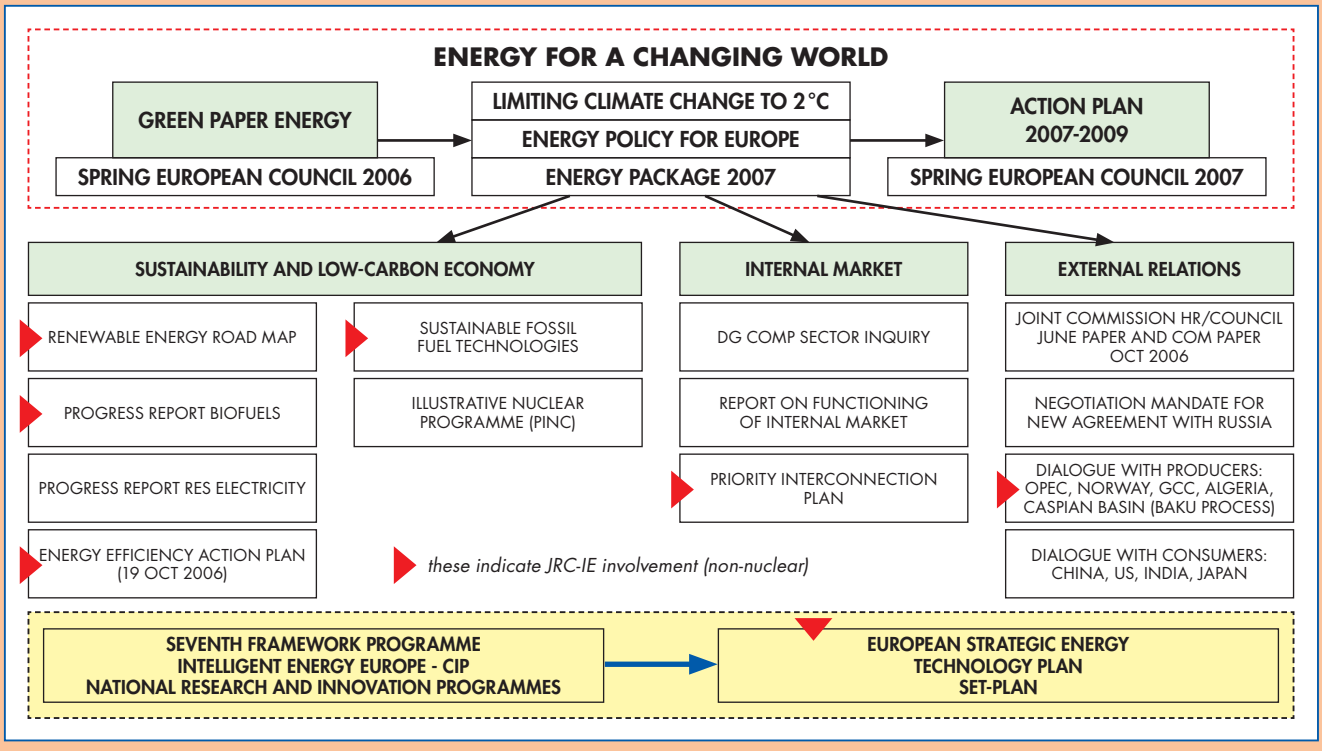


Fig. 1 - Overview of JRC-IE involvement in the Energy Package

In addition to the above policy initiatives under the lead of DG TREN, the Institute has expanded the scope of policy-support to other Commission Directorates-General, including DGs ENV, AGRI, ENTR, RELEX, JLS and even ECFIN and TAXUD, on energy-related topics within the competence areas of these DGs. Examples range from carbon capture and storage (CCS), over the nitrates directive, homologation of hydrogen-propelled vehicles, the definition of criteria for the criticality of energy infrastructures, to taxation issues on natural gas.

In the area of energy research policy the IE has maintained its deep involvement in a number of energy-related European Technology Platforms, most notably the Hydrogen and Fuel Cell Technology Platform (HFP) and the Zero Emission Fossil Fuel Technology Platform (ZEP). In HFP, IE has been the lead in the formulation of the Platform's Implementation Plan which translated the overall research and deployment strategies into specific objectives and milestones for four application sectors. Also IE acted as the main Commission driving force behind the efforts of establishing a Joint Technology Initiative on Fuel Cells and Hydrogen, i.e. a public-private partnership for progressing with the Implementation Plan. Within ZEP, the Institute is highly active in a number of dedicated working groups. It also takes care of the technological issues at the intersection between ZEP and HFP, such as related to the production of hydrogen from fossil fuels.

The hydrogen and fuel cell facilities inaugurated in 2005 produced first experimental results. In the area of fuel cell performance, test procedures were validated and applied to commercially available stacks within shared cost actions and third party work. For hydrogen solid state storage, considerable progress has been made in the identification and quantification of possible measurement errors and in the comparison of results obtained by different techniques. Also additional test equipments were made operational. The hydrogen sensor test facility produced its first results on commercial sensors which resulted in peer-reviewed publications. The fuel cell performance and hydrogen sensor activities have successfully fed into international standardisation activities under ISO and IEC. In the area of waste and biomass, a prototype pyrolysis rig was commissioned and the design of the laboratory-scale gasifier was completed. All these facilities are involved in ongoing or approved shared cost action projects.

During 2006 the JRC (non-nuclear) Energy Strategy for FP7 was finalised and approved at JRC level. It pays considerably higher attention to energy security issues and includes experimental activities related to low-carbon fossil fuel technologies, to the concept of the "refinery of the future", and to energy storage. These new areas of activity are also included in the FP7 Specific Programme and will have to be implemented in the coming years.

The combined output from the projects in the area Cleaner Energies for 2006 comprises 12 peer-reviewed journal articles, 18 conference contributions (many of them invited), 5 EUR reports, co-editorship of 2 books, 12 deliverables to EU standardisation and reference systems, 6 Enlargement/ Integration workshops and over 100 contributions to policy-making at EU level and for member states' and international institutions.

Finally, the IE has stepped up its representation and dissemination efforts at major international events such as e.g. the General Assemblies of the HFP and ZEP and as EC representative at meetings of the International Partnership for the Hydrogen Economy (IPHE) and the Carbon Sequestration Leadership Forum (CSLF). Within the International Energy Agency (IEA), the Institute participates in a number of technical tasks under the Hydrogen and Fuel Cell Implementing Agreements and it represents the EC in the Executive Committee of the Hydrogen Implementing Agreement. Links with the Energy Research Centre of the Netherlands (ECN) and with Dutch Technical Universities have deepened. The practice established in recent years of as giving presentations to municipalities and schools was kept up.

Systems for Alternative Fuels (SYSAF)

In its Green Paper on a *European Strategy for Sustainable, Competitive and Secure Energy* (COM(2006)105), the Commission recognises that there is no single solution to our energy problems, and that it is necessary to deal "with a wide portfolio of technologies: renewable energy technologies, making clean coal and carbon capture and sequestration an industrial reality, developing economically viable biofuels for transport, new energy vectors such as hydrogen and environmentally friendly energy usage (e.g. fuel cells) and energy efficiency". In a future sustainable energy economy, hydrogen and electricity are expected to become important and complementary energy carriers. Specifically, hydrogen can play a key role in adapting energy supply to demand, as it has the potential for large-scale, even seasonal, energy storage.

Also in the transport sector hydrogen is expected to play a considerable role. In the White Paper on *a transport policy for 2010* (COM(2001) 370), the Commission has identified three main alternative fuels: biofuels in the short-term, natural gas in the mid-term and hydrogen in the long-term. Similarly, in the Green Paper on *the security of the European Union's energy supply* (COM(2000) 769), the Commission has proposed as objective for road transport the replacement of 20% of conventional fuels with substitute fuels by 2020.
However, hydrogen market penetration still calls for a major effort in terms of research and technological development. This includes establishing and validating new concepts and technologies for safe and efficient storage and handling, as well as harmonised measurement techniques and test protocols for assessing the storage potential.
The SYSAF project performs R&D in this area aiming at establishing approaches for performance evaluation of hydrogen storage systems in terms of safety, efficiency and reliability. This effort will provide the automotive, transport and energy industry, as well as the European policy makers and regulators, with the necessary information and assessment means for designing or assessing performance of on-board and stationary hydrogen storage systems. Safety being a critical concern in fuel storage and manipulation, laboratory activities are complemented by numerical modelling- based safety approaches for validation and interpretation of test results.
The SYSAF work plan for 2006 consisted in the finalisation of the experimental facilities and the generation of first test results.

Development of facilities and experimental activities

High-pressure Gas Storage Facility (GasTeF): Goal of this laboratory is the safety and performance testing of high-pressure tanks for hydrogen and methane storage for transport applications. When finalised, the facility will allow simulating a typical life cycle of hydrogen car tanks, with fast-filling and hold- or slow emptying periods, in order to assess parameters such as gas permeation and long-cycles structural stability. In 2005, most of the effort was devoted to the civil construction and the design of the high-pressure distribution system. In 2006 this system has been finalised according to plan the only delay being the procurement of an up-to-date compressor. The construction and commissioning phase will therefore extend into 2007.

Hydrogen Solid-State Storage Laboratory (SolTeF): this laboratory aims at exploring and identifying the most appropriate measurement methodologies, defining best practices and contributing to the development of standardised procedures in the field of hydrogen sorption measurements. It is equipped with instruments covering different characterisation techniques, temperature/pressure regimes and sample sizes. The experimental activity focuses on a broad range of storage materials and their sensitivity to the sample history, the experimental conditions and the testing techniques used. In 2006, this work has been presented at the International Symposium on Metal-Hydrogen Systems, and further in three articles prepared for publication. Round-robin tests on various reference materials have been organised in the frame of the Integrated Project NESSHY, aimed at identifying causes of deviation between laboratories. Participation to the exercise has been extended to include internationally recognised centres of excellence in the USA and China.
The laboratory is involved in various international collaborations where it provides sorption capacity measurements on a number of advanced materials for hydrogen storage. The work performed in this frame has resulted in co-editorship of the book "The Hydrogen Cycle - Generation, Storage and Fuel Cells."

Hydrogen Safety Sensors Testing Laboratory (SenTeF): an automated test bench for gas sensors has been completed and tested based on the functional requirements derived from market and gap analyses performed in 2004 and 2005. The facility allows assessment of hydrogen detector performance by monitoring parameters such as reaction time, accuracy

and stability under various temperature and pressure conditions, and can further perform cross-sensitivity, poisoning and long-term cycling studies.

A guideline document for performance testing of hydrogen sensors for automotive applications has been prepared. The guidelines are based on a survey of both industrial needs and available established and draft standards (e.g. the International Standard IEC 61779 for electrical apparatus for the detection and measurement of flammable gases, and the UN-ECE proposals for new draft regulations for motor vehicles using gaseous and liquid hydrogen).

A number of commercially available detectors have been selected in collaboration with the research partners of the IP StorHy and have been tested to check the practical applicability of the proposed test procedures. Within the frame of the NoE HySafe, the facility has been used in a series of round-robin tests with European partners, with results expected to be published in 2007. Contacts with sensor manufacturers have been consolidated, so that in 2007 the testing campaign can be extended to prototype detectors which are currently still under development.

European and International Collaboration

SYSAF participates to the NoE HySafe on safety of hydrogen as energy carrier, to the Subproject Safety Aspects and Requirements of the IP StorHy (Hydrogen Storage Systems for Automotive Application) and contributes with modelling work to the STREP HyApproval on hydrogen refuelling stations. Additional work is performed on detectors tests in the frame of the project InsHyDe, a spin-out from the NoE HySafe which focuses on small hydrogen releases in confined spaces.

In the field of hydrogen solid-state storage SYSAF is Work Package leader in the Marie Curie Research Training Network HyTRAIN and the Integrated Project NESSHY on novel solid state storage methods for hydrogen. In this frame, SYSAF has started in 2006 the development of a material properties database which will be made available to European partners aiming at facilitating inter-laboratory data exchanges, comparisons and retrievals.
SYSAF has supported the Enlargement and Integration (E&I) action by training a scientist from Turkey on hydrogen storage technologies and delivering expert advice to Tubitak, Marmara Research Centre, (Turkey) in the frame of the project HyProstore (Specific Support Action co-financed by DG-RTD).

During 2006 a number of collaborations with international organizations were established or continued. The IEA Hydrogen Implementing Agreement Executive Committee approved the set-up of Task 22 "Fundamental and applied hydrogen storage materials development" in October 2006. SYSAF participated in the drafting of the work plan of Task 22 and will contribute through an experimental project in collaboration with the University of Uppsala. In the area of hydrogen sensors, SYSAF obtained the liaison-D status and has participated in the activities of ISO TC197/WG 13 on Hydrogen Detectors.

At the request of the US Department of Energy (DoE), project staff has contributed to the Annual Merit Review Meeting of the DoE hydrogen storage research activities. In the broader context of the International Partnership for the Hydrogen Economy (IPHE), SYSAF has delivered expert contributions upon request to various working groups.

Clean and Efficient Energy from Waste and Biomass (CLEANWEB)

Introduction

CLEANWEB targets EU policy objectives related to waste management, energy and biofuels as presented in documents including the Green Paper on *"Security of Energy Supply"* (COM(2000) 769), *A European Strategy for Sustainable, Competitive and Secure Energy* (COM(2006) 105), the Communication *"Promotion of Electricity from Renewables"* (COM(2000) 279), *an EU Strategy for Biofuels* (COM(2006) 34), the Green Paper on *Energy Efficiency* (COM(2005) 265), *the Biomass Action Plan* COM(2005) 628), *the European Climate Change Programme* (COM(2000) 88) and *"Winning the Battle Against Global Climate Change"* (COM(2005) 35). The Action provides S&T expertise on a long-term basis to the Commission for both policy development and implementation work, as well as to international organisations (International Energy Agency, International Solid Waste Association) and to relevant industrial partners in the New Member States and in Candidate Countries. For the waste and biomass industries and their support organisations, the Action facilitates direct scientific and technical collaboration through the PREWIN[1] network and other consortia for technical projects aimed at increasing plant reliability, maximising energy recovery and minimising emissions.

In 2006 the key areas of activity included direct support to EU policy, underpinning research in collaboration with other research institutes and universities, as well as industry on subjects linked to the recovery of energy and materials and the production of alternative/renewable fuels. In addition, the Action participated in the JRC Integration and Enlargement activity, training of young researchers and the hosting of visiting scientists.

Policy Support

Work included invited participation in DG ENVs follow-up of the proposed new Waste Framework Directive on its passage through Council and European Parliament discussions. CLEANWEB provided industry data obtained from PREWIN for energy efficiency calculations and the impact of climate on waste incinerator plant energy efficiency. Technical support was provided for the compilation of the Energy Efficiency BREF, within the IPPC Directive and for the formulation of the TREN Energy Package. CLEANWEB worked with DG ENV and DG AGRI to organise a European conference to promote dissemination of the Nitrates Directive: IE input was in the field of energy production from biogas as a means to mitigate nitrate enrichment of ground water and methane emissions. Similar technical input was also made to work of DG ENV in the context of the Second phase of the European Climate Change Programme (ECCP2). Extensive responses were given to a number of interservice consultations, most notably involving the Biomass Action Plan and the EU Strategy for Biofuels. The Action provided Commission representatives to IEA Bioenergy Tasks 36 & 37 and the ISWA Thermal Treatment working group. Detailed technical reports from the activities of the latter were provided to TREN, RTD & AGRI for policy development and legislative issues.

PREWIN European Network

As network Operating Agent effort was dedicated to consolidating the membership in 2006 and preparing a new Collaboration Agreement for the next 4 years. The current membership now stands at 75 organizations from 15 EU and non-EU countries. Network members from Finland and Germany hosted the two General Assembly and Steering Committee meetings in May and November, respectively. The network continues to develop and up-date technical documents and to provide direct input to policy development (specific input to the proposed new Waste Framework Directive on invitation of DG ENV). Work on new documents on residue management and thermal spraying for corrosion protection has been carried out and draft texts prepared.

Key Results and Achievements

A considerable effort was made in 2006 to build new equipment for the new research field in CLEANWEB, alternative fuels. The following main achievements, derived in part in the Plant Simulation Test Laboratory (PSTL), and in part in collaboration with partners of Shared Cost Actions and in the frame of bilateral collaboration agreements, were:

- The laboratory-scale gasifier, an Internal Circulating Fluidised Bed (ICFB) system has been built in the PSTL. The gasifier is designed to afford efficient heat transfer from an integrated combustor to the endothermic gasification process that is designed to produce a high-energy value syngas. The simple design of the gasifier, which can be fed with biomass, waste or coal, should ensure relatively easy operation. The design work was carried out in collaboration with a Detached National Expert and using a cold fluidised bed, Plexiglas model, which allows fluid flow studies of the circulating system with multiple internal design options. The gasifier will become fully operational

[1] PREWIN European Network: Performance, Reliability and Emissions Reduction in Waste Incinerators

in 2007 and work has already been scheduled within a new competitive project;
- The waste combustion bed sensor, originally developed within the frame of a PhD study, has been up-graded to include sensors for CO, CO_2 and O_2, and additional thermocouples. With theses additional gas sensors, there is a need to improve the whole insulating capacity in order to keep the temperature of the core of the assembly low enough to allow a good functioning of the electronics without substantially increasing the size of the main container. This work is now included in an EU-sponsored project and is enabling a better understanding of the combustion of waste which is being fed-back to optimise process control leading to better combustion efficiency and ultimately to improved energy efficiency. Incinerator trials are scheduled for 2007;
- A small-scale laboratory pyrolysis facility was commissioned. The facility includes a small, 50 g, batch reactor for fuel feedstock, a zone for containing a catalyst at a different temperature and collection vessels for liquid and gaseous products, thereby allowing mass balance studies to provide basic data for either larger-scale pyrolysis or gasification. The main work for this test facility is included in a new Collaboration Agreement with a Polish institute;
- A study is being carried out to investigate the tar degradation mechanisms. Tars are formed during the gasification process and have to be removed in order to enable further use of the high-energy value singas. To examine these mechanisms, a synthetic tar-containing syngas with labelled compounds will be used. The catalytic degradation will be performed using a fixed bed reactor and the degradation products will be analysed using a Gas Chromatograph coupled with a Mass Spectrometer. This study is part of collaboration with a Dutch university.
- A new study was initiated to develop the potential of electrolysis to increase hydrogen production from different qualities of water. The study is part of a new collaboration with a Dutch university, the Bulgarian Academy of Science and the FCTEST Action in Petten.

All of the above examples have contributed to enhanced collaboration with external, particularly industrial organisations, which have in turn enabled better scientific and technical support to policy makers.

Enlargement Activities

The CLEANWEB contribution to Enlargement and Integration comprised two technical information workshops:
- Zilina (Slovakia), June 19th and 20th 2006, on the subject of "Biomass Fuel Preparation and Small-Scale Heating Systems: Local Solutions for Local Needs". The workshop was attended by 31 participants from Slovakia, Bulgaria, Czech Republic and Romania, along with invited speakers from Austria, and Italy.
- Sofia (Bulgaria), October 19th and 20th 2006, on the subject of "Methods for Alternative Fuel Production from Biomass and Waste". The workshop was attended by 61 participants from Bulgaria and Romania, along with invited speakers from The Netherlands and Czech Republic.

Publications and Conferences

During the year 13 presentations, 5 of which were invited, were made at 8 conferences and workshops. There were 4 papers published in journals, 8 in conference proceedings, and 7 papers were awaiting publication at the end of the year.

Training

During the year CLEANWEB hosted 2 PhD students, 3 post-docs, 2 visiting scientists and 1 Detached National Expert for different periods of time, all of whom contributed to various parts of the scientific work of the Action. Seven of the 8 visitors were from New Member States or Candidate Countries

Fuel Cell Testing & Standardisation (FCTEST)

Introduction

Fuel cells offer a clean, highly efficient, flexible and reliable way to convert the chemical energy of fuels such as hydrogen, but also fuel gas derived from fossil and renewable sources, into electricity and heat. Their integration into energy systems positively contributes to reduction of emissions and results in energy savings. Their flexibility to adapt to diverse energy sources moreover decreases EU dependency on foreign energy imports. Fuel cells have the potential for large-scale centralised power generation and also for decentralised generation close to the point of end-use. The latter allows an easier exploitation of the heat generated in fuel cells (CHP).

Although the potential benefits of hydrogen and fuel cells are significant, many challenges, both technical and non-technical, must be overcome before they can offer a competitive alternative for energy conversion. Fuel cell technologies are not yet mature enough and need to be further developed to fully allow the transition towards a hydrogen economy, initially through the utilisation of increasingly decarbonised fuels, and eventually as part of a renewable energy economy. For rating improvements in fuel cell technology, commonly agreed measures for system performance such as power density, dynamic behaviour and durability are indispensable. For that purpose harmonised and validated testing procedures and methodologies are needed for entire fuel cell systems as well as for system components under a variety of conditions, such as different applications and stack design concepts, type and quality of fuels etc. This will facilitate a smooth introduction of the technology, enable regulators and policy makers to remove non-technical barriers, provide equal opportunities for market operators, and provide for a solid comparison basis for users.

Achievements

- *Fuel Cell Testing*
  The state-of-the-art fuel cell testing facility (FCTEST) is used in experimental campaigns to test and evaluate PEFC stacks, components and systems under conditions that typically exist in stationary and transport applications. The electrical and environmental performance of fuel cells in off-grid and grid-connected configuration are characterized over a wide range of power output, from a few kW up to 100 kW electrical peak power. The facility consists of an automated and computerized fuel cell test station, gas analyzers, a multi-axial vibration system housed in a walk-in environmental chamber and ancillary equipments for safe, reliable and unattended operation.

  i. *Validating & benchmarking fuel cell test procedures and test protocols:* A test campaign involving leading national laboratories from Europe, North America and Eastern

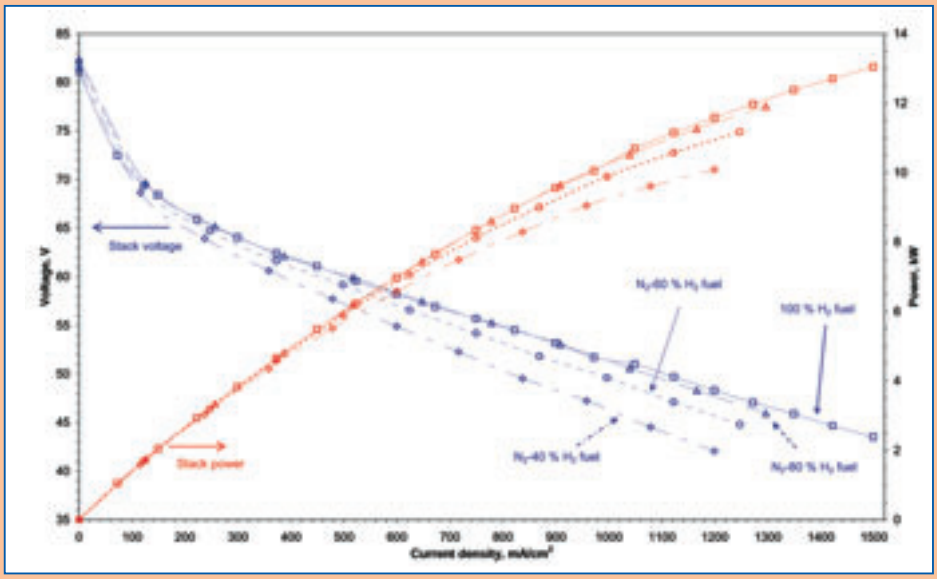


Fig. 2 - Effect of the dilution of hydrogen fuel by addition of nitrogen gas on the performance of a PEFC stack. The blue curve shows the polarization curve (voltage vs. current density) at a stepwise increasing current density for four different fuel compositions. The red line shows the corresponding stack power. The increase in nitrogen in the fuel leads to a decrease in the cell voltages, and in the stack voltage and power. The maximum attainable current density decreases dramatically from 1500 mA/cm² to about 1200 mA/cm².

