joint research centre
EUROPEAN COMMISSION

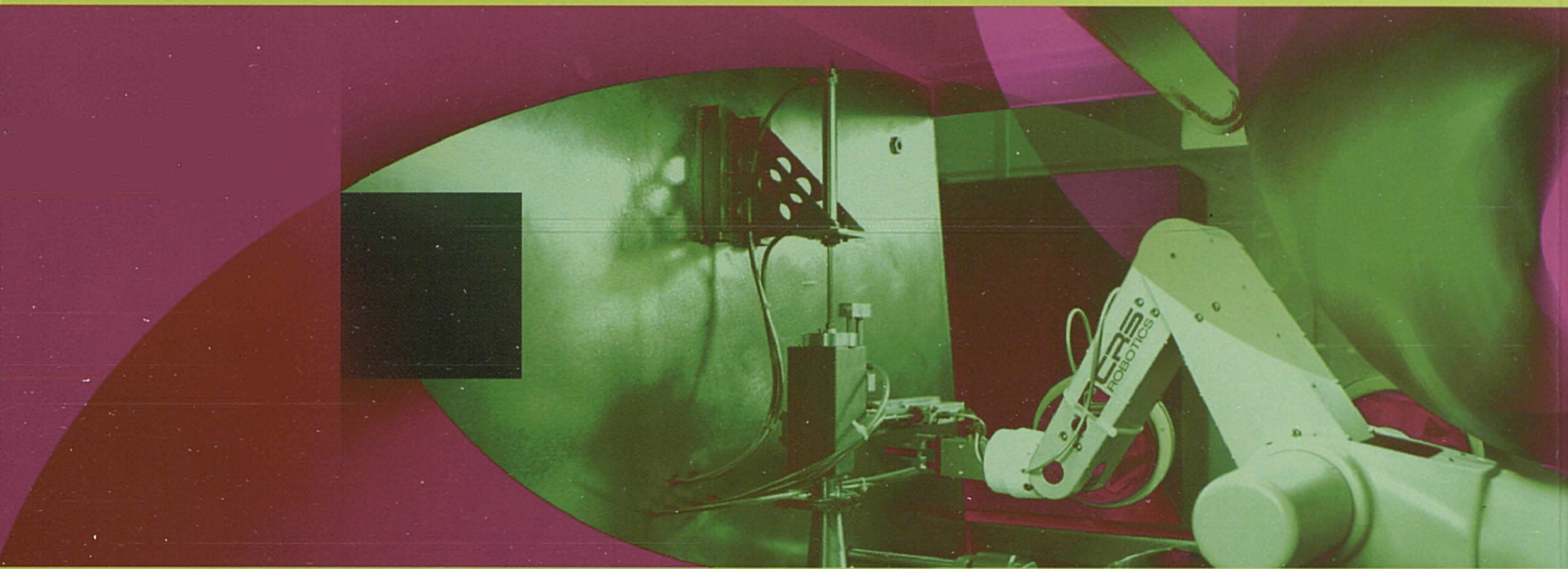
Annual Report
Institute for Advanced Materials

iam

Institute for Advanced Materials Annual Report 1999

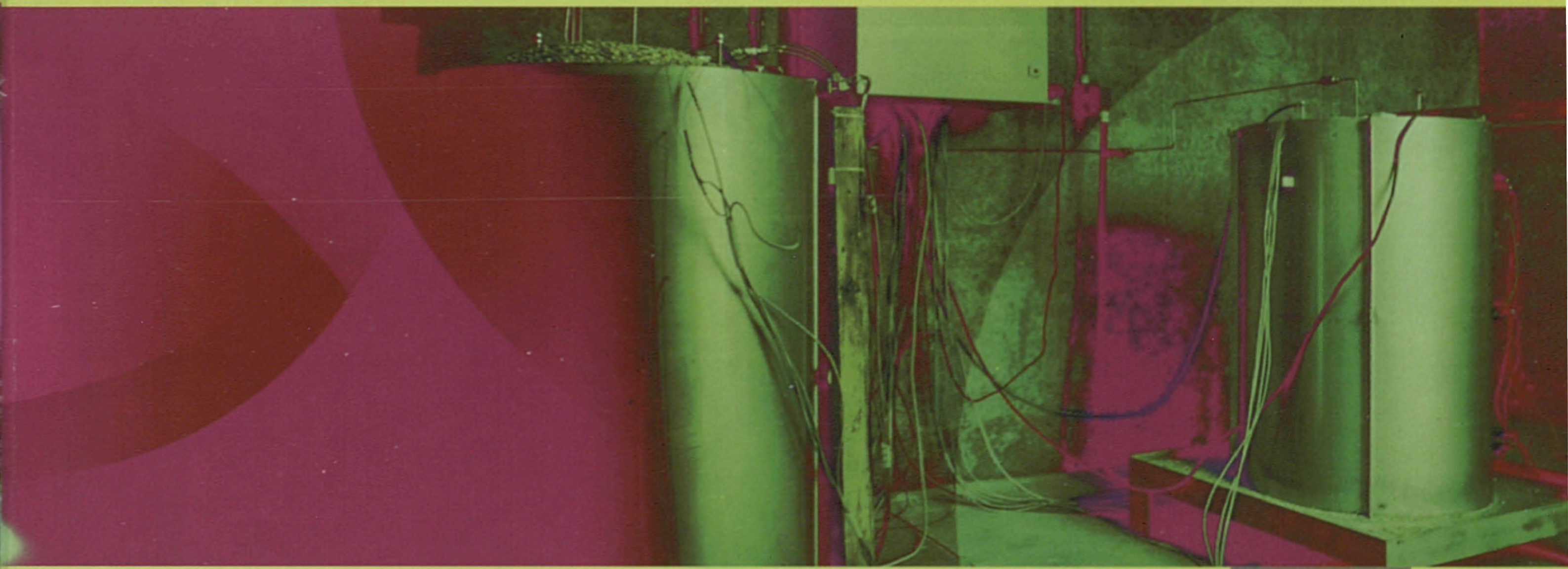
EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Report EUR 19597 EN


CRS
ROBOTICS

Institute for Advanced Materials

iam



EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Report EUR 19597 EN

European Commission • Joint Research Centre (DG JRC)
Institute for Advanced Materials http://www.jrc.nl/

Contact:

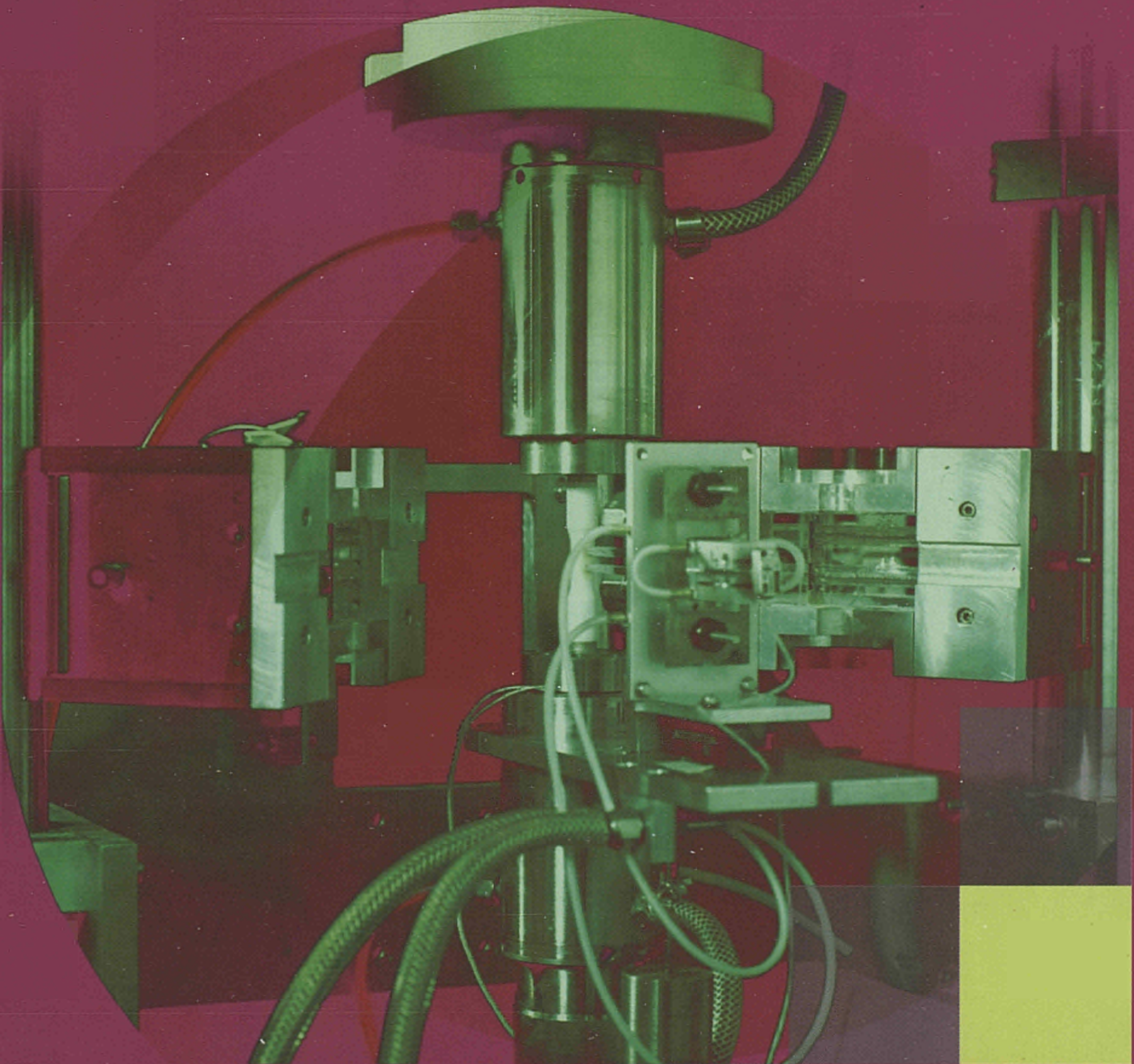
Ulrik von Estorff
vonestorff@jrc.nl

Luxembourg: Office for Official Publications
of the European Communities, 2000

ISBN 92-828-9692-7

Graphic design and layout:
C. Montero • Information and Public Relations Unit • JRC Ispra

Printed in Italy



FOREWORD

1999 was the first year of the new EU Framework Programme for research, FP5, which meant a substantial reorientation of the activities of the Institute for Advanced Materials. We have changed our work programme from wide spectrum generic materials research to well-targeted research and technical development supporting major EU policy issues. The new programme consists of 12 projects, clustered around three themes: emission reduction technologies, structural safety and nuclear medicine. Well aligned with the mission of the JRC, our work addresses the EU policies on environment protection, citizen safety and citizen health and underpins industrial competitiveness and sustainable growth. The core competencies needed to execute this programme remained, however, in materials science and technology, structural integrity and neutron radiation utilisation. Major achievements of this programme will be presented in the second part of this annual report.

The scientific contents and competence of the Institute to execute the new work programme were evaluated by a high-level Audit Team. Our plans and resources were found convincing, but very challenging.

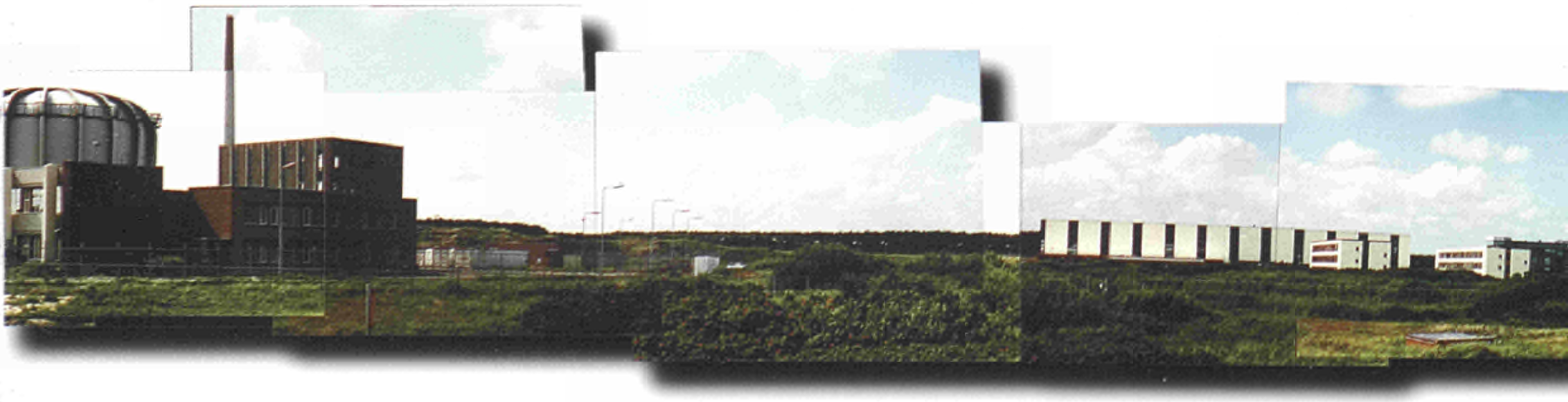
The first year of the FP5 also brought new possibilities to participate in Shared-Cost Actions (SCA) programmes. IAM participated in 42 submitted proposals, today we know that our success rate will be well above 50%. This achievement is mainly a result of serious strategic preparation in IAM operated networks, combining key players in their specific areas in Europe.