Asia in the frame of the FP6 STREP project FCTES^{QA} (Fuel Cell Testing, Safety & Quality Assurance) applied Test Module TM 5-3 (developed within the FCTESTNET network) to a PEFC stack of 11 kW nominal power, as part of the test programme to assess stack performance at various electrical load levels. The validation exercise provided additional elements to complement the existing test procedure, making it easily reproducible in different laboratories. These include the definition of the inlet flow rate at open circuit voltage conditions, and the definition of the stack temperature, starting from the temperature of the stack coolant. The resulting polarization curve is given in figure 2 for different fuel compositions.

ii. *Characterization of fuel cell performance:* For example, tests at ambient conditions were conducted within the FP6 CELINA (fuel CELl application IN a new configured Aircraft) STREP project. Figure 2 illustrates the stack performance in terms of stack voltage and electrical power output at different current densities (polarization) and fuel compositions. Such performance curves are of particular relevance for the supply of onboard reformed fuels to the fuel cell stack.

- *Fuel Cell catalyst testing*

In the catalyst testing laboratory, isotopic exchange studies have been performed to investigate the temperature dependence of CO adsorption and de-sorption on commercial platinum-based fuel cell catalysts. CO is a known poison of PEM Fuel Cell anode catalysts, even at ppm levels, as it adsorbs strongly to Pt and blocks sites for the hydrogen oxidation reaction. If hydrogen is produced via reformation of hydrocarbons then it will contain significant levels of CO. An example set of data for CO exchange at a concentration of 1000ppm in an inert diluent (Ar) on a commercial Pt/C catalyst is given. From this data, kinetic parameters relating to the CO adsorption/desorption process can be determined.
These experiments have been performed as a precursor to FP6 FCANODE (Non-noble Catalysts for Proton Exchange Membrane (PEM) Fuel Cell Anodes) STREP.

In addition, complementary Steady State Isotopic Transient Kinetic Analysis (SSITKA) measurements have been performed as part of an exploratory research project in collaboration with the Isotope Measurement Unit at IRMM Geel. These tests have specifically investigated the competitive adsorption between hydrogen and low concentrations of CO at PEFC anodes and have demonstrated slower rates of exchange on PtRu compared to Pt catalysts at low CO concentrations. Whilst these experiments are ongoing, this can be tentatively attributed to the increased competition for sites on PtRu (cf. Pt) due to significantly weaker CO bonding.

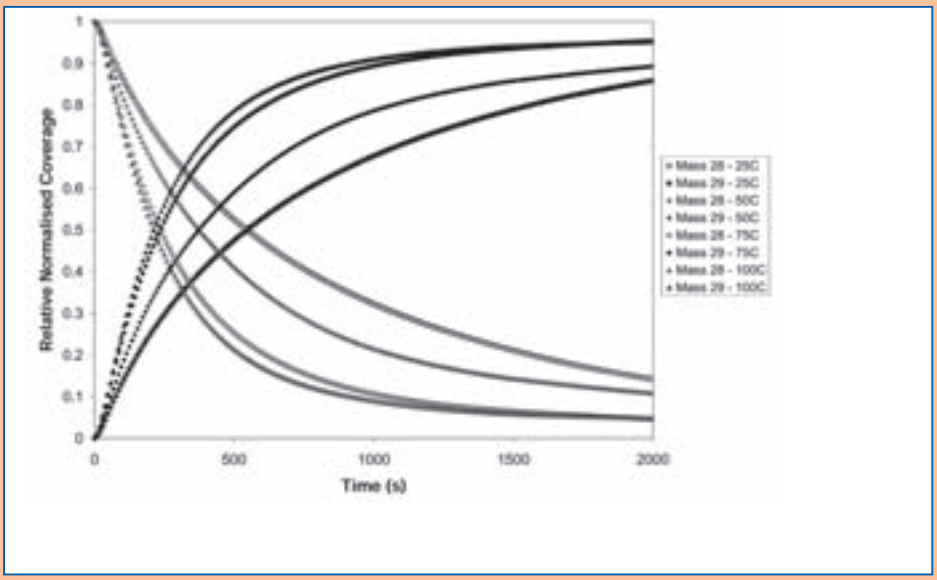


Fig. 3 - Set of normalised data for CO exchange at a commercial Pt/C PEMFC catalyst (loading of 1mg/cm^{-2}) for 1000ppm CO in Ar (flow rate = 30ml/min) and temperatures of 25-100°C.

- *Modelling & simulation of fuel cell performance*
  Numerical modelling is performed to increase understanding of the underlying mechanisms affecting fuel cell performance. This allows to underpin interpretation of experimental results and to optimise test protocols based on mesoscopic modelling of fluid flows with the use of the Lattice-Boltzmann Equations (LBE).

  Results of this activity include:
  - the reconstruction of 3D porous media structures from 2D digital images of real fuel cell electrodes. This image reconstruction allows calculating the fluid flow evolving in a real electrode structure;
  - Numerical derivation of the permeability coefficient tensor of a porous SOFC cathode electrode, thus allowing a better understanding of anisotropic proprieties of the electrode. These results will be further employed for a more solid Computational Fluid Dynamic (CFD) simulation of single cells and stacks.

- *Networking, indirect actions, and policy support*
  The action is the scientific coordinator in four competitive projects:
  - FP6 STREP Fuel Cell Testing, Safety & Quality Assurance (FCTES^{QA});
  - FP6 SSA Fuel Cell Testing and Dissemination (FCTEDI);
  - FP6 STREP Non-noble Catalysts for Proton Exchange Membrane (PEM) Fuel Cell Anodes (FCANODE);
  - FP5 Thematic Network, Fuel Cell Testing and Standardisation Network (FCTESTNET).

  The action is a partner in another four indirect actions:
  - FP6 SSA NanoCoFC (Enhancement of Research Capabilities on Multi-functional Nanocomposites for Advanced Fuel Cell Technology through EU-Turkish-China Cooperation);
  - FP6 STREP fuel CELl application IN a new configured Aircraft (CELINA);
  - FP6 SSA Harmonization of Standards and Regulations for a sustainable Hydrogen and Fuel Cell technology (HarmonHy);
  - FP5 SCA Fuel cell energy system standardised for large transport busses and stationary applications (FEBUSS).

In support of EU policies, the action contributed at the request of the Implementation Panel (IP) Transportation of the HFP with clarification of the needs and suggestions for improved harmonisation of Regulations, Codes and Standards (RCS) and of pre-normative issues from a European perspective. It also took part in meetings of the IEA Advanced Fuel Cells Annex XIX, and of international standardisation groups IEC (TC105) and ISO (TC 197) WG 12. Specifically, it delivered the FCTESTNET fuel cell glossary to IEC TC 105 enabling the latter to produce a standardized fuel cells glossary and definition of terms. It introduced a New Work Item Proposal (NWIP) for standardisation of single cell PEMFC to this body jointly with FCTES^{QA} consortium members, NREL of US and NEDO of Japan. The action attained status as an official Liaison of category B in this organization while it is officially accepted as category D liaison in ISO TC 197 WG 12. The latter body requested the Institute to consider research work aimed at establishing test protocols for characterisation of fuel cell tolerance to fuel impurities and contaminants. Furthermore, the Institute acts as the technical interlocutor for the CEN H_2&FC mandate M-349 under Grant Agreement SA/CEN/ENTR/349/2005-05, Standardisation for Hydrogen and Fuel Cell Technology.

Sustainable Energy Technologies Reference and Information Systems (SETRIS) Assessment of Clean Energy Technologies (AceTech)

Background

The energy scene in Europe is changing at a fast pace, driven by pressing concerns about the security of energy supply, the volatility of fuel prices and its impact on the competitiveness of the European economy, and the environmental footprint of the energy sector with respect to greenhouse gas emissions, and thus global climate change. The Commission has responded to this and has put forward at the end of the year a package of actions considered to be the founding stone for an Energy Policy for Europe (EPE). It is the first comprehensive and fully integrated action package for climate change and energy which also underlies the key role of innovation in shaping the EPE. Energy and energy research policies hence, will increasingly depend on the accuracy and timing of information used during the decision-making process, that on the one hand has to respect the balance of the intertwined policy drivers, noted earlier, while on the other hand has to act urgently and effectively.

The JRC draws upon all energy related scientific and technical expertise from five of its institutes, under the umbrella of the Sustainable Energy Technologies Reference and Information System (SETRIS). SETRIS provides coherent, timely and comprehensive scientific and technical support to the conception, development, implementation and monitoring of policies of the European Union related to energy and energy research. More specifically, SETRIS provides validated information, expert opinion and assessments on energy technologies, the safety and security of energy supply and the management of energy demand and energy efficiency, essential for underpinning effective sustainable energy and energy research policies. To perform its role, SETRIS delivers from a number of individual Actions, each providing its own expertise and specialised competences. The different Actions under SETRIS reside in the Institute for Energy (IE), the Institute for Perspective Technological Studies (IPTS), the Institute for Environment and Sustainability (IES), the Institute for Transuranium Elements (ITU) and the Institute for the Protection and the Security of the Citizen (IPSC). The effective coordination of SETRIS by IE ensures the quality and timeliness of scientific and technical (S&T) support to policies. Significant steps were made in 2006 to position SETRIS as an indispensable scientific reference system (SRS) and the portal of the European Commission for all energy technology issues.

The core activities of SETRIS include: techno-economic and socio-economic assessments of energy technologies, monitoring of technology development, modelling of energy supply and demand, development and analysis of scenarios for the evolution of the European energy system, assessment of the safety and security of energy infrastructures, of energy- and fuel chains, and the collection, validation and harmonization of data on energy technologies. The SETRIS portfolio of energy technologies includes: (i) decarbonised and efficient fossil fuel power generation technologies, carbon capture and storage, cogeneration of heat and power, and co-firing of coal with biomass, (ii) hydrogen and other alternative fuels, (iii) renewable energy sources, such as photovoltaics and biomass for heat, electricity and fuels, and, (iv) nuclear energy.

IE leads and coordinates SETRIS through its Action "Assessment of Clean Energy Technologies – AceTech". AceTech has catalysed the value-added integration of the SETRIS Actions and has facilitated the interactions between the JRC, other Commission services and Community stakeholders. Furthermore, AceTech contributes to the mission of SETRIS being the JRC's expert Action on advanced decarbonised fossil fuel power generation and cogeneration, and on hydrogen related technologies. AceTech provides support to policies for the transition towards a less carbon intensive energy system by providing information and expert opinion on the technologies that will be deployed in the medium and long term, based on a solid, continuously expanding knowledge base. AceTech also contributes to Technology Platforms. It has had a significant role in the hydrogen and fuel cells Technology Platform where it has led the preparation of the strategic documents, including an Implementation Plan, and is currently working on setting the ground for a Joint Technology Initiative in this field. It is also actively involved in Zero Emissions Fossil Fuel Power Plant Technology Platform (ZEP ETP), participating in the Working Group on Infrastructure and Environment.

The main output of the Action comprises: expert opinion and advice to policy makers including the provision of information on technologies based on specific requests; policy support oriented technical reports; articles in peer-reviewed journals; presentations and papers in conferences, workshops, and expert meetings; reviews of documents on behalf of other Commission services; and representation of the Commission in international bodies.

Achievements
In 2006, the Action provided S&T support to a number of Commission services, mainly to DG RTD, DG ENV and DG TREN, for various initiatives related to energy and energy research policies.

AceTech has supported the Commission activities on the decarbonisation of the power generation sector and on the management of CO_2 emissions. Carbon capture and storage, including enhanced oil recovery, the cogeneration of heat and power, the co-firing of coal and biomass and the assessment of advanced gasification and other power generation fossil fuel based technologies were themes studied extensively throughout the year. More specifically, the Action has provided energy technology data and information and contributed extensively to the preparation of the Impact Assessment of the Communication on the Sustainable Power Generation from fossil fuels(COM(2006)843). It also participated in the second phase of the European Climate Change Programme by contributing to two Working Groups (on 'Carbon Capture and Storage (CCS)', and on the 'Energy Supply' task of the 'Review of ECCP I') by making presentations and commenting on their final reports. It also produced an extensive technical note on the trade-off between acid gas pollutants and CO_2 in plants that capture CO2 and provided further information on emissions of CCS plants with the aim to evaluate their environmental footprint. This S&T support has also been valuable to DG RELEX in the ongoing cooperation with China on the development and implementation of clean coal technologies. In this context, the Action has become a key partner to DG ENV in the preparation of a regulatory framework for CCS. The Action was also invited to participate in a number of international conferences and workshops on CCS to present its work on EOR, including such high level ones as an EU-OPEC meeting. The key results of that study were included in presentations by DG RTD and were summarised in the Annual Report of a major oil company and in consultations by several stakeholders. The Action has represented the Commission to the technical groups of the Carbon Sequestration Leadership Forum and in an international workshop on near term opportunities for CCS, co-organised, in addition to CSLF, by IEA and G8 with a keynote presentation. The Action has been involved with the preparation of the strategic documents of the ZEP ETP as an invited technical expert in the Working Group on Environment and Infrastructure, contributing to the drafting and the review of the Strategic Research Agenda and the Strategic Deployment Document of the Platform. In addition, the Action organized a Workshop on advanced fossil fuel power generation in the frame of its enlargement activities that addressed the issue of security of energy supply, CCS and technology development. The presentations were made by prestigious European associations and were attended by 36 national policy makers and power plant operators from 15 new Member States, acceding and candidate countries and west Balkan states. Finally, the Action produced a leaflet on clean coal technologies and their impact on coal supply and distribution. In the context of cogeneration of heat and power, the Action has played a central role in supporting the preparation of the Annexes of the Cogeneration Directive. Acetech has participated as an expert in the technical committee for the implementation of the Directive, analysed the position papers of the major European associations, identified shortcomings in the proposed methods for calculating energy savings and outlined the process for the assessment of national potentials.

The development of a hydrogen-including economy has been another focal point of activity within the Action in 2006. IE led JRC's contributions in the inter-service Project Team of the Commission and through the Secretariat of the Hydrogen and Fuel Cell Technology Platform where the IE plays a pivotal role. The IE organised and steered the coordination group of the Implementation Panel (IP). Again the IE has been responsible for and led the drafting of the key document of the Platform, the "Implementation Plan-Status 2006" that proposes a European technology development and deployment programme for hydrogen and fuel cell technologies. Furthermore, it participated and contributed to the JTI Task Group meetings, organised Platform meetings, including the 3rd General Assembly, and represented the Platform in conferences where it made presentations and disseminated related information. AceTech has also represented the Commission in hydrogen related activities of international organisations. In the frame of the Hydrogen Implementing Agreement (HIA) of IEA, IE has as an active member in its Executive Committee and is participating in a number of HIA Tasks such as, 18 and 16. AceTech also represented the Commission to the International Partnership for the Hydrogen Economy (IPHE) reviewing strategic documents in the context of the Implementation-Liaison Committee and assisting DG RTD to organise the European inputs into the IPHE Priority Scoreboard Workshop.

The IE has provided acknowledged policy support to DG TREN for the development of the Renewable Heating

and Cooling Directive by analysing the input to the Public Consultation and summarising the key options for possible action. In the context of biofuels, AceTech participated in the inter-service group on the mid-term review of the Directive reviewing related documents, and has commented on the draft Communication prepared by DG AGRI. The Action also represents the Commission on IEA Task 41 seeking for an international consented view on the RTD gaps and needs for 2nd generation biofuels.

In the area of energy security, Acetech has invested considerable efforts to include this critical aspect of the EU energy system in its activity portfolio. These efforts covered studies on the security and reliability of oil, gas and electricity infrastructures following an all-hazards approach, the quantification and routing of imported energy, and safety assessments of energy and fuel-chains.

The abovementioned institutional activities are strongly embedded in major European collaborative projects funded under the Framework Programme.

Above and beyond the earlier mentioned contributions, the Action played a significant role in establishing the Commission's position in the future Energy Policy for Europe package at large. It contributed to both the Green Paper on a 'Secure, Competitive and Sustainable Energy for Europe' and the supporting staff Working Paper; it has significantly influenced the measures proposed by the Commission for the 'Energy Package', in particular, including that of the Strategic Energy Technology Plan. Energy Technology and the innovation required to shift our energy system towards a sustainable path are now a pivotal enabler of our energy policy, thus providing Acetech and the broad JRC Energy reference system with more challenges and opportunities for its work in FP7.

2006 Output in short

- Provided continuous support to the conception, development and implementation of Commission policies on the decarbonisation of the power sector, hydrogen and fuel cells, alternative fuels for the road transport, climate change, international collaboration, renewable heating and cooling, and cogeneration;
- Participated and contributed to many inter-service consultations including those on the Green paper on energy policy and the 'Energy package';
- Three techno-economic reports on advanced power generation technologies, hydrogen and renewable technologies, and biomass;
- Organised one enlargement and integration workshop;
- Has provided the outputs and created again the ground for broad recognition and outreach of the Unit, Institute and the JRC with its work on:
  - CO_2 storage and Enhance Oil Recovery
  - Implementation Plan of the Hydrogen and Fuel Cell Technology Platform.

Publications & Conferences

During the year 15 invited presentations were made at International conferences, meetings and workshops. There were 3 EUR reports published, 1 Conference proceedings and 1 peer reviewed article whilst several are pending.

Training

During the year ASSETS hosted 2 PhD students.

Nuclear Safety

Nuclear Safety at the Institute for Energy
The nuclear activities of the JRC aim to satisfy the R&D obligations of the Euratom Treaty and to support both Commission and Member States in the field of safeguards and non-proliferation, waste management, safety of nuclear installation and fuel cycle, radioactivity in the environment and radiation protection.

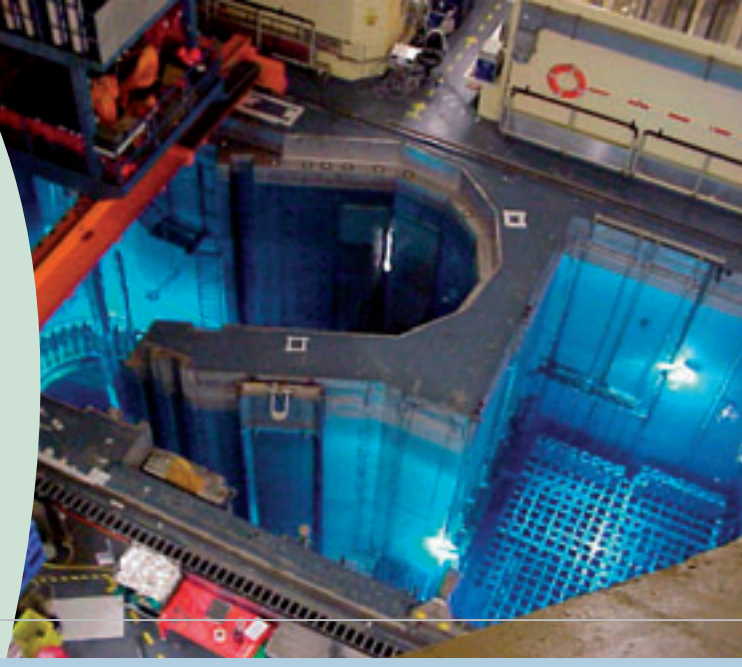
In this context the IE activities aim at contributing to the high safety level of nuclear installations in the enlarged EU and Neighbouring Countries. Main areas addressed are safety of ageing components in nuclear power plants, safe operation of nuclear installations, analysis and management of nuclear accidents, as well as assessment methods for packages for disposal of high level nuclear waste and spent fuel.

Two key themes throughout this work are:
- Networking: the Member States have always considered that networking in research is a useful tool for facilitating collaboration and possibly harmonisation at EU level. With this in mind, JRC runs several European Research Networks with the participation of utilities, regulators, research centres and other stakeholders;
- Risk-informed procedures and decision-making, based on advanced probabilistic and statistical methodologies, coupled with increasing hardware performance of the informatics systems enables full exploitation of the benefit of '*best-estimate*' approaches and avoids '*compensation*' by conservative assumptions.

The Actions in this area focus on the long term safe operation of both Western and Russian power reactor types. The activities concentrate on providing the scientific and technical knowledge, especially in important safety issues needed for policy support and for safety enhancement in general.

Highlights of IE activities in 2006 include:
- Research on materials degradation by irradiation, corrosion and thermal fatigue;
- Guidelines and best practices for efficient and effective in-service inspection by non-destructive testing of nuclear components (including risk-informed methods and qualification of inspection methods) and reliability of ultrasonic inspections;
- Support to the setting-up of the new Network for Excellence NULIFE on life assessment methodologies for nuclear power plants;
- Best practice recommendations for integrity assessment of bi-metallic welds in the coolant piping to the reactor vessel and the development of a European procedure for assessment of thermal fatigue;
- Dissemination of PHEBUS results in the field of severe accidents for improving the predictive capability of the computer codes for simulating source term release and for enhancing accident management measures;
- Calculation of the risks and loads connected with a potential hydrogen explosion;
- Probabilistic / risk / reliability studies, especially in connection to ageing of plants and the reliability of passive safety systems;
- Launch of studies on advanced structural integrity assessment methods for transport packages for nuclear waste, including finite element analysis of drop tests and associated dynamic material characterisation tests.

Safety of Ageing Components in Nuclear Power Plants (SAFELIFE)/(NULIFE)



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 2006 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 new Members States who joined the EU in 2004 or are in accession at present.

A policy of continuous RTD, plant ageing monitoring and surveillance is required to ensure that sufficient safety margins are maintained. SAFELIFE's R&D helps underpin the Commission's knowledge base in this area and its input to the nuclear energy debate. Furthermore, it combines this technical expertise with the JRC's independence to promote integration of European R&D efforts, and to accelerate, through consensus, the harmonisation of procedures and practices.

During the first year of the FP7, the SAFELIFE Team is proposing a work- plan finalised to conclude the running tasks on mature issues and at the same time to launch newer tasks; in particular, more effort towards colleting data and knowledge management, state-of-the-art reports on critical issues, harmonisation of safety approaches, methods for the nuclear energy sector, plant vulnerability, supporting the GEN IV initiative and provision of strategic materials, data and related simulation and modelling tools.

SAFELIFE provides an integrated approach to research and development on safety issues for plant life management of ageing nuclear power installations. The project focuses on establishing European best practices for deterministic and risk-informed structural integrity assessment of key components considering all nuclear power plant (NPP) designs (both western and Russian). It exploits IE's competence in testing and characterisation of materials degradation (radiation embrittlement, thermal fatigue, and stress corrosion cracking), structural mechanics, non-destructive testing & in-service inspection (ISI) qualification, neutron methods and advanced modelling techniques for residual stress analysis, as well as developing appropriate new areas of expertise.

The strategic multi-annual goals of SAFELIFE are as follows:

- Provide a basis for harmonisation of European codes and standards on key primary components of light water reactors through developing and disseminating best practices;
- Support long-term EU policy needs on PLIM and advanced reactor concept through enhancing JRC R&D competence and capabilities in nuclear safety technology;
- Integration of R&D efforts in line with ERA principles by linking our R&D to utilities, manufacturers, R&D organisations and regulators through continuing exploitation of networks and collaborating with EC and international organisations;
- Implementation of an effective plan for training, mobility, dissemination and knowledge management and development of competitive activities complementary to SAFELIFE objectives.

The activities in 2006 were organised following key primary circuit components: reactor pressure vessel, primary piping, core internals and their weldments. In addition to these component-specific activities, further activities cover method development on more generic topics supporting decision making in life management, namely: uncertainty management, maintenance optimisation, human factors and safety culture issues, and risk-informed approaches. Active components are not covered by dedicated R&D work at present; however they are included in the scope of the maintenance optimisation tasks.
In 2006 SAFELIFE continues successfully the systematic approach to use the available capabilities to actively support advanced reactor materials research and advanced analysis, as applied to the behaviour of materials under high loading rates due to 'external events'.

Networking
SAFELIFE continues to support European Networks and training activities within the frame of ERA as well as a proactive policy for the integration of experts and organisations from new member states and candidates countries in its activities. Regarding the European Networks, effort has been devoted in 2006 to complete the integration of the existing European Networks: NESC, ENIQ, AMES, NET, AMALIA & SENUF. Emphasis has been given to further develop strategic partnerships; evolving existing family of structural integrity networks to an umbrella network in the area of structural integrity R&D for NPP applications, in collaboration with key partners and DG RTD support creating the NULIFE (Nuclear Plant Life Prediction) Network of Excellence (NoE); SAFELIFE played a

major part in developing the NULIFE NoE. Led by VTT (Technical Research Centre of Finland), the five-year project has a budget in excess of EUR 8 millions, with partners drawn from leading research institutions, technical support organisations, power companies and manufacturers throughout Europe, NULIFE integrates safety-oriented research on materials, structures and systems and exploits the results through the production of harmonised life time assessment methods. NULIFE will fill a need foreseen by the JRC for improving the impact of R&D output for utilities and safety authorities in a long-term sustainable framework. Some existing network activities will be merged into NULIFE, assuming the agreement of the corresponding steering committees.

Customer orientation

The customer support has been enhanced as well in 2006, including:

- Continued support to DG TREN for participation to different working groups; in particular the Working Party on Nuclear Safety (WPNS) to review community work on nuclear safety and identification of specific work that has contributed to EU harmonisation, IAEA representation, technical support to the working group with nuclear regulators and support projects on harmonisation of codes and standard systems;
- Support to IAEA, for different CRPs and for the Extra budgetary Programme on Safety Aspects of Long-Term Operation (SALTO) of water-moderated reactors, for issuing recommendations to ensure safe long-term operation of water moderated reactors;
- Support to OECD as active member and key contributor to the activities of OECD/NEA on Stress Corrosion Cracking (SCC) of reactor internals, Special Expert Group on Human and Organisational Factors (SEGHOF) and to the working group on Integrity and Ageing of Components (IAGE). In addition a key contribution to PROSIR report (PROSIR is an OECD-NEA sponsored project related to the probabilistic structural integrity of PWR reactor pressure vessels);
- Support to EsReDa activities, in particular the editing of the last Book on *'Ageing of components and systems'*;
- Support to CEN and/or ISO technical Working Groups;
- Support to dissemination of R&D results to utilities and safety authorities via seminars, EUR reports, training workshops and presentations in key conferences.

SAFELIFE has contributed significantly to the JRC's integration and enlargement programme, hosting several visiting staff and grant holders predominantly from the NMS and the CCs, continued support for participation of experts to meetings of network and collaborative projects as well as Workshops and seminars in targeted areas. For example a Training Workshop in the area on Decision Making for Plant Life Management has been successfully organised in Lijubliana, Slovenia.

The main deliverables for 2006 include: EU best practices, state-of-the-art reports, advanced modelling, improved structural integrity assessment procedures, material characterization, Harmonised European Procedures, round-robin exercises, exploratory tasks, development of new experimental and computational methods. The SAFELIFE achievements are also disseminated by publications in international journals and presentations to conferences. In the following, examples of key deliverables are given grouped for thematic areas.

Support to GEN IV and other activities

Support of technical safety assessment and R&D on ageing issues for advanced reactor systems (complementary to SAFETY-INNO), considering in particular vessel and piping issues. Significant progress in the characterisation of RAM (reduced activation martensitic) steels has been achieved and the main results published.

Advanced analysis tools and material database suitable for modelling dynamic behaviour for integrity and vulnerability of NPP structures, have been developed. In particular, benchmarking studies were performed using EUROPLEXUS for JRC and Spanish data in co-operation with Tecnatom.

Exploratory Research

The HIPOS Exploratory Research on the Feasibility of Intense Positron Beam using HFR neutron beams has been finalised, demonstrating the possibility to build a new unique facility around the HFR.

Fig. 4 - Fracture testing RPV materials.

Advanced Structural Integrity Assessment Techniques and the European Network for Evaluating Structural Components

How can real or postulated flaws influence the safety margins of reactor components? Answering this question is critical to demonstrating adequate safety margins for nuclear plant and is an integral part of ageing management for long term operation. Within the SAFELIFE Action a series of multi-disciplinary activities focus on development and verification of advanced flaw assessment techniques. As part of this the Institute coordinates the Network for Evaluating Structural Components (NESC) and supports IAEA and OECD/NEA expert groups. We also participate as Task Leader in CEN Workshop Agreement on the FITNET European Fitness for Service Procedure. Recent highlights of our activities include:

- *Evaluating postulated reactor pressure vessel flaws:* JRC has successfully coordinated an extensive experimental programme with European and US partners to produce a fracture data set for a reactor pressure vessel (RPV) steel. This unique data set includes results from a variety of standard and non-standard specimens, and covers a range of microstructures (weld metal, cladding and base ferritic steel). It constitutes an important resource for benchmarking advanced integrity assessment methods used to evaluate the risks associated with postulated cracks under severe operational transients.

  In parallel activities we have:
  - Contributed to two IAEA coordinated research programmes, one on bias between different types of test specimen (figure 4) used to measure fracture toughness on surveillance samples and the other on new guidelines for analysing pressurised thermal shock transients;
  - Launched a new testing series for studying the behaviour of sub-surface cracks using large scale bend beams with simulated flaws (figure 5).

- *Coordinating the Network for Evaluating Structural components:* NESC brings together 24 organisations to perform benchmark-type projects aimed at verifying advanced structural integrity assessment procedures. In the future the activities will be integrated into the new NULIFE Network of Excellence.

- *Dissimilar metal welds:* over the period 2000-2006 a major NESC project was organised to study dissimilar metal welds. These are a common feature of light water reactors in connections between ferritic components and austenitic piping systems. The Institute has now released a major EUR report on "Assessment of Dissimilar Weld Integrity: Final Report of the NESC-III Project". The conclusions address inspection performance, laboratory-scale testing on welds and the potential benefits of advanced fracture mechanics methods. In addition to coordinating the project, the JRC-IE made significant technical contributions in the areas of mock-up fabrication, inspection performance and weld residual stresses. JRC, with the support of a Bulgarian detached national expert, also produced a review of dissimilar metal welds in Russian-design reactors.

Fig. 5 - Tests on beams with simulated sub-surface flaws.

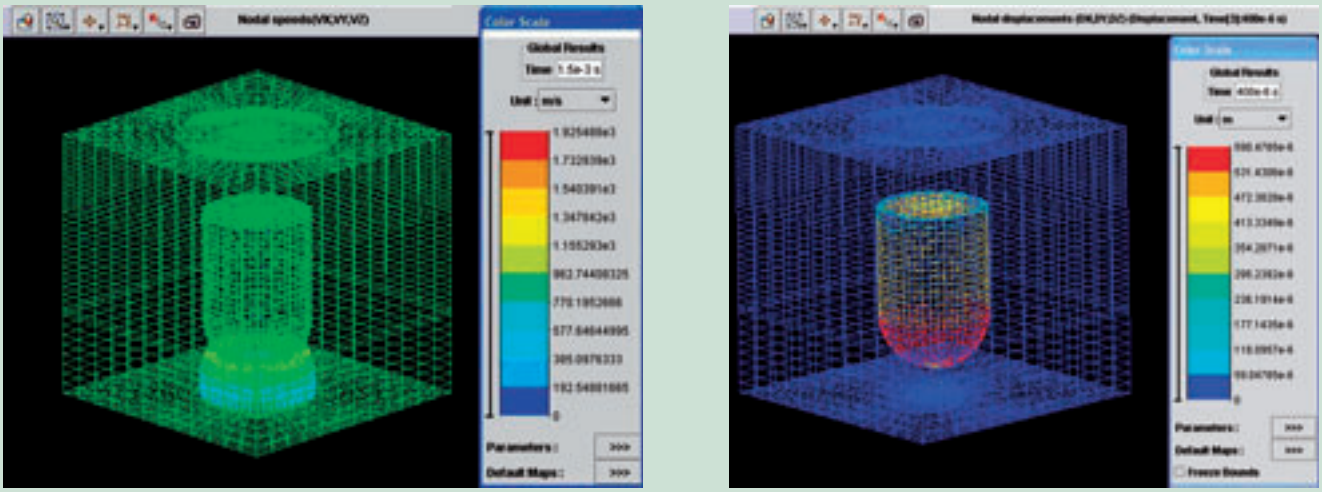
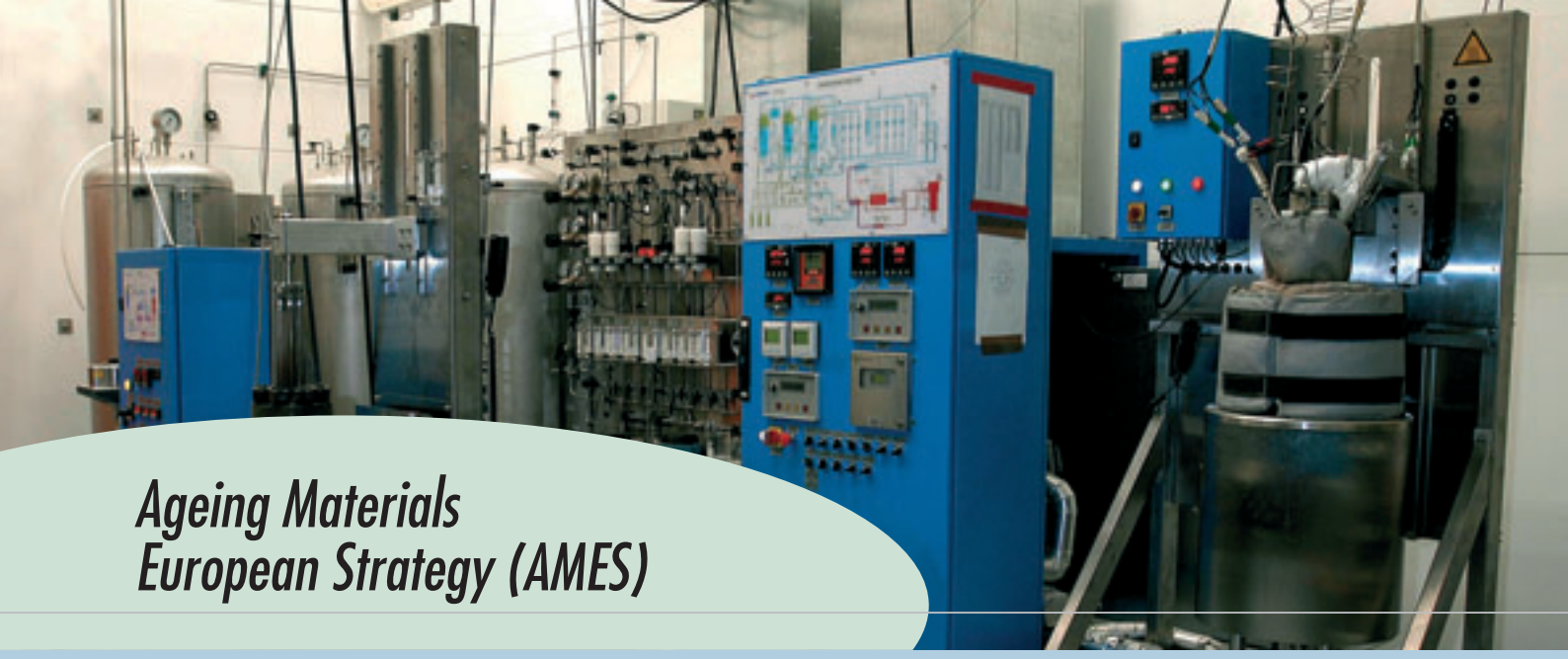


Fig. 6 - Simulation of an explosive pressure wave passing over a pressure vessel a) nodal velocities and b) resulting wall displacements.

- *Thermal Fatigue:* This is an area in which the Institute has developed significant in-house expertise as well as coordinating the NESC-Thermal Fatigue project. NESC-TF has created a database of over 40 operational service and mock-up data sets from different European organizations and is developing a European thermal fatigue damage procedure, covering thermo hydraulics, material performance, strain evaluation through finite elements, damage analysis, fracture mechanic and ISI performance.

- *Dynamic behaviour of structures under extreme loads:* Exploratory studies are being performed on the behaviour of power plant structures to blast waves from postulated explosions. This involves examining how material properties change under high strain rate conditions and finite element simulations of structural behaviour. The results are used to identify the important parameters to consider for having a rather good assessment of the global behaviour and integrity of the structure. Figure 6 shows predicted levels of deformation in the wall of an idealised pressure vessel subject to a shock wave.

- *Training:* A successful workshop in the nuclear safety series "How safe is it? Understanding what advanced structural integrity assessment can deliver", was held in October 2006. There were a total of 35 participants from Europe and neighbouring countries. The successful multidisciplinary programme combined technical presentations from several IE staff as well as those from selected participants.



Ageing Materials European Strategy (AMES)

AMES EN represents the key EU experts in the field of radiation embrittlement of materials and RPVs. The main objective is to improve understanding of reactor pressure vessel integrity issues, with emphasis on material characterisation, radiation embrittlement understanding, fracture toughness and application of probabilistic approaches for structural reliability analysis.

The first bi-annual AMES Conference "Through Life Toughness Prediction in Reactor Steels" took place in Héviz, Hungary, on 6th to 8th February 2006. Some research priorities were identified during the discussion sessions:

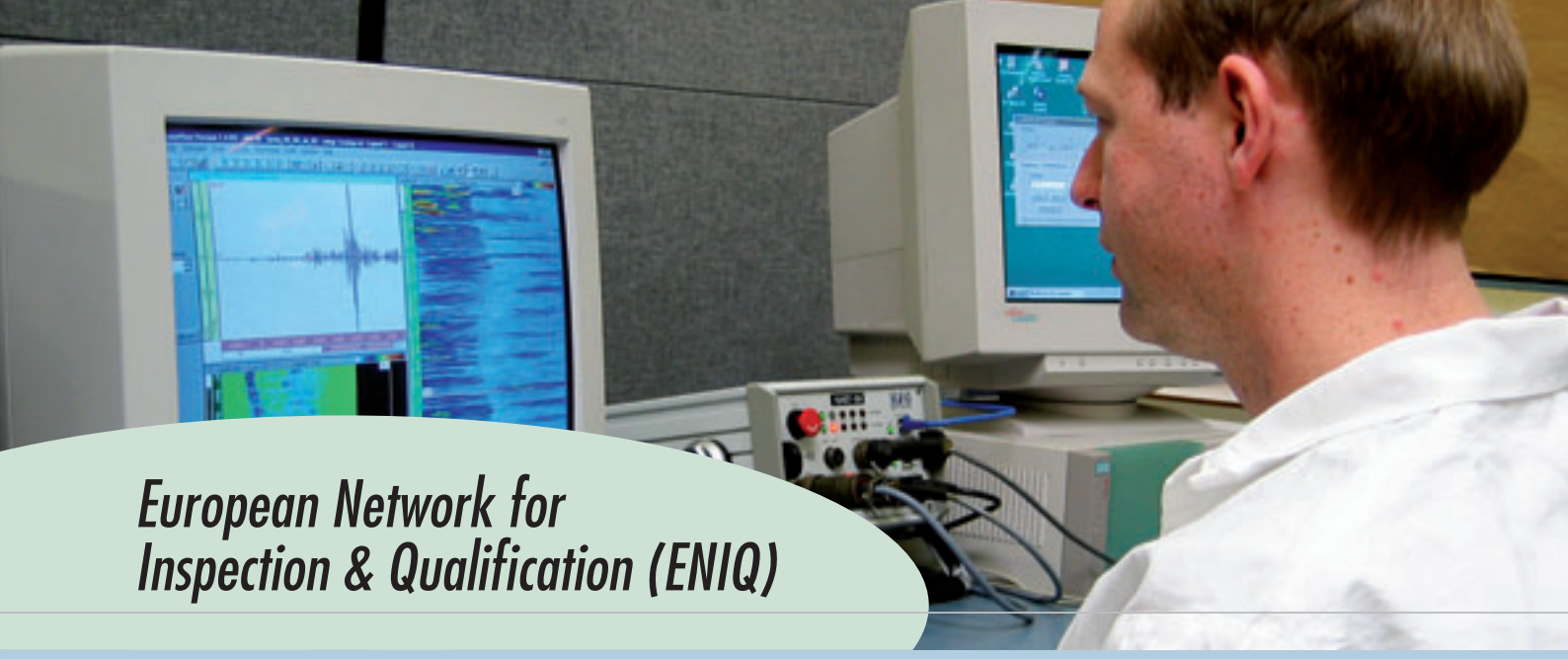
- Master Curve shape change for high shifts;
- Re-embrittlement rates & residual shifts;
- P segregation open issues;
- GEN IV materials radiation damage issue;
- Vulnerability NPP structures (aspects of materials and their ageing);
- IASCC;
- Positron annihilation;
- Si-Mn/Ni effects, etc.;
- High Cu & fluence rate.

AMES EN works in close co-operation with the PERFECT IP and is embedded into NULIFE NoE.

The SAFELIFE AMES group has dedicated in 2006 a major effort to radiation embrittlement modelling, e.g.:

- Development and characterization of large material test matrix for reference RPV materials, e.g. realistic welds and model steels;
- Testing at the Positron Annihilation Spectroscopy facility (PASS) of GEN IV RPV materials and model alloys (binary-ternary Fe-Ni-Mn);
- Development of a semi-mechanistic model of radiation embrittlement (fluence rate effect, matrix damage, etc.);
- The common irradiation project between FZR(D) and AEKI(Hu) is a positive example of international co-operation. The irradiation programme of VVER440 (Greifswald) and VVER 1000 (PERFECT) materials has been carried out in the unique AMES irradiation facility LYRA at HFR;
- Irradiation campaign preparation in LYRA at the HFR to study the embrittlement of materials for the future IAEA CRP on Mn effects in high Ni steels (model alloys, model steels and realistic welds).

1st bi-annual AMES Conference Hungary 2006.



European Network for Inspection & Qualification (ENIQ)

In-service Inspection by Non-destructive Testing – Effectiveness and Reliability

The ENIQ Network

ENIQ - the European Network for Inspection and Qualification – is a utility driven network that works for the harmonisation of in-service inspection (ISI) issues at a European level. More specifically ENIQ is working on inspection qualification (reliability of in-service inspection techniques) and risk-informed ISI (strategies for effective ISI planning based on risk considerations). IE is contributing in the network with scientific work to underpin the development of a common understanding in Europe.

In-service inspection is performed by application of non-destructive techniques (NDT), such as ultrasonics, X-ray and eddy current, to assure the integrity of safety significant pressurised nuclear components. NDT is applied to confirm that components are either free of defects or that occurring defects are detected before safety is threatened.

JRC-IE, as operating agent of the network, contributes both to the R&D work that supports the development of a common understanding in Europe and to the organisation of the network.

Through its work ENIQ supports EU policy areas such as:

- Increased *nuclear safety*;
- *Harmonisation* through publication of consensus reports by European utilities and close co-operation with safety authorities;
- The *European Research Area* by acting as a platform for Europe wide cooperation in R&D;
- *Enlargement* through participation from all new EU states with nuclear power, and thus covering both western and Russian designed reactors.

In 2006 ENIQ held eight meetings in various standing committees and projects. The work programme includes international projects with partners from North America, Japan, IAEA and the OECD Nuclear Energy Agency.

ENIQ Task Group on Risk

The ENIQ Task Group on Risk (TGR) works on developing Risk-informed In-service Inspection (RI-ISI) for European NPPs. After the publication of the utility consensus document "European Framework Document for RI-ISI", the ENIQ TGR has developed a new work programme on specific technical aspects of RI-ISI that will support the framework document. Progress has been made on:

- RISMET – a benchmark study of risk-informed ISI strategies – was initiated as cooperation between JRC-IE and OECD/Nuclear Energy Agency. In the benchmark study several different methods (EPRI, WOG-Westinghouse, WOG adjusted to Swedish regulatory requirements as well as a traditional ASME ISI programme) have been applied (for the first time ever) to the same set of piping systems of a nuclear reactor. The aim is to identify the impact of different methodologies on reactor safety and how the main differences influence the final result, which is the inspection programme. More than 20 organisations (North America, EU and Japan, IAEA) have joined the 2-year project. The analysis of the benchmark results in the broad international group is expected to give further insights into the consequences and benefits of RI-ISI and to support the development of a common understanding;
- Guidelines for the use of so called Expert Panels within the RI-ISI process, including composition of experts, responsibilities, planning and preparation of the expert panel, conduction of the expert panel, documentation of the expert panel work;
- Considerations of the role of ISI within the philosophy of defence-in-depth.
- Guidelines regarding the verification and validation of structural integrity models (SRM) and codes used for RI-ISI;
- Further development of the RI-ISI concept to cover not only pipe work, but also the reactor pressure vessel (RPV) and RPV internals;
- Further, work is being done to develop a model for quantitative assessment of NDT system reliability (through ENIQ qualification) in order to adapt the results to the needs of a RI-ISI approach.

ENIQ Task Group Qualification

ENIQ finalised a pilot study in order to explore the potential use of so-called Technical Justifications (TJ), used for qualification of NDT systems. The main results are published in the "TJ for the ENIQ 2nd Pilot Study" and in "Final Report of the ENIQ 2nd Pilot Study". The pilot study showed the TJs potential to reduce the need for expensive and inflexible full-scale mock-ups of the component for which the NDT system is being qualified. It was also concluded in the pilot study that:

- TJs may identify the need for improvements in the inspection if it is to meet its objectives;
- Data from studies reported in the literature can provide valuable information very cost-effectively but checks must be made that the NDT systems essential parameter values make the work relevant;
- Progress in computer models showed that there are models for ultrasonic testing which give largely conservative predictions of defect response when used within their regimes of validity. But all models used in TJs should be experimentally validated;
- The analysis of essential parameters carried out in the TJ illustrates the success of the approach contained in newly published Issue 2 of the "ENIQ Recommended Practice 1 on Influential/Essential Parameters".

Work has started on a new Recommended Practice (RP), which will cover best practice in Europe on the qualification of personnel being part of an NDT-system. It should give guidance for those countries that are yet to put personnel qualification into practice.

Work is also in progress to revise previously published guidelines, in order to update them and draw them in line with current best practice: "European Qualification Methodology Document", "ENIQ RP2: Recommended Content for a Technical Justification" and "ENIQ RP 3: Strategy Document for Technical Justification".

European Round Robin on NDT capability of Dissimilar Metal Welds – NESC III

In relation to the previously mentioned work on Dissimilar Metal Welds – NESC III – IE have conducted a Round Robin Trial amongst European NDT laboratories in order to investigate the capability of current NDT systems to detect, characterise and size defects in dissimilar metal welds (DMW). A pipe assembly (figure 7) containing two DMWs (alloy 182 and stainless steel respectively) with deliberately introduced defects unknown to the participants was circulated and inspected by eight European teams.

The analysis shows that some teams performed well, but that sizing of defects in DMWs is still a challenge to many laboratories, see figure 8. Further, a number of human errors, such as misreporting of data, incorrect evaluation of ultrasonic signals and setting up equipment for incorrect location was observed in the study. Based on the results it was recommended that special attention be given to the definition of realistic inspection targets both for detection and sizing.

Fig. 7 - Inspection by ultrasonics from the inside of the piping segment containing two dissimilar metal welds. Unknown defect must be detected and sized within +/-3 mm by the eight participating teams.

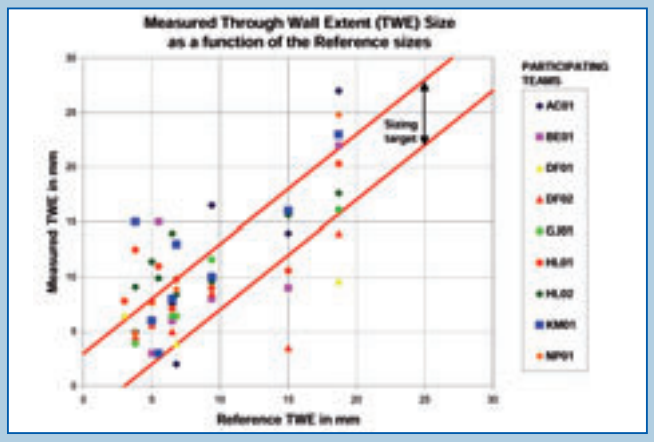


Fig. 8 - Measured through wall extent size by all teams of the defects present in the dissimilar metal weld assembly. The figure shows that only one team (GJ01) managed to size all their reported defects within the agreed sizing target of +/- 3mm.

Ageing of Materials under the Effect of Environmentally assisted Stress Corrosion Cracking (AMALIA)

The AMALIA laboratory is now fully operational and allows core internals studies – The AMALIA facility is a high temperature and pressure water chemistry loop for simulating corrosion processes in BWR, PWR and SCWR conditions.
In 2006, testing of stress corrosion cracking (SCC) susceptibility of AISI 316L austenitic stainless steel in BWR water parameters continued. The work was focused on comparison and correlation of the results obtained from tests carried out at different displacement rates on 10x10x10 mm and 3x4x27 mm SEN(B) specimens. Examples of fracture resistance J–R curves are presented in figure. 9.

As it can be observed, the J-integral values are comparable for both samples and converge at the end of the test.

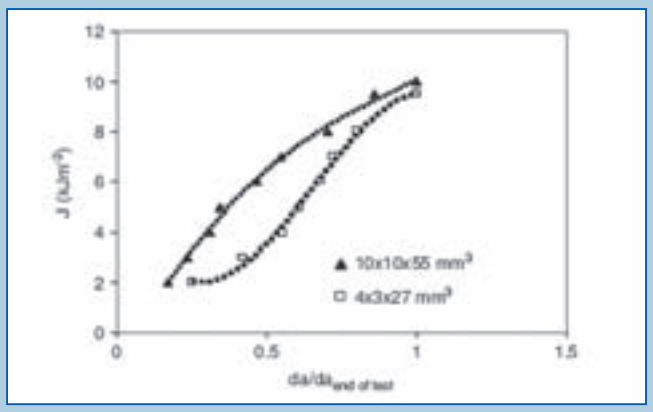


Fig. 9 - Examples of fracture resistance J–R curves.

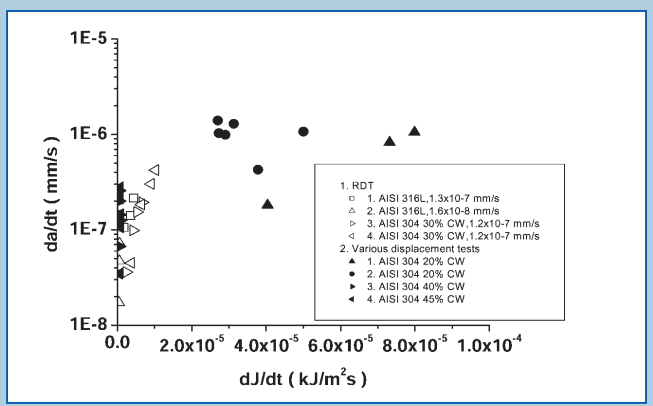


Fig. 10 - Crack growth rates as a function of specimen size/geometry independent loading rate, dJ/dt.

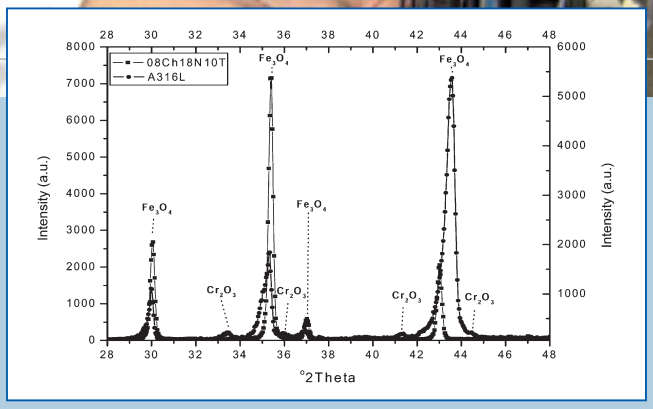


Fig. 11 - A comparison of XRD results for both tested materials after 300h.

SCC experiments in frame of the PERFECT project on cold worked (from 20%-45%) AISI 304 type stainless steel in BWR water conditions has been finalized. The results were published at The 13th International Conference on Environmental Degradation of Materials in Nuclear Power Systems. The results of the crack growth rates are presented as a function of specimen size/geometry independent loading rate, dJ/dt, in figure 10.

The crack growth rates were dependent on the applied dJ/dt even for the specimens loaded at very low dJ/dt, which indicates that the size of the remaining ligament affects the crack growth rate.

In 2006 a second loop and autoclave to allow EAC (Environmental Assisted Cracking) and corrosion testing in SCW (Super Critical Water) conditions have been commissioned. First test were focused on characterization of oxide layer composition and morphology of the various stainless steels exposed in SCW conditions (T = 600°C and p = 250 bar) and various analytical methods (SEM, XRD and XPS) were used. For example, chemical composition of the corrosion layer was characterized by X-ray Diffraction. A comparison of XRD results for both tested materials after 300h exposition is shown in figure 11.

XRD, XPS and SEM-EDX analyses confirmed that the surface layers were composed of two sub layers with the top magnetite layers growing probably preferentially from solution and mixed Cr and Fe oxides in the inner layer.
A dedicated Expert Group, AMALIA, is also developed integrated into the European Federation of Corrosion - EFC WP4 "Nuclear Corrosion".

Publications and Conferences

During the year the work was published in 1 international journal and presented at 1 International Conference.

Safety of Eastern Nuclear Facilities (SENUF)

Background and Rationale
The SENUF project (originally embedded into the SAFELIFE action of the IE) aims at facilitating the harmonization of safety cultures between the New Member States (NMS) and the European Union (EU), the understanding of needs to improve the nuclear safety in CCs, and the dissemination of JRC-IE nuclear safety institutional activities to CCs. Under the SENUF project umbrella, a number of activities was developed on both research (with the support of the SENUF network) and support to the Commission policy making.

Since 2003 the SENUF network addressed the operation safety programs at the nuclear facilities bringing together all stakeholders to favour fruitful technical exchanges and feedback of experience, namely: Beneficiaries, End Users, Eastern and Western nuclear industries. The specific objective for 2006 was to strengthen the Working Group on Nuclear Power Plant Maintenance, as a contribution to the improvement of their Operational Safety level.

In the field of policy support, the JRC/IE supported the Directorate General for External Relations, EuropeAid Cooperation Office and Enlargement in the preparation of the nuclear safety programmes and their implementation. Specific staff skills and experience were dedicated to these activities.

Scientific Output
The SENUF (Safety of Eastern European Nuclear Facilities) network continued its activities on the optimisation of the maintenance programs. The status report on "Advanced Maintenance Strategies" has been finalised and the database for "Specific and Advanced Maintenance Tools and Devices" is available for use. Further activities on Reliability Centred Maintenance (RCM), Risk Monitors as a tool to support maintenance planning, On-line maintenance activities and Risk-Informed maintenance optimisation are envisaged under the new project SONIS.

Achievements
In support to European Commission Directorate Generals IE is regularly participating in the planning meetings of the IAEA RER projects, dedicated to the Eastern European Nuclear Power Plant Safety.

Cooperation with TREN has been strengthened in 2006 with contributions to the WPNS (Working Party on Nuclear Safety) Sub-Group 1 on Safety of Nuclear Installations, mainly dealing with harmonisation topics. JRC is providing to DG TREN specific insights on the actual status of activities in various international organisations, including the IAEA and OECD/NEA as well as specific assessments or their use for the development of common views among the EU Member States on nuclear safety and regulation. In addition, JRC is requested to support DG TREN on a Road Map for Nuclear Safety of operating NPPs in Ukraine.

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 with DG RELEX in the Steering Committee of the Extra-Budgetary Programme on Safe Operation of Long Term Operation of Water Moderated Reactors within the IAEA, with a participation in each of the 4 technical Working Groups.

Support to Enlargement activities
A PECO Training Workshop on "Technical and Scientific Support to PHARE Countries on Nuclear Safety" was held in Petten, attracting 30 participants, from Bulgaria, Czech Republic, Hungary, Lithuania, Romania, Russia and Slovakia attended. 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.

Other activities
JRC/IE has significantly contributed to the preparation of the Working Group reports in the frame of the IEAE EBP SALTO programme. Those reports haven been submitted to the Steering Committee for discussion by the end of the year.

JRC/IE has significantly contributed to the preparation of the final Programme Report " IAEA Extrabudgetary Programme on safety Aspects of Long Term Operation of water moderated reactors. The programme's objective is to establish recommendations on the scope and content of activities to ensure safe long term operation of water moderated reactors.

Preparation for FP7
At the request and in collaboration with EU Member States the JRC has prepared a vision on the possible way and practical means to be used for enhancement of the operational experience feedback system at EU level. The main emphasis was given on the establishment of common EU activities which can help to optimize the use of national technical and scientific resources for operational event analyses, improve the communication means and ensure effective closure of the operational experience feedback loop by submitting event safety significant information to the right users at national regulatory authority level. A mechanism to foster the effectiveness of operational experience feedback system in the EU countries, including establishment of EU Clearinghouse on Operational experience feedback within the IE, was proposed and submitted for consideration to EU Member States in 2006.

A new project on Operational Safety of Nuclear Installations (SONIS) was developed in the framework of the FP7. The action will particularly address maintenance-surveillance and in-service-inspection programs, developing advanced techniques for integration of maintenance and in-service inspection programs into broader approaches to plant asset and safety management. In the field of fire safety, SONIS will identify the challenges posed by large fire scenarios on plant safety, where conventional assessment techniques are not applicable, and develop safety strategies for a safe plant shutdown. In the field of organizational issues, SONIS will address the following: new organizational models optimally integrating operating cost optimization, safety and asset management, safety culture issues, recovery of the operational experience feedback, safety performance indicators, knowledge management issues, effective control of external suppliers, control of organisational changes, and man-machine interface issues, to the extent needed in order to develop models and techniques for state-of-the-art safe plant management.

The action addresses the operational programs in place at the existing nuclear installations, as well as for advanced reactors, of both Western and Eastern European designs.

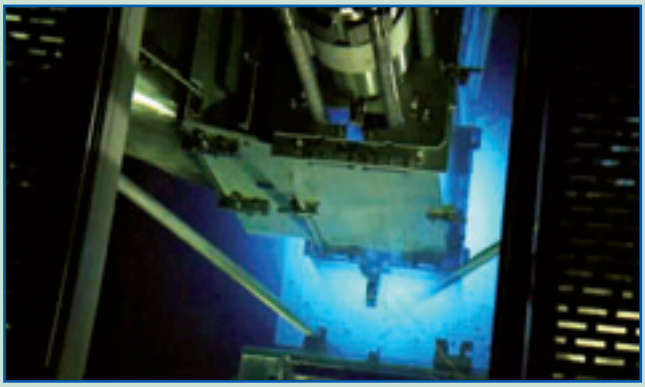


Fig. 12 - PHEBUS reactor.

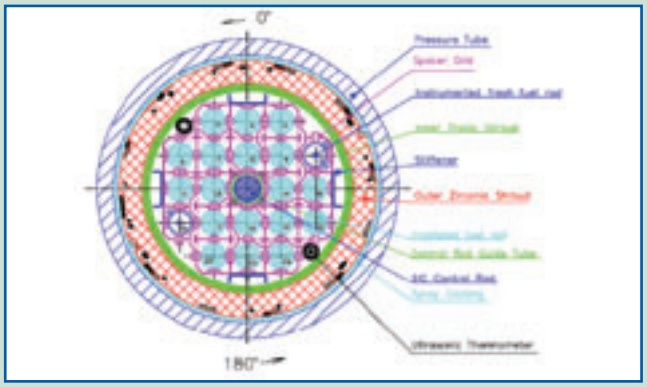


Fig. 13 - Horizontal cross-section of a Phebus test bundle. The Ag-In-Cd control rod in its center is surrounded by fuel rods, the thermally insulating multi-layered shroud and the cooled pressure tube.

Accident Management and Analysis (AMA)

Phebus

Phebus is an international nuclear accident research project, and within the Phebus Network, JRC-IE is playing a leading role in the Programme Committee and the Steering Committee. The Phebus Programme itself is jointly managed by the EC and IRSN/CEA with contributions from Switzerland, USA, Canada, South Korea and Japan. Numerous scientific workshops were co-ordinated by JRC-IE to promote European and international co-operation in the field of severe accidents. Mainly in the scientific workshops, the results of Phebus the Fission Products tests were analysed and discussed by means of post-test analyses performed with computer codes.

Over the last twelve years, five experiments were performed in the driver core of the Phebus reactor (see figure 12). Due to the established proto-typical reactor conditions the physical processes in a light water reactor during a severe accident were simulated. In four experiments the test device consisted of a 21-rod bundle (see figure 16) whereas in one experiment a debris bed with UO_2 and ZrO_2 particles was inserted in the driver core in order to study the formation of a molten materials pool and the fission product release. In these tests the degradation of bundle components, the release of fission products from the bundle and their transport in the circuit as aerosols, vapours or as gases were examined. Furthermore, in the containment, the aerosol behaviour and the iodine chemistry were studied. In 2005, a new six-year Source Term Program based on separate-effect tests was successfully launched. It is focused on (i) the iodine chemistry in the containment atmosphere and in the sump water, (ii) the ruthenium release in air atmosphere, (iii) the boron carbide oxidation and the fission product release from fuel.

In 2006 JRC-IE concentrated on further study of the ruthenium release due to its high safety relevance in an accident with air-ingress. In this case volatile ruthenium oxides are formed such as RuO_4, RuO_2 and they can easily reach the environment. These oxides are not only radiotoxic but chemically toxic as well. Several series of separate-effect tests using short fuel rod segments with mixed powder components of inactive materials have been performed. The test results imply that owing to oxidation of spent fuel in air most of the initial Ru mass dispersed in the fuel can be released from the reactor core to the containment or environment. Some amount of the released gaseous Ru, namely RuO_2, undergoes precipitation and deposits on the cold surfaces, other parts are released in gaseous form (RuO_4). The deposited RuO_2 can serve as a secondary source for further gaseous Ru release if the temperature of the deposition surface increases.

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

In 2006 the validation efforts of the European severe accident code ASTEC continued. In particular the physical models of fission products release and transport were studied as described below.

Nuclear Fuel Bundle

The release kinetics and final release mass of iodine measured in the Phebus FPT1 test was very well reproduced (see figure 17) by the V1.2 version of the code. Furthermore, using the modelling capabilities of ASTEC, it was established that, compared to monodisperse fuel grain size distribution, the polydisperse distribution has no significant influence on the final released mass of volatile and semi-volatile fission products if the average value of grain size is the same for both distributions.

Primary Circuit

The fission products released from the bundle undergo chemical reactions in the circuit piping and the steam generator. According to the circuit analyses carried out by ASTEC, the reaction of cadmium with hydrogen iodide ($Cd + 2HI = CdI_2 + H_2$) is one of the most important chemical reactions in the steam generator. In the presence of Cd vapour released from the AIC (Silver, Indium, Cadmium) control rod and significant iodine release from the fuel rods, solid CdI_2 can precipitate and deposit in steam generator. As a result, this reaction significantly retains the iodine in the circuit. In the opposite situation, i.e. in absence of cadmium, the amount of iodine released to the containment as HI gas corresponds to at least 30% of the initial iodine mass in the spent fuel. This could be the case of LWR with boron carbide control rods.

In a framework of a JRC-IE contract, the formation of the molten pool in the bundle tests was analysed with the SVECHA code developed in the Nuclear Safety Institute of Russian Academy of Sciences. The novel code version models not only the fuel pellet dissolution by the surrounding melt but the melt oxidation by a steam flow as well using a one dimensional approach when the geometry of molten pool is characterised only by radial coordinates. The saturated melt contains liquid phase and precipitated ceramic phase.

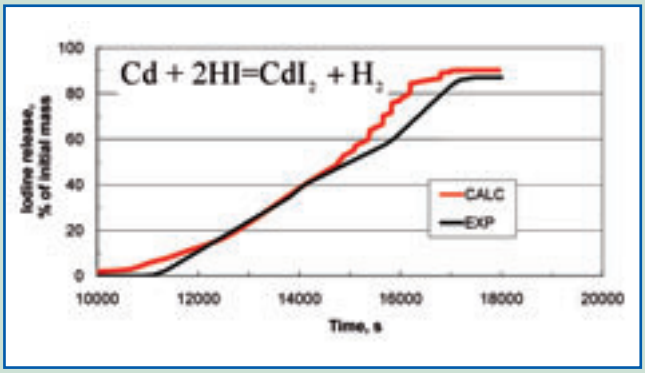


Fig. 14 - Timing of elemental iodine release from bundle and one of the most significant chemical reactions involving gaseous iodine (HI) and control rod material (cadmium vapour) in the circuit as calculated by the ASTEC code for the Phebus FPT1 experiment.

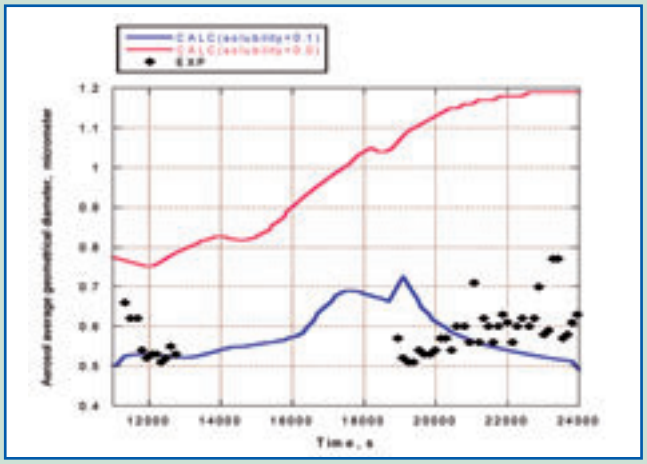


Fig. 15 - Influence of the solubility factor on the timing of average aerosol diameter as calculated by the ASTEC code in the containment atmosphere for the Phebus FPT1 experiment.

The main governing parameters of dissolution and oxidation are the temperature differences between the solid and liquid regions of the molten pool. The application of the SVECHA code allowed to evaluate the timing of fuel dissolution and oxidation and the composition of resultant corium materials in local (around one fuel rod) and global (around 8 and 20 fuel rods) molten pools found by post-test examinations of the Phebus FPT0 and FPT1 test bundles. It was pointed out that from local molten pools located in the upper part of bundle the downward materials relocation of liquid melt can occur separately from that of the solid ceramic melt. The relocating liquid melt contains dissolved uranium and the relocation happens at temperatures significantly lower than the melting point of the intact uranium dioxide pellets. A two-dimensional model of molten pool is under development; it will be capable to calculate the pool behaviour in more accurately.

The activities in frame of SARNET (Severe Accident and Management Research Network) of the 6th Framework Programme are also focused on the better prediction on the "source term" of the fission product release to the environment. Specific modules of the European Integral Code ASTEC (Accident Source Evaluation Code) were applied in order to analyze the fission product release from the fuel, the fission product transport in the circuit, the iodine chemistry and the aerosol behaviour in the containment. In particular, it was shown that the modelling of solubility of aerosol particles in water condensed on their surface is essential to correctly calculate the average aerosol diameters measured in the Phebus containment (see figure 15)

Hydrogen Safety

In case of a severe accident in a nuclear reactor with core meltdown, the interaction of the hot core with the cooling water can generate large amounts of hydrogen. The most relevant property of hydrogen related to safety is its flammability, as a hydrogen explosion can generate high overpressures with the potential to endanger the integrity of the containment, which would have devastating effects on premises and people. Therefore the prediction of the consequences of hydrogen explosions is a crucial stage of the safety analysis of a nuclear power plant. Due to the extremely high costs of experiments, computer codes have been developed with the purpose of providing estimates of the explosion consequences.

The most common codes for this purpose used today are Lumped Parameter codes, which are based on 0-D modelling of the reactor containment and have therefore their inherent limitations. More reliable results might be obtained when using Computational Fluid Dynamics (CFD) codes. CFD Codes are based on a 3-D description of the containment and therefore allow including multi dimensional effects into the simulation such as shock focussing.

In this context, the CFD code REACFLOW has been developed at JRC in order to perform numerical simulations of hydrogen combustion and explosion simulations in the nuclear but also non-nuclear field. Nevertheless to perform such combustion/explosion simulations it is essential to know the hydrogen distribution in the containment. This can be predicted also with CFD codes but requires different physical models than those in REACFLOW because of effects like steam condensation and covering large time scales. Therefore the CFD code ANSYS-CFX was chosen and validated for this purpose. Figure 16 is illustrating the follow up of events from hydrogen release and dispersion, ignition, possible flame acceleration (FA) from slow to fast flames and in worst-case even DDT (Deflagration-Detonation Transition). Slow flames can be regarded as non-critical, because there is no build-up of pressure waves, whereas fast turbulent flames and detonations are critical, because there is build-up of pressure waves. Obviously it becomes very important to understand and predict well the mechanisms of flame acceleration, which depend very much on scale and confinement, the initial hydrogen amount and distribution and the turbulence within the flame and ahead of the flame.

In order to evaluate and to improve the accuracy of REACFLOW predictions during flame acceleration, significant validation work has been carried out during the years. The validation was performed using experiments of hydrogen explosions on different scales both in confined geometry and unconfined geometry and new also for conditions with hydrogen gradients involved. Adaptive meshing is an almost unique numerical feature of REACFLOW, which allows us to do accurate predictions within and close to the flame even on large scales. This essential feature of adaptation has been developed even further. In figure 17, the propagation in a region of the large-scale RUT facility is shown. Here adaptation is based on concentrations as well as pressure, allowing following the flame as well as the pressure waves ahead of the flame in very detail.

As mentioned above the initial hydrogen distribution in a given volume e.g. the reactor containment has an important

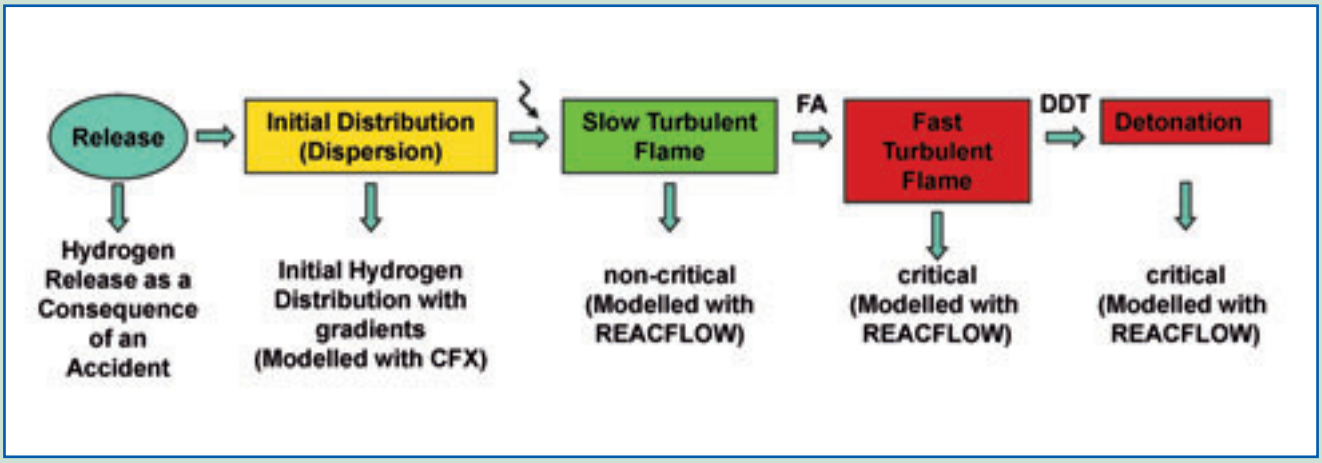


Fig. 16 - Follow-up of possible events from hydrogen release to hydrogen combustion/explosion during a severe accident.

influence on the flame acceleration process and there has to be evaluated carefully. This requires also validation of the codes and models, e.g. turbulence models. Afterwards the validated code and model can be used for any type of dispersion simulation e.g. a hydrogen release and dispersion simulation in a typical nuclear reactor containment as shown in figure 18.

Our activities in numerical modelling of hydrogen dispersion and explosions in the nuclear field are integrated in the Network of Excellence (NoE), SARNET. SARNET deals with all the issues related to severe nuclear accidents, aiming to include the more recent and suitable physical models into a common European reactor safety code, ASTEC. In SARNET, IE leads the sub-task on hydrogen combustion in the nuclear containment.

Given the current great interest for the "hydrogen economy", the models and the numerical algorithms of REACFLOW can be also used in the non-nuclear field and were therefore successfully transferred from nuclear safety applications to non-nuclear safety investigations. In the framework of the NoE HySafe, ("Safety of Hydrogen as an Energy Carrier") and the STREP HyApproval, on the approval procedure for hydrogen re-fuelling stations, REACFLOW was validated and used for several applications e.g. hydrogen safety in a re-fuelling station as shown in figure 19.

Under a Third Party contract a safety study for a hydrogen driven bus to be operated in Hong-Kong was performed and results were successfully peer-reviewed by an external referee.

Risk-Informed Decision Making and Probabilistic Safety / Risk Assessment

'Risk informed decision making' significantly contributes to maintaining and improving nuclear safety and in general safety of hazardous industries by providing the framework for consistent risk informed regulation. It complements the deterministic approach to safety and maintains the concepts of defence in depth and adequate safety margins. Risk informed decision-making is a broader concept than just the use of Probabilistic Safety Assessment (PSA). Risk informed decision making uses the results of 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. Continuously updated information on the JRC-IE activities

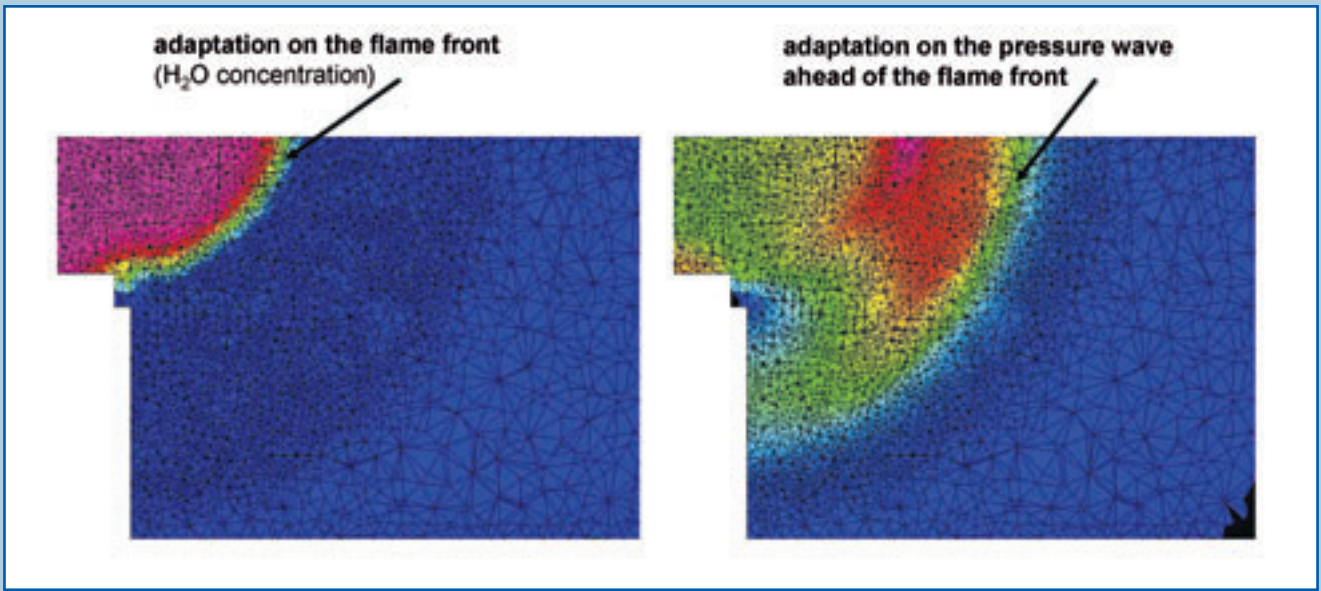


Fig. 17 - Hydrogen explosion modeling with the CFD-code REACFLOW: Advances in Grid Adaptation by Multiple Adaptation Variables.

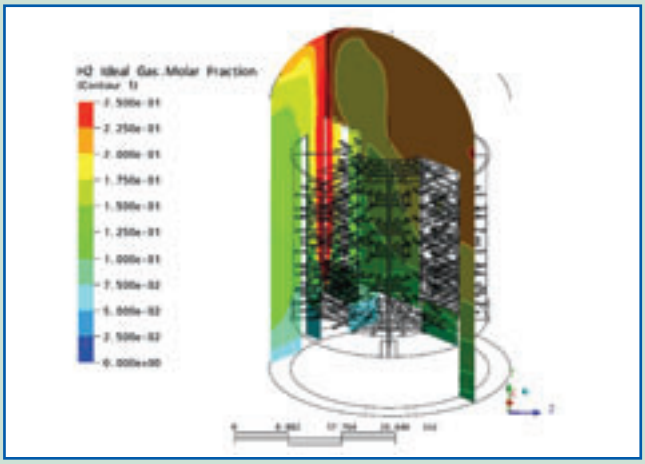


Fig. 18 - Hydrogen distribution in a Nuclear Power Plant during a hypothetical severe accident. Total amount released 1000 kg hydrogen in 1000s.

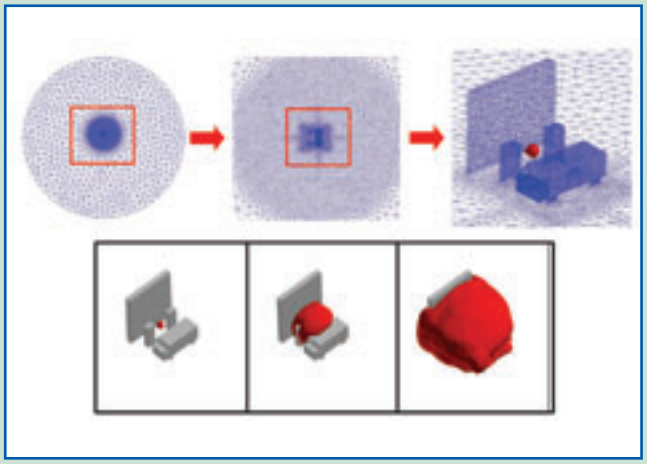


Fig. 19 - Hydrogen combustion validation simulation for re-fuelling station. At the top the computational grids and its refinement around and with the re-fuelling station is shown at the bottom the propagation of the flame during the simulation.

on energy risk assessment and risk comparison is available under: *http://www.energyrisks.jrc.nl/APSA*

JRC-IE Activities in the area focus around three areas:

- *Use of Probabilistic Safety Assessment for Evaluation of Ageing Effects for the Safety of Nuclear Power Plants:*
  In the nuclear energy production the PSA is an essential element of Safety Analysis and Licensing Process. Some of the major safety goals are formulated in probabilistic terms How could aging of systems, structures and components impact on safety of nuclear power plants from the probabilistic point of view and how could PSA help in evaluation of ageing effects to the safety?
  A basic assumption applied for the PSA modelling is that the component failure rates and initiating event frequencies are constant in time. As soon as plants get closer to the specified lifetime and in case of lifetime extension, this assumption could not be valid anymore. How to consider and to detect in time a possible increasing of failure rates due to the aging, what models and data could be used for such analysis?
  To answer these and other related questions since 2004, JRC-IE is running an International Network on Incorporation of Ageing Effects in PSA, consisting of about 20 participants from EU Member States, Russia, USA, Canada, Japan and Korea, working on issues related to probabilistic modelling of ageing effects in nuclear power plants.
  In October 2006, a 3-days international workshop on status in probabilistic modelling of ageing effects in PSA and further research needs was organized by JRC in Bucharest, Romania. More then 40 representatives from regulators, utilities and research institutions from Europe, Russia, USA and Korea participated.
  Also in 2006, a major case study on comparison of time-dependent reliability modelling at plant safety system level was made among the Network partners, using real operational experience data and models from Romania. The results clearly show the inadequacy of certain time-dependent reliability models for real applications and helped to define basic data requirements when using time-dependent modelling.

- *Reliability of Passive Safety Systems:*
  Innovative reactor concepts make use of passive safety features to a large extent in combination with active safety or operational systems. A „passive system" does not need external input, such as energy, to operate and it relies only upon the natural laws of physics. This is why it is expected that passive systems combine the advantages of simplicity, reduction of the need for human interaction and reduction/avoidance of external electrical power or signals. Historically, passive systems were considered completely reliable. However, experimental evidence and computer simulation have shown that this is not the case. Consequently, the need for inclusion of passive systems reliability values in PSA arose.
  JRC-IE is contributing to the IAEA Coordinated Research Project (CRP) on „Natural Circulation Phenomena, Modelling and Reliability of Passive Systems that Utilize Natural Circulation". This contribution is twofold. Firstly, JRC-IE is contributing to the further development of the RMPS methodology to assess the reliability of a generic passive system. The issue of distribution sensitivity is being addressed through the development of the extended rejection method, whose target is to assess the sensitivity of the system probability failure and other statistics to changes in the probability distribution functions of critical and design key parameters. Secondly JRC-IE is collaborating with other participants in the application of the RMPS methodology to the reliability assessment of the PRHR system of the CAREM advanced reactor.

- *Risk Zoning around Nuclear Power Plants:*
  In terms of reference of nuclear power plant risk zoning, some of the important zones around nuclear power plants are evacuation, sheltering, stable iodine intake/quick actions, plant internal zone and plant external zone. The proper response to an emergency requires understanding of the underlying hazards. Understanding of degraded core behaviour, containment phenomena and fission product behaviour is extremely important in emergency plans (EP) used to manage severe accidents. Such knowledge can be distilled from plant-specific Probabilistic Safety Assessment (PSA) studies. They are currently being carried out or are already available for the nuclear power plants in all EU Member States. Their results provide radiological source terms and frequencies for the range of accident sequences that could occur. The JRC-IE activity on risk informed supporting of emergency zoning within overall nuclear power plant accident management continued. Besides other things, one important issue is the different EPs in different EU Member States.

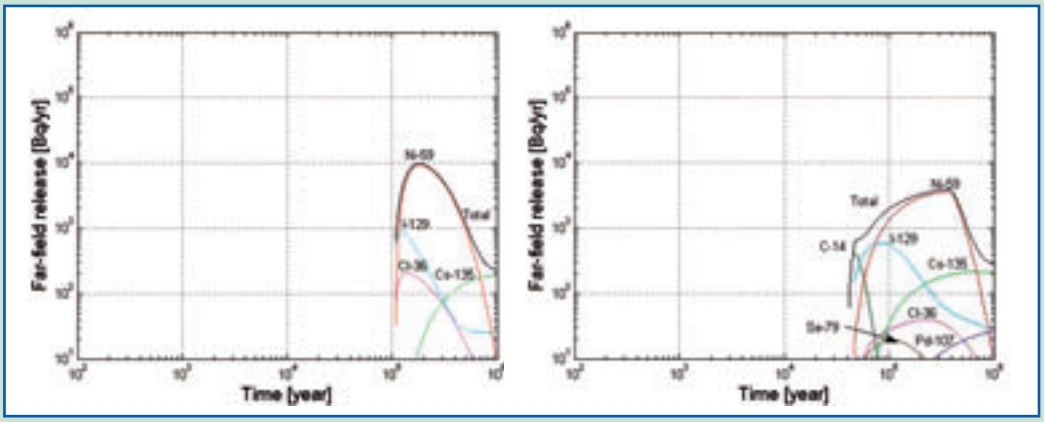


Fig. 22 - Computed release rate from far-field for the case when a canister fails after 100,000 years

(left) Spent fuel/Carbon steel/Bentonite/Crystalline rock

(right) Spent fuel/Carbon steel/Bentonite/Clay

Casks for High-Level Nuclear Waste (SAFECASK)

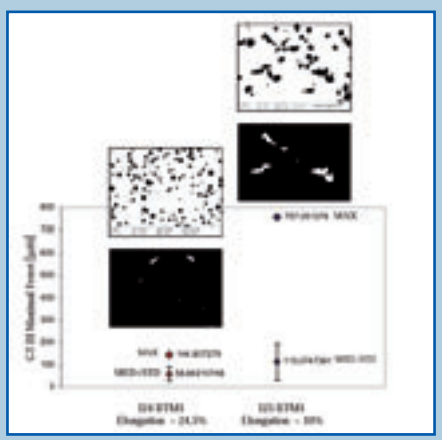
Effective and safe waste management is recognised as a determining factor for the continued use of nuclear energy and the waste package itself is central to the process. Their design depends on the required functioning, which differs for geological disposal, storage and transport. Different designs and concepts have and are being developed at national level in many countries operating nuclear installations. The objective of SAFECASK is to develop best-practice assessment methods and acceptance criteria for packages for radioactive waste and spent nuclear fuel with international partners.

A three-year research programme with Scandinavian partners was concluded in 2005 to determine the failure probabilities for copper cast iron canisters under the large pressure load that could occur during a future ice-age and the associated allowable defect sizes. Much of the work was reported in 2006, this resulted in 10 presentations in both journals, specific reports and conference proceedings. It was concluded from this project that the failure probability remains extremely low. The results are supporting documents for the license application for an encapsulation plant. A key aspect in this work has been IE research on how to relate defect and microstructure of canister materials to the mechanical properties for which there is need for objective and fast methods for material characterization. IE has therefore developed an image-processing tool (IAOGT) for characterization of ductile cast iron. Figure 20 shows how the ductility can be related to the length of poorly shaped graphite nodules (Graphite Type III).

Transport casks need to be designed against dynamic loads from accidents or handling. Casks need to be certified by drop tests and/or numerical simulations. The trend with higher burn-up and long-term storage has raised new issues that require additional research. IE has therefore started a collaboration with German partners to develop methodologies for design and assessment of impact loads. Figure 21 shows a drop test where a cask is dropped on a pin from one metre and the measured deformation in the cask's fins and the pin and computed deformations. In addition to the development of numerical analysis tools IE also started experimental programmes to determine dynamic material properties.

The design requirements on waste packages depend on the functioning and the entire waste management system. Modelling of deep geological repositories in clay and crystalline rock considering different failure scenarios for waste packages was therefore performed. Figure 22 shows the computed dose rate in clay and crystalline when a canister fails after 100 000 years. There is always a certain degree of uncertainty for assessment of repository systems. The emphasis in 2006 was therefore on uncertainty and sensitivity analysis

In addition to the scientific work, IE has also provided support to the European policy making in radioactive waste management. A number of specific studies were therefore done for DG-TREN to assess strategies in different EU and non-EU countries.



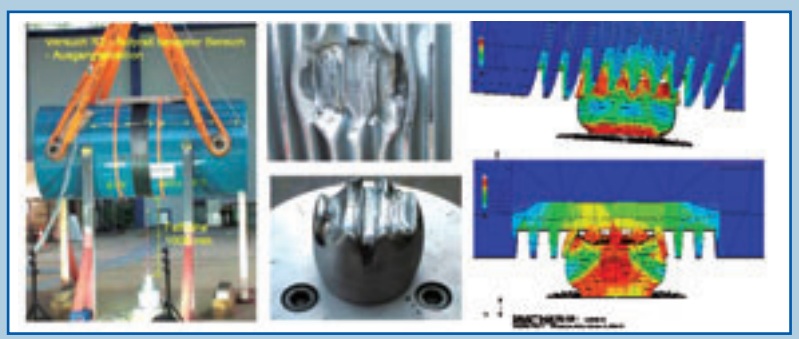


Fig. 21 - Drop test of cask for radioactive waste a) Experimental set-up b) deformed fins and pin after test) computed deformations

Fig. 20 - Example of IAOGT image processing code to characterize the microstructure of ductile cast iron for two different tested tensile specimens with elongation at fracture of 24.5% and 10%. The y-axis gives the graphite nodule length (ferret) of graphite type III. The figure inserts show the original micrograph and filtered out image corresponding to graphite type III. The symbols indicate maximum, median and standard deviation of ferret,(maximum dimension of an ellipse around the object).

Data Management and Dissemination (DMD)

A secure ODIN (Online Data Information Network) Web Portal (https://odin.jrc.ec.europa.eu) has been installed at Petten in 2004 to support European energy related R & D projects and actions. ODIN provides access to various web-enabled database applications which share fast cabling, firewall, secure connection, redundancy to guarantee high availability, central data and user management, professional hard- and software infrastructure, e.g. ORACLE as a powerful RDBMS, and professional database servers with high capacity Raid Arrays for the storage of data and documents. The DMD (Data Management & Dissemination) sector continuously maintains, upgrades and further develops databases, administration tools and software packages.

In 2006 the server infrastructure was improved and new databases and software tools were added. Figure 23 gives an overview of the ODIN Web Portal at the end of 2006. ODIN contains 10 complex database applications with intelligent user-guidance for data entry and retrieval. Five databases are related to nuclear energy, three of them deal with energy and nuclear safety related engineering and one was developed for document management. The materials database Mat-DB and the document management database DoMa contain nuclear and non-nuclear data and documentation.

Statistical and user management functionalities were implemented, which allow monitoring and better management of the ODIN database users. At the end of 2006 Odin had already more than 1000 registered users. Figure 24 shows the number of actual ODIN visits in 2006.

New analysis routines were added to the Mat-DB evaluation program library which enables the users to analyse experimental materials data for life time predictions and component design. These analysis routines can also be used independently of Mat-DB which could be very useful for training and education of young European materials scientists. Nearly all IAEA materials data for monitoring embrittlement of nuclear reactors world-wide were uploaded into Mat-DB. These data are confidential and will only be available by the overall IAEA data administrator and the associated IAEA partners.
A complex database structure for the storage of hydrogen test data on new materials (e.g. ab- and desorption tests), as well as the results of inter-laboratory comparison exercises were implement under ORACLE. The name NESSHY-DB reflects to Novel Efficient Solid Storage for Hydrogen Database. A JAVA programmed data retrieval application was successfully pilot tested.

In a similar way the new Hydrogen Incident and Accident Database (HIAD-DB) was implemented and successfully pilot tested. HIAD-DB is a European knowledge base and reporting regime to assist industry and authorities in better understanding the relevance of hydrogen-related incidents and accidents as well as the safety actions taken. It is not a standard industrial accident database but a collaborative process in the form of a web-based Information System to

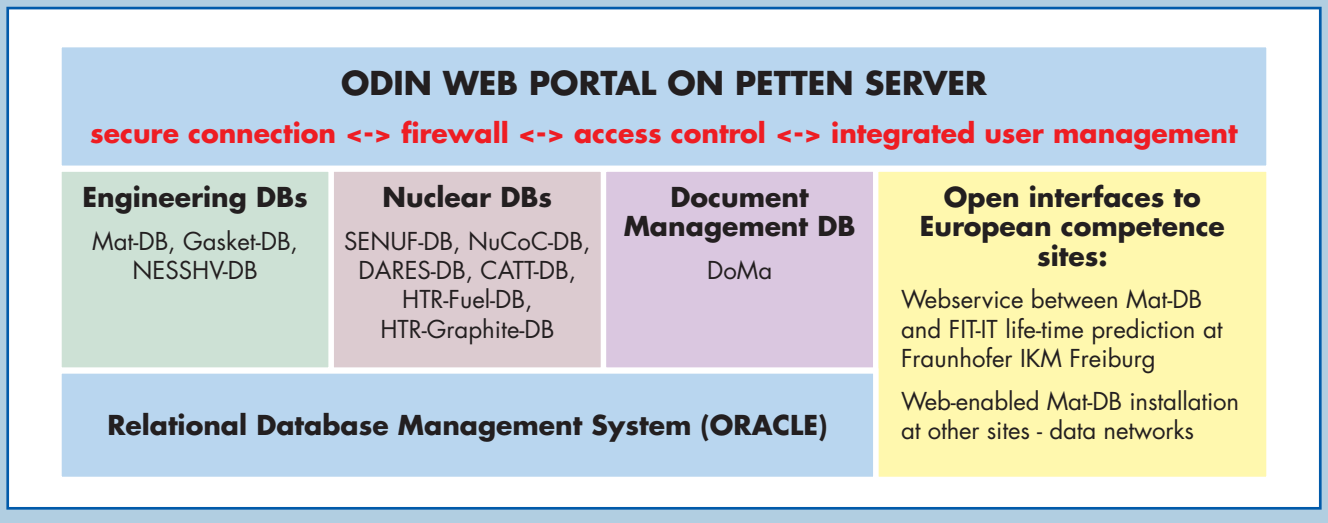


Fig. 23 - ODIN Web Portal.

promote safety actions taken by industrial and other partners as a consequence of hydrogen related incidents and accidents. The information held by HIAD is relevant for risk assessment and serves the objective of corporate learning about risks and safety related to hydrogen applications.

In cooperation with the Dutch Research Centre NRG a HTR-Graphite Database (HTR-Graphite-DB) was implemented under ORACLE. The database contains experimentally measured High Temperature Reactor graphite element data and is restricted to members of the European R&D project 'RAPHAEL'. Data entry and retrieval user-interfaces are under development.

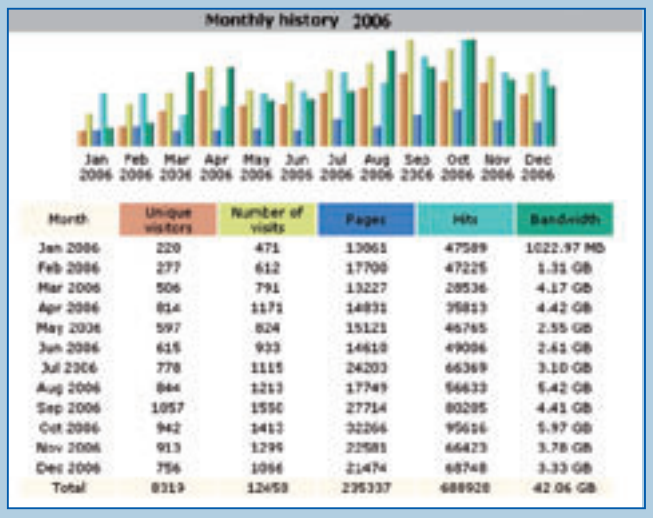
DMD as the representative of JRC is also involved in a Coordinated Research Project with IAEA in respect to 'Comparative Analysis and Tools for Nuclear Knowledge'.

Workshops

A Mat-DB customer workshop was held on October 16th and 17th, 2006 at Aachen, Germany at IRTA (partner company for Mat-DB commercialisation). More than 40 participants from industry and research attended the workshop. The new Mat-DB web application was presented and new updates and upgrades were discussed with the customers.

Publications and Conferences

In 2006 two presentations were made at international conferences in Canada and Liege.



Month	Unique visitors	Number of visits	Pages	Hits	Bandwidth
Jan 2006	220	471	13061	47589	1022.97 MB
Feb 2006	277	612	17700	47225	1.31 GB
Mar 2006	506	791	13227	28536	4.17 GB
Apr 2006	814	1171	14831	35813	4.42 GB
May 2006	597	824	15121	46765	2.55 GB
Jun 2006	615	933	14619	49006	2.61 GB
Jul 2006	778	1115	24203	66369	3.10 GB
Aug 2006	844	1213	17749	56633	5.42 GB
Sep 2006	1057	1550	27714	80295	4.41 GB
Oct 2006	942	1413	32266	95616	5.97 GB
Nov 2006	913	1295	22581	66423	3.78 GB
Dec 2006	756	1086	21474	68748	3.33 GB
Total	8319	12458	295337	688920	42.06 GB

Fig. 24 - ODIN visitors in 2006

Support to TACIS & PHARE

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 European Commission' Directorate General (DG) 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 TSSTP unit of the Institute for Energy is involved in all the areas where the TACIS and PHARE nuclear safety programmes have focused on:

- 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.

In 2006, JRC/IE participated in the preparation of TACIS procurement documents and in tender evaluations leading to contracts for major equipment supplies at the following nuclear power plants:

- Balakovo, Beloyarsk, Kola, Novovoronezh, Smolensk (Russia);
- Kmelnitsky, Rovno, Zaporozhye (Ukraine).

The support provided by JRC/IE for On-Site Assistance comprised:

- Review and approval of Technical Specifications for equipment supplies and Terms of Reference (ToR) for services contracts;
- Participation of JRC/IE experts in all procurement processes, particularly technical evaluation of tenders for safety-related equipment;
- Technical support in the project management and follow-up of contracted projects.

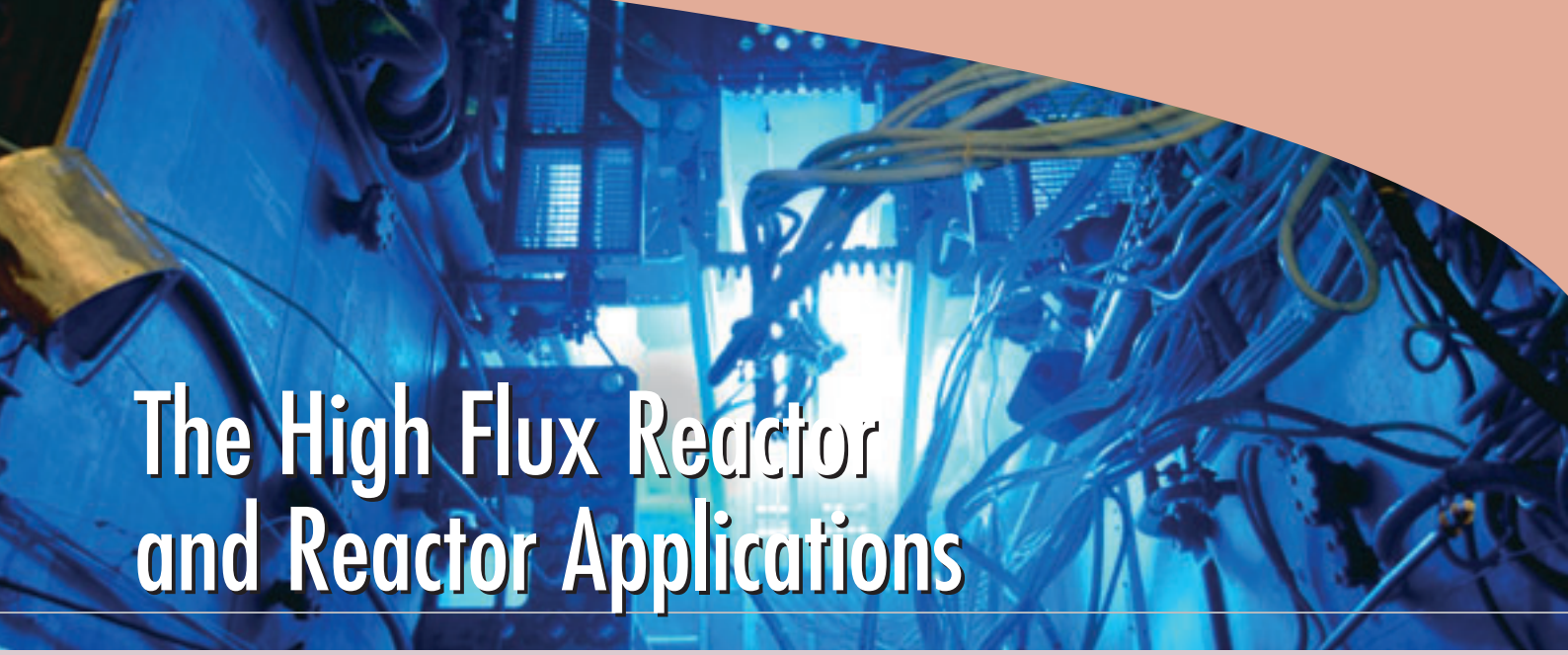
In Design Safety, the TSSTP unit has been involved in the preparation of the TACIS 2006 Annual Programme through the review of Project Description Sheets, has developed Terms of Reference for many design safety projects in the field of RPV internals, Accident Analysis, Accident scenario assessment, Equipment of Off-Site Emergency Centres & Safety Related Equipment Qualification programmes. Ongoing projects on Maintenance, Certification, 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 followed on behalf of AIDCO-A4.

In 2006, Dissemination of Russian and Ukrainian TACIS and PHARE project results has been a major challenge with seminars held in Moscow and Brussels to present the achievements. A common WEB-enabled Database has been developed which includes short descriptions of most of the projects as well as extended summaries for some selected projects. This database has the objective to allow the nuclear community, as well as other interested, to get a better visibility of the scope, status and results of these nuclear safety programmes. In the context of the forthcoming phasing-out of PHARE and TACIS nuclear safety programmes, this information tool has its importance and should also serve for preparing the future INSA activity plan.

TACIS Regulatory Assistance to Regulators and their Technical Safety Organisations has the objective to transfer regulatory methodology including the formulation of legislation and regulatory guidelines. Most emphasise has been on the processing of Technical Specifications for supporting equipment supply. Also the progress of the Technical Support Organisations (TSO's) has been monitored concerning the regulatory aspects of the industrial projects, which are being implemented.

The Industrial Nuclear Waste Management and the Decommission activities are largely concentrated on the Chernobyl area of Ukraine and the North Western area of Russia. The preparation of the Semipalatinsk (Kazahkstan) aerial survey to establish the non-contaminated areas required a major effort.

In conclusion, the described actions 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

Introduction

In 2006 the High Flux Reactor has successfully confirmed its role as key European nuclear research infrastructure.

In line with its mission, the HFR has continued to provide valuable contributions in the field of research into neutron material interaction in support of EU policies. The mission is deployed by optimal use of the reactor in the fields of:

- Nuclear safety of innovative reactors and existing reactors;
- Health and environment;
- Fusion energy;
- Fundamental research.

This includes participation in institutional and competitive activities as well as networking, training of young researchers and specific support towards new Member States.

A very high utilization factor of all irradiation positions and associated facilities is the result of the remarkable reliability of the HFR operation and of the highly qualified teams developing and supporting the experimental work.

In the area of nuclear fission the scientific work in 2006 has encompassed safety aspects of both existing and future nuclear reactors. The HFR has become a key player in establishing European best practices for deterministic and risk-informed structural integrity assessment of key components considering all existing nuclear power plant designs. In 2006 R&D work has increased in the field of future nuclear power plants for the medium and the long term, focussing on the safety analysis and safety optimization of reactors, fuels and materials with improved sustainability and waste management features.

2006 has once more demonstrated that the neutrons produced at the HFR are essential for health. The development and exploitation of Neutron Capture Therapy at Petten has not only continued to perform clinical trials, but it has also intensified its research activities into dosimetry, treatment planning, radiobiology, boron compound testing and looking at other types of cancer, as well as non-cancerous diseases. The HFR has confirmed its position as the main producer of medical radioisotopes in Europe, and one of the main producers in the world. The supply of medical isotopes grew by more than ten percent in 2006, rising to a new record level.

HFR's high versatility provides extremely relevant R&D capabilities also for fusion power plant technology. In 2006 the main areas of interest for irradiation experiments have been concentrated on the ITER vacuum vessel, the blanket development and the development of the reduced activation materials.

On May 6, 2006, after more than 5 years of analyses, 10 years of irradiation tests, 3 years of licensing and a huge effort by a large number of staff the HFR has started operation with a fully Low Enriched Uranium core loading. This is a major achievement for the HFR: the conversion allows long-term fuel supply and offers an important contribution to the global effort of diminishing the use of proliferation-sensitive high-enriched uranium.

2006 has been a record year for environmental aspects. As a result of several shipments, more than 400 spent Highly Enriched Uranium fuel elements have been removed from Petten in 2006, which is more than in any year before. The continuous improvements driven by safety culture have led to a thorough cleanup of the HFR pool, with the complete removal of high active waste originated from the HFR operation.

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 ongoing FP5 and new FP6 indirect actions. The tasks focus on the safety analysis and safety optimization of reactors, fuels and materials with improved sustainability and waste management features. In 2006, the action comprised the following activities:

- Activities related to the High Temperature Reactor Technology Network;
- Fuel Irradiations for High Temperature Reactors and Transmutation;
- Structural material out-of-pile tests for innovative reactors;
- Safety and feasibility studies on innovative reactor concepts;
- Exploratory research on energy efficient power conversion methods and process heat use.

High Temperature Reactor Technology Network – HTR-TN

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 organization of specialist meetings, seminars and conferences. Further information can be found at www.jrc.nl/htr-tn.

Achievements in 2006

JRC-IE operates this network, contributes to the coordination of related projects and provides technical input through both institutional and competitive actions. HTR-TN is driven by currently 21 partners and 2 observers from research and industry with several new companies having applied for participation in 2006.

The network partners efficiently coordinated and supervised the execution of several HTR-related R&D projects within the EU's 5th and 6th Framework Programme, and started preparation of related project proposals for the 7th Framework Programme.

Much of JRC-IE's technical achievements within HTR-TN were proposed as Euratom input to the related GIF projects. Several HTR-TN partners including the JRC are members of high-level GIF bodies and of GIF project management boards. After clarification of Intellectual Property exchange, several of these projects are expected to be signed in 2007.

Particular highlights of HTR-TN activity were the contributions to the very successful organization of the HTR 2006 conference in Johannesburg, South Africa in October 2006 (http://htr2006.co.za/). The quality of papers has reached very high standards, and participation and press response were unparalleled. The next venue will be Washington DC, USA in September/October 2008.

IE, on behalf of EURATOM, participates in the Risk and Safety Working Group (RSWG) of the Generation IV International Forum and contributes to the development of a homogeneous approach to safety in the design of Generation IV Reactor Systems. The results from the working group activities in 2006 were summarized in a report "On the Safety of Generation IV Nuclear Power Plants", which outlines the Generation IV Safety Philosophy, Design and Assessment of Innovative Systems, Generation IV Safety Methods and Tools and future activities of the RSWG and contains an example on the application of the Objective Provision Tree as Demonstration/Case Study. The JRC contributed to the drafting of the main chapters on safety assessment tools and review of the final report.

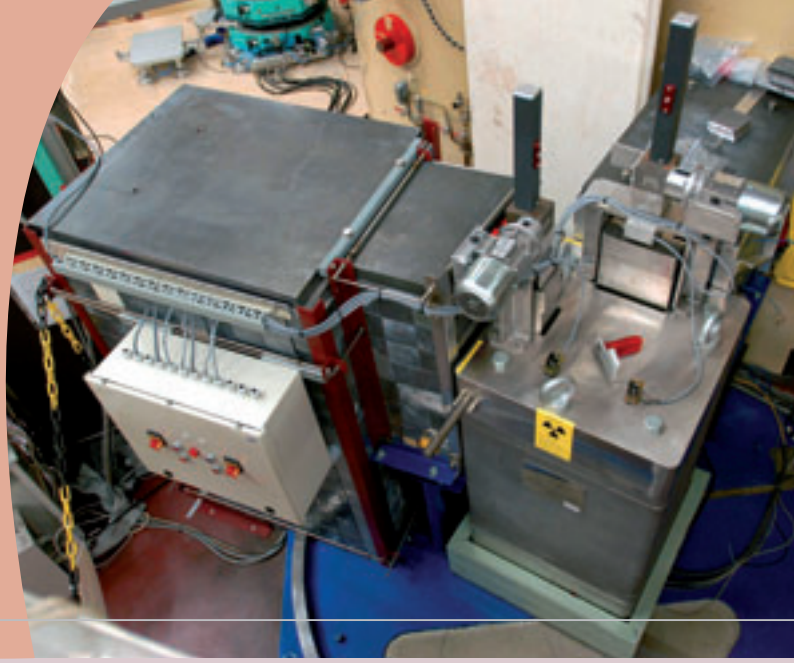


Fig. 25 - Top view of the HFR/HB4 experimental set-up, the NEU-DI-CIWI facility, for residual stress analysis in irradiated weld specimens based on neutron diffraction.

Neutron Beam Research

In 2006 the HFR Unit has continued its efforts to upgrade and revitalize the neutron beam facilities at the High Flux Reactor. Modifications and upgrades have been made at the Neutron Radiography facility at beam tube HB8, and the Small Angle Neutron Scattering facility at beam tube HB3b.

The NEU-DI-CIWI facility for residual stress analysis at HB4 has been decommissioned after the successful execution of the residual stress analysis in welded irradiated steel specimen in the context of the INTERWELD project, and subsequently the Large Component Neutron Diffraction Facility has been re-installed.

Finally, installation work at the new residual stress diffractometer at beam tube HB5 continued throughout the year.
As a consequence of these upgrading and renovation activities, only very few residual stress measurement campaigns could actually be performed in 2006 at the HFR and details on one of these campaigns are given in the following.

The NEU-DI-CIWI facility at beam tube HB4
The NEU-DI-CIWI facility has been installed in place of the Large Component Neutron Diffraction Facility in front of beam tube HB4 (Figure 25) in 2005. This facility was dedicated to residual stress analysis in irradiated components relevant to nuclear power applications, and its dominant feature therefore was the presence of heavy lead shielding.
Residual stress measurements in welded steel specimens previously irradiated at the HFR in the context of INTERWELD were performed at this facility in 2006. The main objective for these measurements was to shed light on the influence of neutron irradiation on the evolution of residual stress levels in these steel welds representative of core shroud welds of existing light water power reactors. The goal was very innovative and the experience gained by the JRC staff in measurements of radioactive specimens was indispensable. The specimens, welded bars made from austenitic steel grade SS347, had previously been measured as non-irradiated, virgin specimens. At the new shielded facility measurements were taken from test coupons irradiated to two different dose levels, i.e. ~0.3 dpa and ~1 dpa, corresponding to 4 and 11 reactor cycles, respectively. Strict procedures for the execution of these measurements had been established to ensure that workers and visitors at the facility would not be subjected to radiation doses through these experiments.
The comparison of the measurement results obtained from the irradiated welds against earlier measurements on the virgin companion specimens suggested that substantial relief of residual stresses by irradiation had taken place near the specimens' surface. On the other hand, residual stresses found at mid-thickness were apparently not affected by long-term irradiation (Figures 26 and 27).

New facility at HFR/HB5: VISA – the Versatile Instrument for Stress Analysis
Work on the installation of the new residual stress diffractometer at beam tube HB5 continued throughout the year 2006. The new instrument will facilitate handling of much larger specimens in a much more flexible way than the old diffractometer. Specimens of up to 200 kg can be placed and the movement range of the sample positioning tables is now 250 mm instead of 100 mm with the old installation. It is basically possible with this installation, entirely moveable on air pads, to use the second beam exit available, so that a very different neutron wavelength can be employed (Figure 28).

HFR Neutron Radiography Facility at beam tube HB8
The HFR neutron radiography facility has been completely refurbished and re-commissioned in 2005. During commissioning tests the level of background gamma-radiation around the camera station was of an unacceptable value to the new legislations in radiation acceptance and it was decided to install a new camera station incorporating a substantial amount of lead shielding. Whilst not compromising the main performance criteria of the radiography facility, tests have shown that the objective of a substantial reduction of the gamma-background dose-tempo has been achieved with an actual factor of 20x.

HFR Small Angle Neutron Scattering Facilities Development
Small-Angle Neutron Scattering (SANS) is a technique used for characterizing sizes (size distributions) and shapes of inhomogeneities in materials and in their mutual interactions. Applications in material science include: nucleation and growth of precipitates and voids, characterization of distributed damage in metals and ceramics as a result of

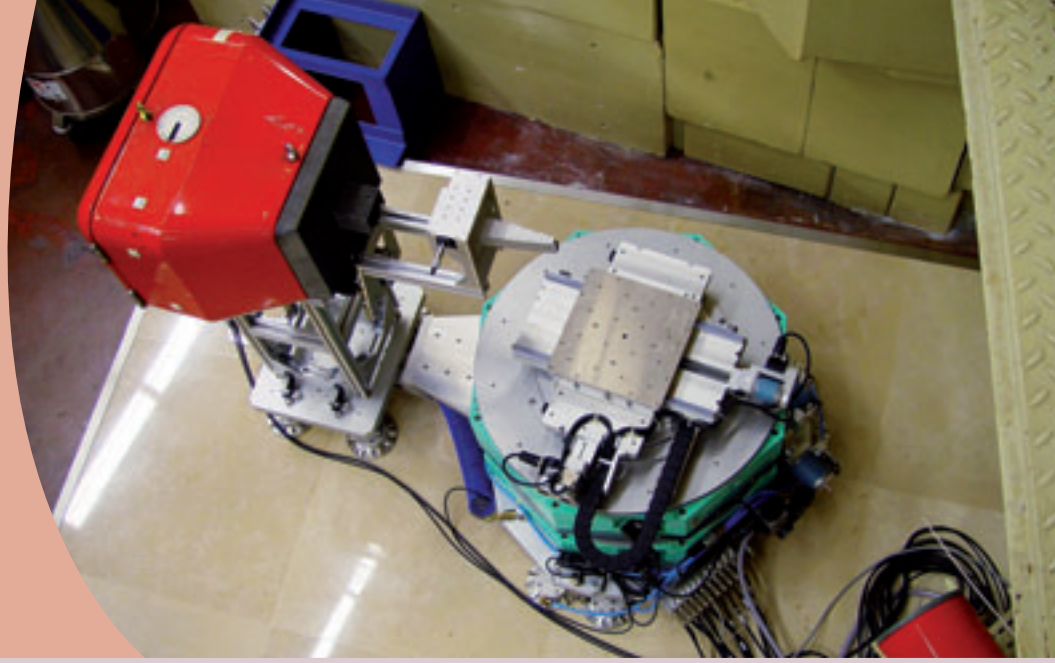


Fig. 28 - HFR/HB5: new diffractometer for residual stress analysis (VISA) installed on "Tanzboden" floor

creep and fatigue, microstructural changes after heat treatment and porosity of materials. SANS is currently emerging as a powerful non-destructive method for the investigation of irradiation and thermal ageing induced damage in steel alloys.

The current HFR/SANS facility at beam tube HB3b, developed and built in the late 80's – early 90's, has main characteristics comparable to those of other European SANS instruments with pinhole geometry. The neutron flux is ca. 10^4 n $cm^{-2}s^{-1}$, which constitutes a relatively low flux and its neutron wavelength is fixed at 4.75 Å. For these reasons a development project has been initiated in 2003 for the construction of a new SANS facility at the HFR. Based on the proposed upgrade, it is expected to achieve a neutron flux in the order of ~10^6 n $cm^{-2}s^{-1}$ as it is available at most similar facilities in Europe. In addition, the envisaged upgrade will give access to a much larger range of long wavelengths.

The main objective of the new HFR/SANS facility is to develop the capability to efficiently analyze radiation, thermal ageing and fatigue-induced damage in welded steel alloy materials in the context of the SAFELIFE Action and the NET European Network. In addition, it is expected to contribute to investigations related to innovative reactor concepts, including fusion technology, and to other activities of JRC-IE, for example hydrogen storage materials.

Outline of design concept

The new facility is to be housed in a dedicated new building, designed to allow for handling and storage of shielding equipment, such that investigations of irradiated specimen are possible by both, SANS and neutron diffraction.

Progress in 2006

The original concept included a beryllium based cold neutron source near the reactor in order to shift the neutron spectrum in the beam to the desired low energies. The neutrons were then to be guided to the facility through a neutron guide installation facilitating the transport of neutrons over a large distance with very limited loss in flux. The necessary shielding of the beam will be accomplished using lead and concrete. A neutron velocity selector will give access to wavelengths in the range 5-20 Å, which, together with a detector vacuum chamber significantly longer than the present one, will significantly enhance the Q-range accessible by this facility. Finally, new collimator shall be installed for optimum resolution.

In 2006 the performance analyses of the Be based cold neutron source and the neutron guide system have been undertaken but have unexpectedly shown that the proposed cold neutron source could not deliver the expected gain factor 6 for the neutron flux at about 5 Å. It was subsequently decided to pursue this development without a cold neutron source, as the low flux gain achievable did not justify the investment. Preliminary analyses suggested that even without the cold source the new facility could provide a neutron flux nearly two orders of magnitude higher than the existing facility at the HFR. A modified solution for the neutron guide has been proposed after the analyses, which would give significant advantages for the amount of beam shielding needed and for the size of the SANS facility itself. Analysis concerning the feasibility for such modification is underway.

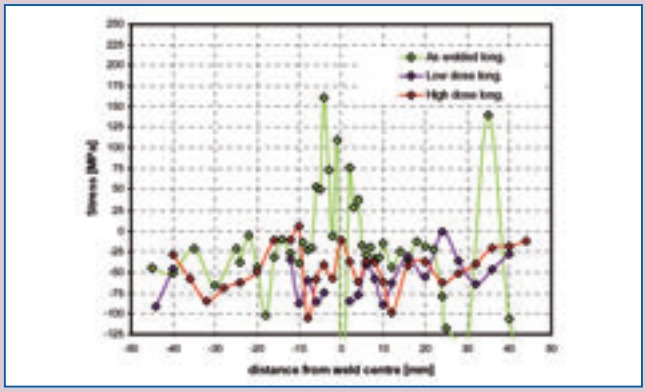


Fig. 26 - Longitudinal residual stresses measured close to the surfaces of irradiated and non-irradiated weld coupons (INTERWELD).

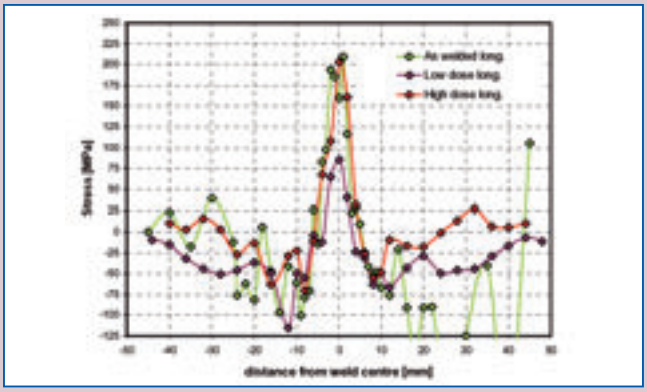


Fig. 27 - Longitudinal residual stresses measured at mid-thickness of irradiated and non-irradiated weld coupons (INTERWELD)

Boron Neutron Capture Therapy (BNCT)

Introduction
The IE Action on the Development and Exploitation of Neutron Capture Therapy has made a number of significant steps during 2006, with work in a wide spectrum of activities around BNCT. In addition, the know-how developed at Petten over the years becomes more in demand from other European research centres, as well as worldwide. The Petten BNCT group started in 2006, with the organisation of regular seminars on different topics related to BNCT, the co-organisation of workshops in other countries and the provision of consultation services as invited experts to interested groups.

Clinical activities
The IE BNCT group contributed to the following clinical activities:

- ***EORTC Protocol 11001:*** ^{10}B-uptake in different tumours using the boron compounds BSH and BPA: Tissue and blood samples taken from patients in the operating theatre in Essen were sent to Petten for measurements by prompt gamma ray spectroscopy at beam tube HB7 to determine the amount of boron in the tissues. Results support, amongst others, the development of BNCT for the treatment of liver cancer.

- ***EORTC Protocol 11011:*** Early phase II study on BNCT in metastatic malignant melanoma using the boron carrier BPA: A patient with melanoma metastases to the brain was treated at the BNCT facility. IE performed the treatment planning, as well as to ensure that the facility is fully operational and functioning, and to coordinate all the technical aspects of the treatment, including security, technical reporting and availability of required staff. To obtain a very homogeneous irradiation dose distribution, the patient received 5 beams on 2 consecutive days (never performed elsewhere in the world). Initial results showed that BNCT has an effect on all tumours.

Application of BNCT to other types of cancer – Liver metastases
Following on from the work started in 2005, when a special facility was designed and built at Petten to hold the liver during treatment, further tests were carried out in 2006 to validate the cooling and thermal neutron distributions in the rotating holder:

- ***Cooling test***
  Cooling of the facility is provided by Cold Gun Sprays®, which are ingenious and simple devices (see Figure 29), that by means of the principle of a vortex tube, utilise standard compressed air to produce a jet of cold air at more or less zero degrees. Tests with the facility have shown that 2 cold sprays can maintain the facility at the required temperature for up to 3 hours.

- ***Gel dosimetry***
  In 2005, some initial measurements using activation foils and gel dosimetry were performed. The results were reasonably satisfactory. Nevertheless, more accurate measurements were required. As such, the gel dosimetry work was more rigorously repeated in 2006. This work was carried out in collaboration with the University of Milan, who are specialist in the field. Gel dosimetry is a technique to obtain continuous images of the absorbed dose. By properly designing the gel isotopic composition, it is possible to separate the gamma dose and the dose due to charged particles, such as those produced in ^{10}B reactions, and consequently the thermal neutron flux can be deduced.

Application of BNCT to non-cancerous diseases – Rheumatoid Arthritis – project status
The results of the irradiation experiments performed at the HFR's BNCT facility in 2005 were analysed during 2006 at the University of Nijmegen. The results showed that high concentrations of the boron-10 can be achieved using liposomes, as the boron carrier. The initial irradiation experiments indicated a reduction in size of the inflammatory joints and elimination of the synovial macrophages (see Figure 33). The next phase of the study, to be carried out in 2007, is to reinforce the idea through further experiments. It should be further noted that these approaches may not only be beneficial to the treatment of arthritis but also to other types of (autoimmune) inflammatory disorders.

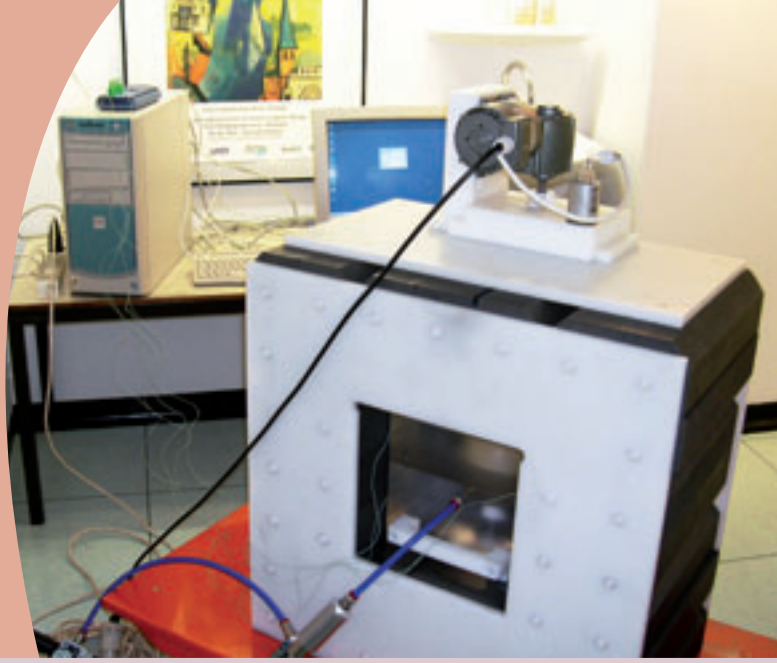


Fig. 29 - Liver facility with Cold Gun Sprays® fitted.

JRC Institutional Programme on BNCT

The research and development activities of BNCT at Petten are supported in the JRC's Institutional Research programme. Progress in a variety of research topics, included:

- ***Beam dosimetry***

  A campaign of measurements using the so-called paired ionisation technique, principally using TE(TE) and Mg(Ar) chambers, is the subject of one of the BNCT Group's Ph.D. students (Neta Roca). However, due to the nature of a BNCT radiation beam, which is a mix of neutrons and gammas, the paired ionisation technique is often only applicable, when applied at a fixed position. Furthermore, correction factors to convert the measured signal to dose are subject to high variability and inaccuracies. The measurements performed at the BNCT facility, aim to obtain a comprehensive understanding of the technique, when applied at any position in the beam, whether in a phantom or not. The work involves modelling the chambers in detail using the reactor physics code MCNPX. The first part of the study compares the results from photon-only (^{60}Co) measurements, which were completed in 2006. The computational model determines the charge created in the ionisation chamber due to the released electrons, which has not been done before. As part of this study, and also as part of the group's activities to encourage collaboration, Prof. Rainer Schmidt (Hamburg University) and 2 PhD students visited Petten to perform measurements with their own ionisation chambers, which complemented the work of Neta Roca.

- ***Radiobiological Dosimetry***

  The use of radiobiological dosimetry to determine dose is being investigated by estimating the level of chromosomal aberrations in human peripheral blood lymphocytes (PBL) exposed to radiation. Although no absolute doses can be derived from the results, the shape of the dose response curve can be regarded as a method of dose validation. PBL of two donors were irradiated with different doses of neutrons in the HB 11 beam, calculated by MCNPX. Preliminary results are shown in Figure 31. As expected, a linear dose response curve was observed, confirming that the MCNPX calculations are correct.

- ***Treatment Planning***

  The trial on multiple brain metastases due to malignant melanoma, as reported above, may involve up to 20 or more metastases in the brain, as well as taking into account the organs at risk (OARs) and the regions of interest. A multi-beam treatment plan using a Monte Carlo based code. Such a multi-beam plan may require 4-5 days calculation time, (see Figure 32). In order to accelerate this procedure, linear programming techniques, such as the Simplex method have been investigated. The resulting calculation showed. Not only quicker calculation times, but also a reduction of the overall irradiation time by up to 30%, thus reducing doses to healthy tissues. Such a procedure may also be of interest in conventional radiotherapy.

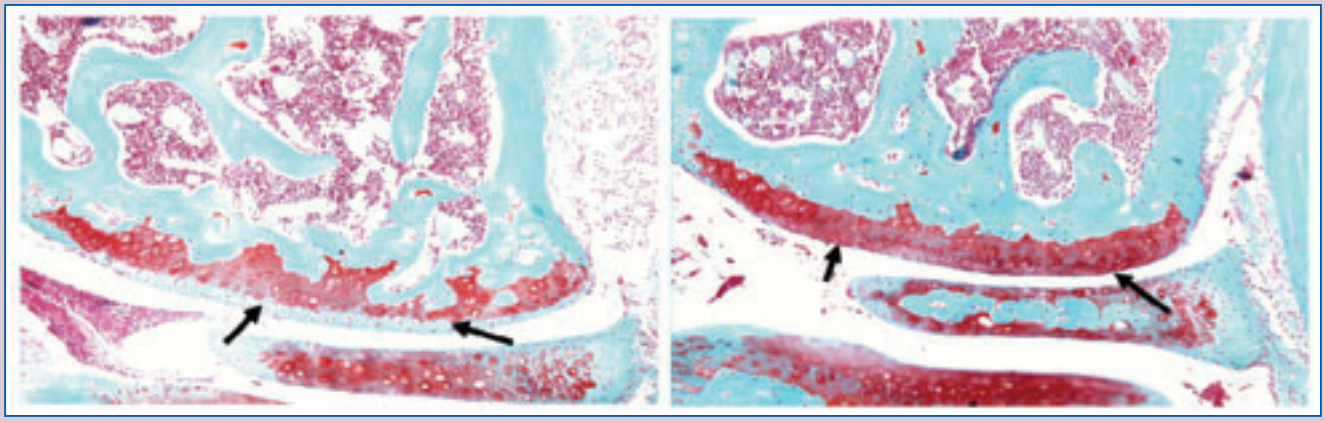
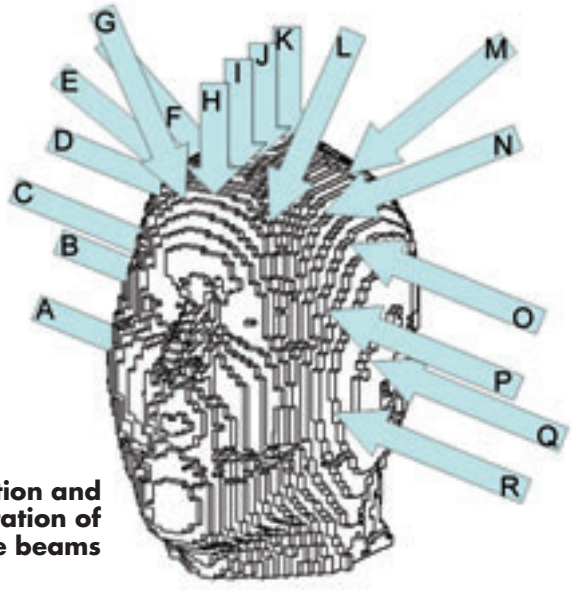


Fig. 30 - Selective elimination of synovial macrophages prior to induction of experimental arthritis prevents early cartilage destruction.



Localisation and orientation of possible beams

Fig. 32 - Possible beam directions (to head model) requiring for each, a separate calculation.

Symposia and Visitors

A number of meetings were attended to discuss progress and collaborative actions, as well as organising and/or attending conferences and symposia. Highlights included:

12th International Congress on Neutron Capture Therapy, Takamatsu, Japan
At this biennial congress on Neutron Capture Therapy Sander Nievaart received one of the Fairchild Awards, which honours outstanding publications from young scientists in the field of BNCT

Enlargement and Integration Activities and Meetings
"Balkan Medicine towards FP7", Bucharest, Romania
A 3-day event was organised by the Romanian Ministries of Education and Research (MER) and Health (MH), the National Authority for Scientific Research and the European Commission with BNCT as one of the many medical topics discussed.

JRC Information Day, Bucharest, Romania
This event, organised between the JRC and the Romanian Ministry of Education and Research, included a presentation by Romanian PhD student in the BNCT Group in Petten)

Liver Workshop Essen
A unique workshop was organised to bring together interested groups to discuss whether it is worth to intensify efforts to use BNCT for the extra-corporeal treatment of liver cancer. The workshop took place in Essen and was co-organised by the University Duisburg-Essen and the IE. The conclusion of the meeting was that BNCT could offer a complementary therapy for liver cancer and as such, research in this area should continue.

Educational and Dissemination Activities

With a growing team of students, post-docs and visiting scientists to the IE BNCT group, there has been a concerted effect to create an educational programme for the group and any interested staff in Petten. Twelve seminars were held in 2006.

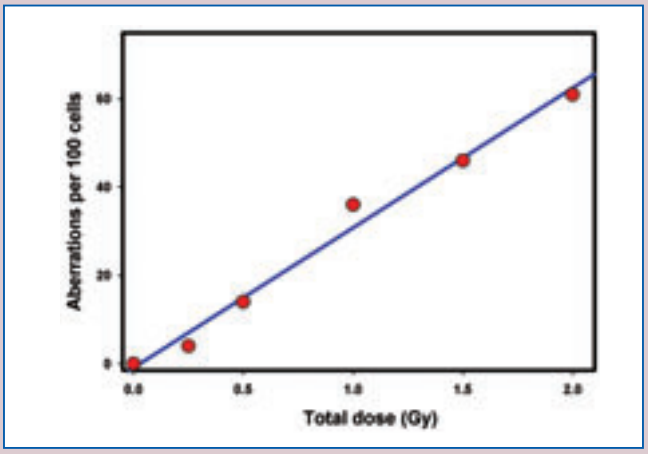
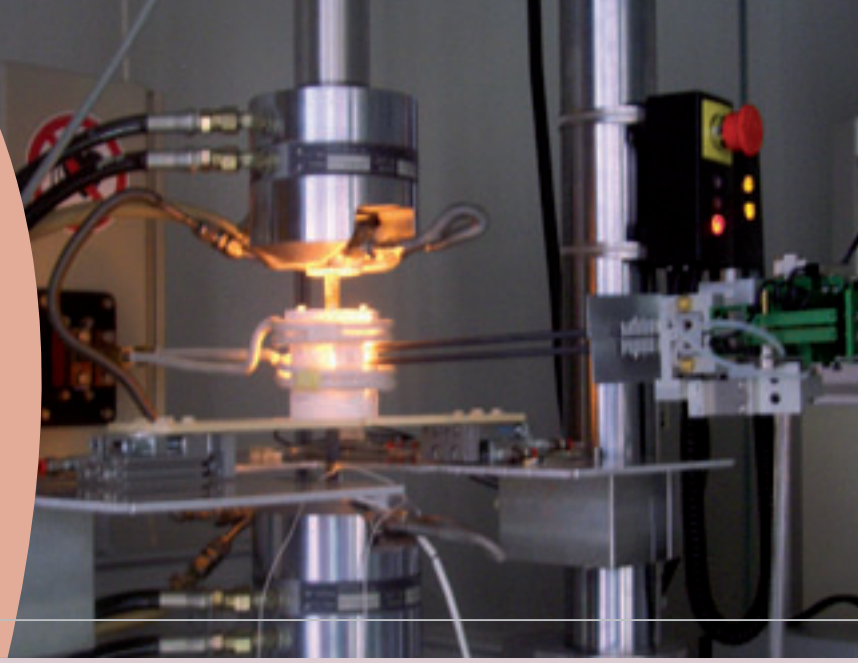


Fig. 31 - Plot of chromosomal Aberrations versus dose.

Structural material out-of-pile tests for innovative reactors



Background
Out-of-pile mechanical testing provides reference properties of high-temperature materials to be used in innovative reactors, e.g. as pressure vessel material, control rods or ancillary components. Later on, specimens of candidate materials may be irradiated at conditions typical for their envisaged use. Post-irradiation testing will focus on determining possible irradiation-induced degradation of mechanical properties.

Achievements in 2006
Materials performance and possible strength deterioration due to hot gas corrosion by impurities in the primary He coolant are of concern in the design of HTR turbine components working in the direct cycle. To establish upper bounds for the mechanical properties degradation that can be expected, IN792 DS and CM247 LC DS blade materials were pre-exposed to different chemistries leading to different materials states, namely (i) ageing heat treated, (ii) fully decarburised, and (iii) heavily carburised. Afterwards the materials were creep tested at 850°C.

As a candidate disc material, the creep and the low-cycle fatigue performances of Udimet720 have also been studied at 750°C and at 650°C, respectively, following pre-exposures resulting in a heavily carburised and in a fully decarburised state. In all cases, strength properties were observed to be deteriorated by the corrosive pre-treatments as compared to the as-received materials. Optical microscopy, SEM and TEM investigations were carried out to characterise failure modes associated with the corrosive attack, as well as the creep and LCF damage.

For indirect cycle power conversion components (turbine, heat exchangers) exposed to a mixture of 80% N_2 and 20% He, the need to perform nitriding tests was identified and work on that issue started in 2006.

For SCWRs, the assessment of the materials performance of ferrous alloys in supercritical water (SCW) is of major concern for the selection of structural materials. While experience from operating LWRs and supercritical fossil plants is available, the understanding of the behaviour of candidate materials in SCW water with normal or hydrogen water chemistry is still insufficient in terms of the general corrosion and stress-corrosion cracking (SCC), as well as the irradiation-assisted stress-corrosion cracking (IASCC) susceptibility. To contribute to the understanding of the basic corrosion kinetics, the monitoring of SCC by means of the acoustic emission (AE) technique has proven a sensitive in-situ corrosion monitoring technique. This has been shown using internally pressurized tubular specimens heated to SCW conditions and subjected to slow load-unload tensile tests. Moreover, a recently commissioned re-circulating water loop with autoclave designed for corrosion and SCC tests under SCW conditions has been used for slow strain-rate tensile testing of stainless steels at temperatures up to 600oC and pressures up to 360 bar. Future work will address fundamental issues of SCW stress corrosion kinetics as applied to candidate materials of interest to SCWR applications, e.g. ODS steels, the performance of which is to be compared to that of various Fe- and Ni-based materials investigated in FP6.

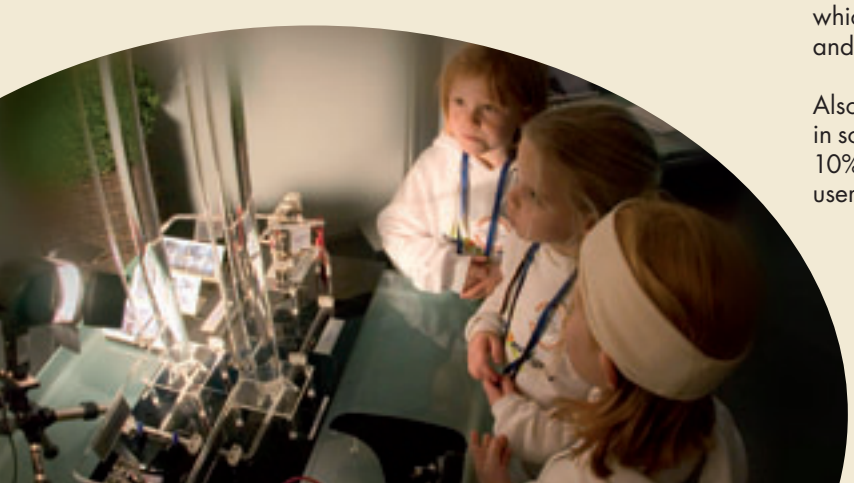
Scientific & Technical Support

Program management and support
In 2006 several important activities were relocated. The IT group and the workshop moved successfully to the new renovated areas in building 313. This transfer included the move of a significant number of central systems to new server and switch rooms, which have been specifically designed with good physical security and disaster recovery in mind. The new central IT facilities will greatly improve the business continuity of the Institute.

Considerable progress was also made with technical improvements to the IT services. The IP Telephony (VoIP) service was successfully initiated and rolled out to the majority of staff, the contract for Internet connectivity was extended with an upgrade to 10 Mbit/s, the ETP/ePO.

An upgrade to all NET1 clients was completed and the central NAS data storage system was upgraded.

In order to provide improved support to projects of the Institute an execution of the investment plan in the areas of the workshop and microstructural analysis was continued. A Computer-Numerical Control (CNC) milling production centre, which foresees the serial production of test specimens, was purchased along with a mobile plasma cutting device, capable of cutting wall thickness up to 45 mm. A purchase of a Wave Dispersive Spectrometer (WDS) for quantitative chemical analysis was completed and it will be installed to the high resolution FE-SEM. Digitalization of optical microscopy was continued through installing a new 5 MP digital camera together with the appropriate software. This will improve the image acquisition processing.



As an example of a new service to the projects of the Institute an animation movie of the Fuel Cell Testing Facility assembly and a walk through of the Fuel Cell Testing Facility was produced by the engineering drawing office.

For the library service contracts were concluded, in combination with JRC Ispra, for on-line access to a much-increased number of scientific journals and to the SCOPUS bibliographic search facility. Both of these new resources satisfy long-awaited user demands for improved library services.

Public Relations and Communication continued to be a key priority within both the Commission and the JRC in 2006. In line with the Commission communication objective to "go local" the IE implemented many actions including visits of all local Councils and provincial responsibles including the Queens representative in North Holland Mr. Borghouts, participation in the ECN Schools initiative in which more than 100 schools have spent a day at the site to learn about energy, and organisation of the 2nd IE Energy competition. Direct participation in actions also continues to increase for example PR & C supports the hydrogen and Fuel cell platform as communication advisor, the support included assistance to the Annual Hydrogen and Fuel Cell event in Brussels, media actions, photography, co-ordination with Commissioners office and co-ordination of the visit of Commissioner Potocnik to the event.

In 2006 IE Programme Office has concentrated in the co-ordination of the preparation of FP7, contributing to the finalisation of IE part of the Multi-Annual Work Programme of the JRC and the planning of IE new scientific projects for FP7. In parallel to this work some 12 proposals for Indirect Actions projects funded by FP6 have been facilitated, out of which 6 were awarded. The overall rate for FP6 is 48.8% and the total number of proposals made is 84.

Also in 2006 users' satisfaction was a high priority objective in scientific and technical support services. A target, less than 10% unsatisfied users, was clearly achieved as revealed in users' satisfaction surveys.

Management Support

2006 was for MSU a year of significant change. IE has continued to put in practise during 2006 the multi-annual Institute Renovation Plan that includes the combined renovation of several buildings. Two of these buildings were stripped to their original supporting structure to allow the construction of new office areas. One building is to be extended with a new passage to accommodate a cafeteria, a new meeting room and a general reception area. A bridge will also be erected between the two major office buildings to facilitate their integration.

The first phase of this project was completed in 2006 with the delivery of building 313 that was provided with the all the necessary technical facilities to relocate the IT services and the workshop. A new Gym for the staff is also included in this building.

Special attention was given to the management aspects of this project, including setting up of a project management structure and dedicated communication channels.) to have all parties - construction company, management of the institute, staff representatives, and dedicated user groups - committed to the execution of this project. The end result in 2007 will be a modern, functional and environmentally "friendly" buildings with state of the art building technology, modern training facilities, video-conferencing, etc...

Finance and purchasing dealt with approximately 1.100 orders in 2006, which included:

- +/- 10 procedures with publication in the Official Journal of the EU;
- +/- 25 procedures between 25k€ and 60k€;
- the remaining orders/contracts were for less than 25k€.

In 2006, an effort was made to simplify and to speed up the procurement procedures (for example: increase of the financial threshold for the small markets, and systematic use of the IT local interface JIPSY).

As in previous years, the entire budget allocated to the Institute (administrative credits and scientific credits) has been spent in 2006.

Within Finances, nearly 3.000 payments have been made in 2006. Improvements have also been implemented in both the internal financial circuits and the area of payment delays where the IE was shown to be one of the best institutes of the JRC with 95% of the payments executed within 45 days.

Key staff including a new sector head was recruited for the human resources management during 2006. The much needed staff allowed the sector to return to full strength and provide a complete service to the Scientific Units. In the field of training several new initiatives have been taken Courses on social and communication skills has been stimulated and new framework contracts have been signed to enable language training on site for several languages at different levels especially in-order to comply with the third language obligations stipulated in the Staff Regulation.

The Institute had a total of 226 staff members at the end of 2006 , details of staff distribution per category and gender are shown in the next chapter Facts and Figures.

The MSU participated in several audits covering different areas. In particular an audit on MSU operations consisting of a quantitative analysis of allocation of resources of MSU staff was of special importance. This latter audit underlined that the MSU covers a very broad area in an efficient way.

Facts and Figures

At the end of 2006, the Institute for Energy had 226 staff members, the distribution between the different grades and gender is shown in Figure 33.

One of the key measures of the scientific productivity of the Institute is the number of scientific publications. Figure 34 shows the IE publications in 2006 categorised by publication type according to the JRC publications system.
Key publications can be downloaded via the Institute website under publications http://www.ie.jrc.ec.europa.eu

Figure 35 shows schematically the budgets for the various 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 activities.

Fig. 33 - **IE Staff Distribution (31.12.06)**

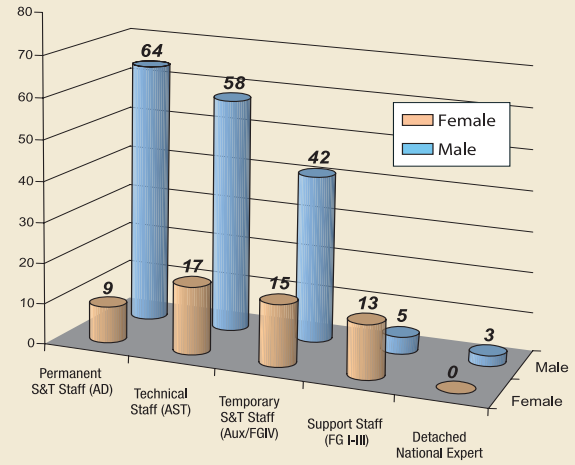


Fig. 34 - **IE Publications in 2006**

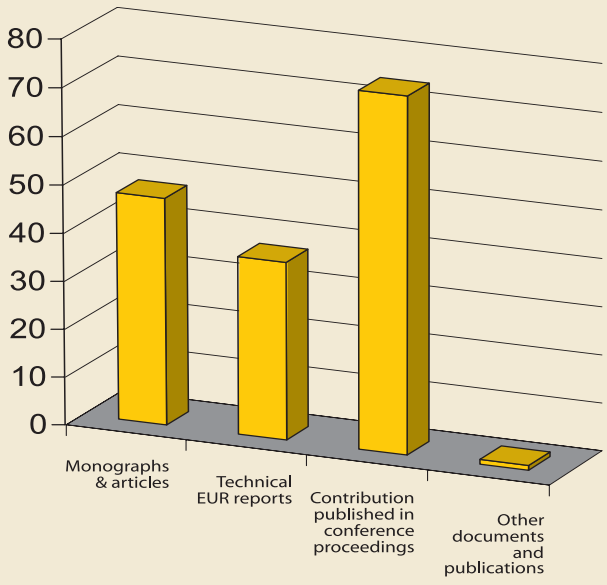
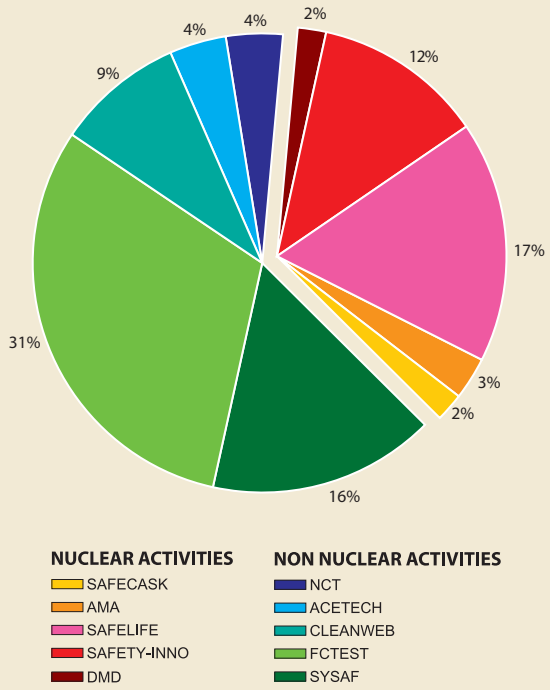


Fig. 35 - **Specific Credits Budget Distribution per Project. Total € 3,848 k**



Total Quality Management including Environmental Issues
Quality, Safety and Environment

The standards, rules and regulations of the Commission and the JRC define the minimum requirements for the management of the Institute for Energy. In addition, the national and international legislation regulates many of the activities carried out at the Institute. The Institute has decided to develop systematic Quality, Safety and Environmental (QSE) management systems to ensure that all necessary requirements are met and that performance is continuously improved. The main QSE activities carried out in 2006 are presented in the following.

Quality management system
JRC-IE has a certified Quality Management System (QMS) since 1999. Current QMS is based on the ISO 9001:2000 standard. The activities of the JRC-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 monitoring and improving the process. JRC-IE has 17 trained auditors who carry out internal QMS audits each year. In addition, an external certification body (TNO Certification) audits the QMS annually.

The management of the JRC-IE defines each year a number of objectives. The progress towards these objectives is followed through a set of Key Performance Indicators (KPI's). These key indicators describe progress in the most critical activities. In addition, each Head of Unit defines Unit level objectives and indicators, which are in line with those of the Institute. The progress towards the objectives is monitored in Management Meetings and in the Institute level and Unit level Management Reviews.

Institute Quality Group consists of the Director, the Quality Manager, and the Quality Officers. This group monitors the implementation of the QMS, reviews new quality documents, suggests improvements, prepares the management system reviews, and plans the internal quality audits.

Environmental management
The JRC-IE has an Environmental Management System (EMS) which meets the requirements of the ISO 14001 standard. The EMS is also a requirement in the Institute's Environmental license granted in March 2005. The EMS was certified for the first time in February 2004. Recertification was started in 2006.

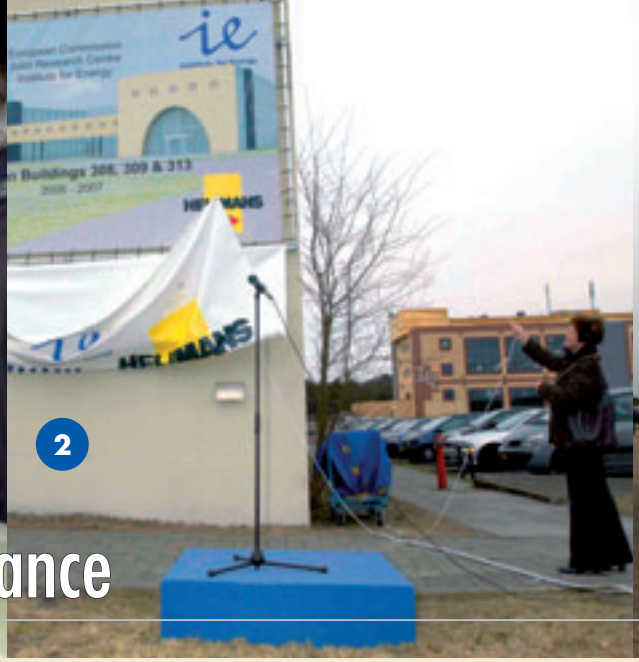
In 2006, the EMS was audited internally as part of the QMS audit. The EMS includes an environmental policy, annual and long-term objectives to improve environmental performance, and the necessary environment related procedures and work instructions. Currently, special emphasis is put on laboratory activities. The environmental outcomes of the JRC-IE are published in the Safety and Environmental Annual Report.

Safety management
Managing safety in a systematic and effective way is seen as a priority at JRC-IE. A new basis for safety management was established in the Commission Decision (C 2006 1623) which introduced the plan to develop a harmonised policy for Health and Safety at Work for all Commission Staff.

During 2006, the Institute has continued to develop and renew the safety related procedures and other documents so that they fulfil the requirements of the safety management standard OHSAS 18001. The aim is that safety management becomes an integrated part of the quality and environmental management systems. Certification of the safety management system was planned for 2006, but this was postponed due to the need to implement the Commission Decision C 2006 1623.

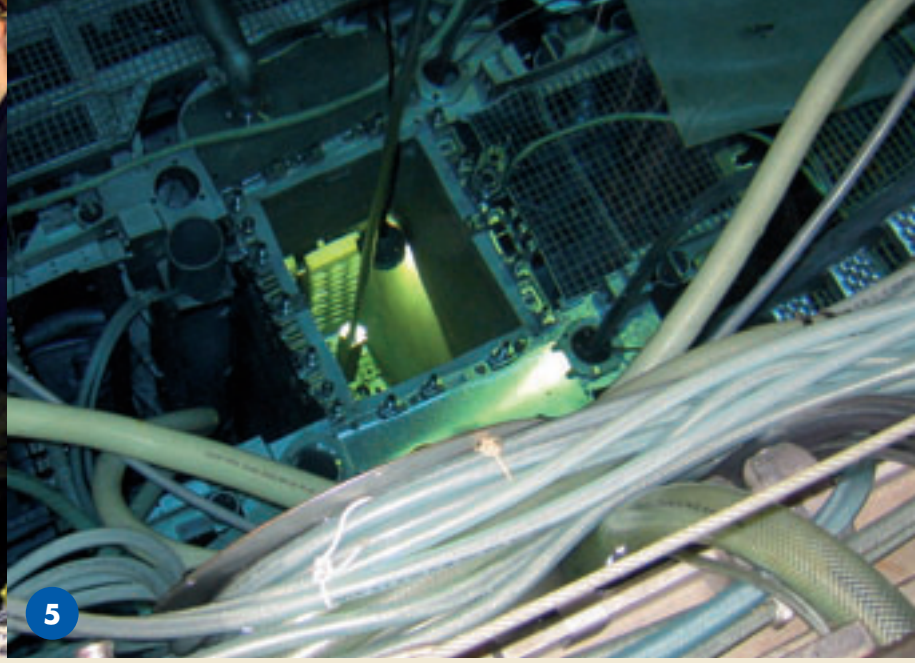
In 2006, the safety related activities included intensified collection and handling of near-accidents reports, regular safety tours in each unit, and several evacuation and emergency exercises. In addition, risk assessments were carried out in a number of laboratories. Awareness on safety issues was increased by regular safety presentations in Unit meetings. Furthermore, all newcomers received safety instruction during the first month of their employment at the Institute. Health and Safety Committee, an advisory body on safety, health and well being issues, was reorganized and had four meetings in 2006.

Operation licences and inspections
The activities of JRC-IE are regulated in several local and national licences. In addition, the site is subject to regular inspections carried out by local and national authorities. The main operation licences include the Environmental licence, Nuclear Energy Law licence, and the Radiation protection licence. The last one requires preparation of a separate annual report. The authorities which inspect the site include the Nuclear Safety Authority, the Labour Inspectorate, the Local Municipality, and the Water Authority. The findings and proposals of these authorities are always systematically analysed and the necessary corrective actions are planned and implemented.


The Year at a Glance

January	Seminar in BNCT: "Radiotherapy: Role and Duties of a Medical Physicist" by Doz. Mikko Tenhunen (Helsinki University Hospital)	
	Visit of Commissioner Andris Piebalgs	1
	Kick-Off Renovation of Buildings 308, 309 and 313	2
February	Visit of BBC journalists	
	Visit of Dr. Rob Adam, Director General South African Departement of Science and Technolgy	
	Visit of Swedish Educational Broadcasting Company	
March	Visit of Finnish Ambassador	
	Visit of Polish Vice Minister of Education and Science (Professor Krzysztof Jan Kurzydlowski)	
	Visit Gemeente Heerhugowaard	
April	IE & ECN Hydrogen for Policy makers workshop	3
	JRC-IE Participation in ECN School Visits: Groep 8 Basisschool de Fontein	
May	Visit Belgium Ambassador, Mr. Luc Teirlinck	4
	HFR conversion to low-enriched uranium fuel completed	5
	Signing of Collaboration Agreement between the Bulgarian Academy of Sciences (represented by its chairman Mr. Zdravko STOYNOV) and the JRC-IE (represented by Director K. Toerroenen).	
June	Participation in the Science Day of the European School	
	Seminar Safety of Russian design nuclear power plants	
	IEA Workshop for Fuel Cells visit to IE Fuel Cell Facilities	
	Visit of Mr. Alfonso González Finat (Director DG TREN)	



July	Seminar in BNCT: "Neuro-Oncology" by Prof. Jan Heimans (VU academic hospital Amsterdam)
September	Visit of DG TREN representatives
	Training Workshop on hydrogen storage organised in the frame of the Marie Curie Training Network HYTRAIN
October	EC Enlargement and Integration Workshop on Use of Probabilistic Safety Assessment (PSA) for Evaluation of Impact of Ageing (Bucharest)
	Energy risks workshop-Effects on the Safety of Nuclear Power Plants
	Senior Advisory Group Meeting on Clean Energy
	Workshop on Advanced Integrity Assessment: "How safe is it? (Enlargement and Integration Training Workshop Nuclear Safety Series.)
	Joint ECN-NRG Visit of representatives from Local Government in North Holland
	Eurelectric Research and development WG Meeting
November	IE Hosts the combined meeting of the Hydrogen and Fuel Cell Implementing Agreements of the IEA
	"GenIV collaboration between JRC IE and VTT" Meeting on materials behavior in new generation of reactors, with the focus on SCWR reactors.
	Joint IE-ECN-NRG Visit of Mayors, and representatives from 6 local councils
	JRC-IAEA International Workshop of In-Service Inspection Qualification Bodies
December	Seminar in BNCT: "Mission of the UICC and running projects" by Dr. Stella de Sabata (International Union against Cancer (UICC))

Glossary and acronyms

ACETECH	**A**ssessment of **C**lean **E**nergy **TECH**nologies
AE	**A**coustic **E**mission
AEKI	Atomic Energy Research
AMA	**A**ccident **M**anagement and **A**nalysis
AMALIA	**A**ssess**m**ent of nucle**a**r power p**l**ants core **i**nterna**l**s
AMES	**A**geing **M**aterials **E**uropean **S**trategies
ANSYS-CFX	*name of nuclear safety Code*
AR	**A**nnual **R**eport
ASME	**A**merican **S**ociety of **M**echanical **E**ngineers
ASTEC	*name of nuclear safety Code*
BNCT	**B**oron **N**eutron **C**apture **T**herapy
BPA	**B**orono**P**henyl**A**lanine
BREF	**B**at **REF**erence Document
BSH	Boron Compound for BNCT
BWR	**B**oiling **W**ater **R**eactor
CATT-DB	Nuclear Database
CC	**C**andidate **C**ountry
CCS	**C**arbon **C**apture and **S**torage
CEA	Name of French atomic energy commision
CEEC	**C**entral and **E**astern **E**uropean **C**ountries
CELINA	Fuel **Cel**i application **i**n a **N**ew configured **A**ircraft
CEN	**C**omité **E**uropéen de **N**ormalisation
CFD	Computational Fluid Dynamics
CHP	**C**ombined **H**eat and **P**ower
CIS	**C**ommunity of **I**ndependent **S**tates
CLEANWEB	**CLEAN** and efficient waste incineration, **W**aste-to-**E**nergy and **B**iomass combustion
CNC	**C**omputer **N**umerical **C**ontrol
CO	Carbon Monoxide
COM-XXX	Publication code of official Commission publications
CRP	**C**oordinated **R**esearch **P**roject
CSLF	**C**arbon **S**equestration **L**eadership **F**orum
DARES	Database on Research Reactors
DG	**D**irectorate **G**eneral
DG AGRI	**D**irectorate **G**eneral **Agri**culture and Rural Development
DG AidCo	Europe Aid Co-operation Office
DG ENTR	**D**irectorate **G**eneral **Ente**rprise and Industry
DG ENV	**D**irectorate **G**eneral **Env**ironment
DG RELEX	**D**irectorate **G**eneral **Ex**ternal **Rel**ations
DG RTD	**D**irectorate **G**eneral Research
DG TREN	**D**irectorate **G**eneral **TR**ansport & **EN**ergy
DMD	**D**ata **M**anagement and **D**issemination
DMW	**D**issimilar **M**etal **W**elds
DoMa	**Do**cument **ma**nagement
E&I	**E**nlargement and **I**ntegration
EAC	**E**nvironmental **A**ssisted **C**racking
EC	**E**uropean **C**ommission
ECCP	**E**uropean **C**limate **C**hange **P**rogramme
ECFIN	**Ec**onomic and **Fin**ancial Affairs DG
ECN	**E**nergy research **C**entre of the **N**etherlands
EMS	**E**nvironmental **M**anagement **S**ystem
ENIQ	**E**uropean **N**etwork for **I**nspection and **Q**ualification
EOR	**E**nhanced **O**il **R**ecovery
EORTC	**E**uropean **O**rganisation for **R**esearch and **T**reatment of **C**ancer
EP	**E**mergency **P**lans
EPE	**E**nergy **P**olicy for **E**urope
EPRI	**E**lectrical **P**ower **R**esearch **I**nstitute
ERA	**E**uropean **R**esearch **A**rea
EsReDa	**E**uropean **S**afety **Re**liability and **D**ata **A**ssociation
ETP	**E**uropean **T**echnology **P**latform
OPEC	**O**rganisation of the **P**etroleum **E**xporting **c**ountries
EUR	Publication code of official Commission Reports
EUROCORR	**Euro**pean **Corr**osion association
EUROPLEXUS	Advanced Nuclear integrity analysis tool
FA	**F**lame **A**cceleration
FCANODE	Non-noble Catalysts for Proton Exchange Membrane Fuel Cell Anodes
FCTEDI	**F**uel **C**ell **Te**sting and **Di**ssemination
FCTES^{QA}	**F**uel **C**ell **Tes**ting**, S**afety **& Q**uality **A**ssurance
FCTEST	**F**uel **C**ell **TEST**ing
FCTESTNET	**F**uel **C**ell **TEST**ing and Standardisation **Net**work
FEBUSS	Fuel Cell Energy Systems standardized for large transport, Busses and Stationary applications
FE-SEM	**F**ield **E**mission **S**canning **E**lectron **M**icroscope
FITNET	European Fitness for Service Procedure
FP	**F**ission **P**roduct
FP5	**5th F**ramework **P**rogramme
FP6	**6**th **F**ramework **P**rogramme
FP7	**7th F**ramework **P**rogramme
FZR	**F**orschungs**Z**entrum **R**ossendorf
G8	**G**roup of **8**
Gasket-DB	Engineering Database
GasTeF	High-pressure Gas Storage Facility
GEN IV	**Gen**eration IV (Reactor design)
GIF	**G**eneration IV **I**nternational **F**orum
HarmonHy	Harmonization of Regulations, Codes and Standards for a sustainable Hydrogen and Fuel Cell Technology
HB	HFR Beam Tube
HFP	**H**ydrogen and **F**uel Cell Technology **P**latform
HFR	**H**igh **F**lux **R**eactor
HIA	**H**ydrogen **I**mplementing **A**greement
HIAD-DB	**H**ydrogen **I**ncident and **A**ccident **D**atabase
HIPOS	**H**igh **I**ntensity **Pos**itron beam
HTR	**H**igh **T**emperature **R**eactor
HTR-TN	**H**igh **T**emperature **R**eactor-**T**hematic **N**etwork
HYSAFE	**Hy**drogen **Safe**ty
HyTRAIN	**Hy**drogen storage **Train**ing network
IAEA	International Atomic Energy Authority
IAGE	Integrity and Ageing of Components
IAGOT	Image processing tool
IASCC	**I**rradiation **A**ssisted **S**tress **C**orrosion **C**racking
ICFB	**I**nternal **C**irculating **F**luidised **B**ed
IE	**I**nstitute for **E**nergy
IEA	**I**nternational **E**nergy **A**gency
IEC	**I**nternational **E**lectronical **C**ommission
IES	**I**nstitute for **E**nvironment and **S**ustainability
InsHyDe	Sub project of the NoE Hysafe (investigating internal releases in confined spaces)
INTERWELD	**I**rradiation effects on the evolution of the microstructure, mechanical properties, and residual stresses in the heat affected zone of stainless steel welds
IP	**I**ntegrated **P**rojects
IP	**I**mplementation **P**anel
IPHE	**I**nternational **P**artnership for the **H**ydrogen **E**conomy
IPPC	**I**ntegrated **P**ollution **P**revention and **C**ontrol
IPSC	**I**nstitute for the **P**rotection and **S**ecurity of the **C**itizen
IPTS	**I**nstitute for **P**rospective and **T**echnological **S**tudies
IRMM	**I**nstitute for **R**eference **M**aterials and **M**easurements
IRSN	**I**nstitut de **R**adioprotection et de **S**ûreté **N**ucléaire
IRTA	Partner company for Mat-DB commercialisation
ISI	**I**n **S**ervice **I**nspection
ISO	**I**nternational **S**tandards **O**rganisation
ISWA	**I**nternational **S**olid **W**aste **A**ssociation
IT	**I**nformatics **T**echnology
ITER	**I**nternational **T**hermonuclear **E**xperimental **R**eactor
ITU	**I**nstitute for **T**ransuranium **E**lements
JLS	Justice Freedom and Security DG
JRC	**J**oint **R**esearch **C**entre
JTI	**J**oint **T**echnology **I**nitiative
KPI	**K**ey **P**erformance **I**ndicator
LBE	**L**attice-**B**oltzmann **E**quations

LCF	**L**ow **C**ycle **F**atigue
LFR	**L**ead-cooled **F**ast **R**eactor
LWR	**L**ight **w**ater **r**eactor
LYRA	Irradiation Facility for the European Network AMES
Mat DB	The Materials **Dat**a**b**ase
MCNP	**M**onte **C**arlo **N**eutron **P**hoton
MCNPX	Reactor physics code
MER	**M**inistries of **E**ducation and **R**esearch
MH	**M**inistry of **H**ealth
MSU	**M**anagement **S**upport **U**nit
NAS	**N**etwork **A**ttached **S**torage
NCT	**N**eutron **C**apture **T**herapy
NDT	**N**on-**D**estructive **T**echniques
NEA	**N**uclear **E**ngineering **A**gency
NESC	**N**etwork for **E**valuating **S**tructural **C**omponents
Nesshv-DB	Engineering Database
NessHy	Novel efficient solid storage for Hydrogen
NET	Network on **Ne**utron **T**echniques Standardisation for Structural Integrity
NEU-DI-CIWI	Neutron beam facility
NGO	**N**on **G**overnmental **O**rganisation
NIS	New Independent States
NMS	**N**ew **M**ember **S**tates
NoE	**N**etwork **o**f **E**xcellence
NoE Hysafe	Network of Excellence Hydrogen safety
NPP's	**N**uclear **P**ower **P**lants
NREL	**N**ational **R**enewable **E**nergy **L**aboratories
NRG	**N**uclear **R**esearch and Consultancy **G**roup
NuCoC-DB	Nuclear Database
NULIFE	Nuclear Plant Life Prediction
NWIP	**N**ew **W**ork **I**tem **P**roposal
OARs	**O**rgans **A**t **R**isk
ODIN	Online Data Information Network
ODS	**O**xide **D**ispersion **S**trengthened
OECD	**O**rganisation for **E**conomic **C**o-operation and **D**evelopment
ORACLE	Database Programme
PASS	**P**ositron **A**nnihilation **S**pectro**s**copy facility
PECO	**P**ays de l'**E**urope **C**entrale et de l'**O**uest
PEFC	**P**roton **E**xchange **F**uel **C**ell
PEM	**P**roton **E**xchange **M**embrane
PEMFC	**P**roton **E**xchange **M**embrane **F**uel **C**ells
PERFECT I.P.	Prediction of irradiation Effect on nuclear Reactor components/Prediction of Irradiation Damage Effects on Reactor Components
PHARE	**P**ologne, **H**ongarije; **A**ide a la **R**econstruction **E**conomique
PHEBUS	The International Experimental Programme
PLIM	**P**lant **LI**fe **M**anagement
PR&C	**P**ublic **R**elations and **C**ommunication
PREWIN	**P**erformance, **R**eliability and **E**missions reduction in **W**aste **In**cinerators
PRHR	**P**assive **R**esidual **H**eat **r**emoval
PROSIR	OECD-NEA sponsored project related to the probabilistic structural integrity of PWR reactor pressure vessels
PSA	**P**robabilistic **S**afety **A**ssessment
PSTL	**P**lant **S**imulation **T**est **L**aboratory
PUBSY	JRC Publications Database
PWR	**P**ressurized **W**ater **R**eactor
QMS	**Q**uality **M**anagement **S**ystem
QSE	**Q**uality, **S**afety and **E**nvironment
R&D	**R**esearch **and D**evelopment
RAM	**R**educed **A**ctivation **M**artensitic
RAPHAEL	**R**e**A**ctor for **P**rocess **H**eat **a**nd **El**ectricity
RBMK	**R**eactor **B**olshoi **M**oshchnosti **K**analnyi (Graphite moderated, pressure-tube type reactor designed and built in the former Soviet Union)
RCM	**R**eliability **C**entred **M**aintenance
RCS	**R**egulations, **C**odes and **S**tandard
RDBMS	**R**elational **D**ata **b**ase **m**anagement **s**ystem
REACFLOW	*name of nuclear safety Code*
RER	**R**egional **E**u**R**opean
RI-ISI	**R**isk **I**nformed- **I**n **S**ervice **I**nspection
RISMET	Benchmarking of risk-informed in-service inspection (RI-ISI) methodologies
RMPS	**R**eliability **M**odelling of **P**assive **S**afety Systems
RP	**R**ecommended **P**ractice
RPV	**R**eactor **P**ressure **V**essel
RSWG	**R**isk and **S**afety **W**orking **G**roup
RTD	HW
S & T	**S**cientific **& T**echnical
SAFECASK	Safe Casks for High Level Nuclear Waste
SAFELIFE	Safety of ageing components in nuclear power plants
SAFETY-INNO	Safety of Innovative reactor designs
SALTO	**S**afety **A**spects of **L**ong-**T**erm **O**peration
SANS	**S**mall **A**ngle **N**eutron **S**cattering
SARNET	**S**evere **A**ccident **R**esearch **NET**work
SCA	**S**hared **C**ost **A**ctions
SCC	**S**tress **C**orrosion **C**racking
SCOPUS	Bibliographic search facility
SCW	**S**uper **c**ritical **w**ater
SCWR	**S**uper **C**ritical **W**ater cooled **R**eactor
SEGHOF	**S**pecial **E**xpert **G**roup on **H**uman and **O**rganizational **F**actors
SEM	**S**canning **E**lectron **M**icroscope
SenTeF	Hydrogen Safety Sensors Testing Laboratory
SENUF	**S**afety of **E**astern **Nu**clear **F**acilities
SETRIS	The **S**ustainable **E**nergy **T**echnologies **R**eference and **I**nformation **S**ystems
SME	**S**mall **M**edium **E**nterprise
SOFC	Solid Oxide Fuel Cells
SolTeF	Hydrogen Solid- State Facility
SONIS	Project on Operational Safety of Nuclear Installations
SRS	**S**cientific **R**eference **S**ystem
SSA	**S**pecific **S**upport **A**ction
SSITKA	**S**teady **S**tate **I**sotopic **T**ransient **K**inetic **A**nalysis
STORHY	Hydrogen Storage systems for automotive applications
STREP	STrategic REsearch Project
SYSAF	**Sys**tems for **A**lternative **F**uels
TACIS	**T**echnical **A**ssistance to the **C**ommonwealth of **I**ndependent **S**tates and Georgia and Mongolia
TAXUD	Taxation and Customs DG
TE	**T**issue **E**quivalent
TEM	**T**ransmission **E**lectron **M**icroscope
TGR	**T**ask **G**roup on **R**isk
TJ	**T**echnical **J**ustifications
TNO	**T**oegepast **N**atuurwetenschappelijk **O**nderzoek (Dutch Research Organisation)
ToR	**T**erms **o**f **R**eference
TSO	**T**echnical **S**upport **O**rganisations
TSSTP	Directorate General **T**echnical and **S**cientific **S**upport to **T**ACIS & **P**HARE
UNECE	**U**nited **N**ations **E**conomic **C**ommission for **E**urope
VISA	**V**ersatile **I**nstrument for **S**tress **A**nalysis
VoIP	Voice over Internet Protocol
VTT	Technical Research Centre of Finland
VVER	Russian pressurized water reactor
WDS	**W**ave length **D**ispersive **S**pectrometer
WOG	Westinghouse
WPNS	**W**orking **P**arty on **N**uclear **S**afety
ZEP	**Z**ero **E**mission Fossil Fuel Technology **P**latform

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Abstract
Report on the activities, accomplishments and resources related to the IE work carried out in 2006. An overview is given of the mission and its implementation, the scientific activities and the relations with the outside world.

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

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