1999 was also the last year of the High Flux Reactor (HFR) Supplementary programme. After major restructuring, downsizing and numerous meetings a new four-year Programme was successfully developed and finally approved by the Council of Ministers in December. Details of this and other HFR related issues can be found in a separate HFR Annual Report 1999.

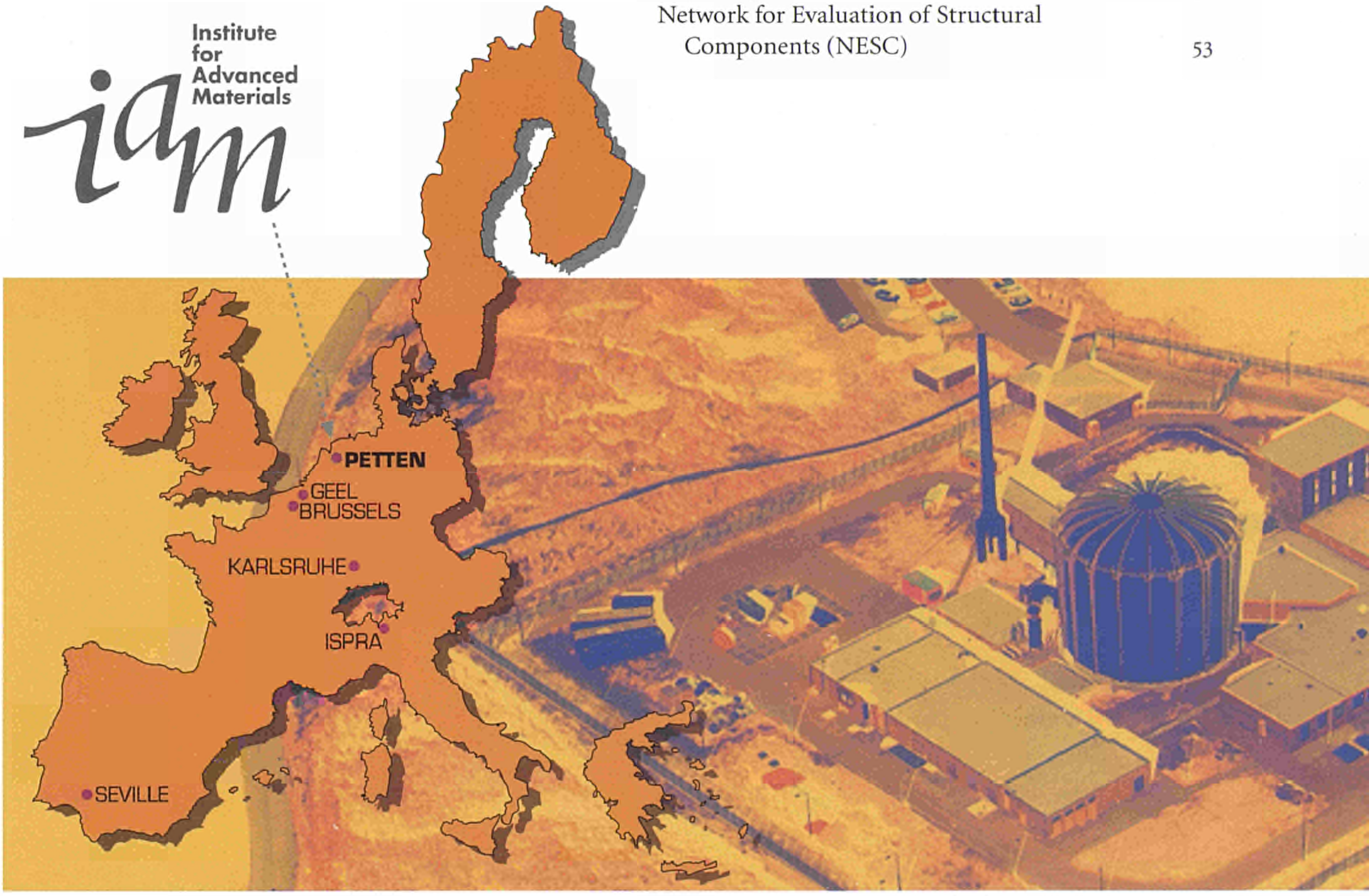
A large effort was devoted in 1999 to quality. After three years of preparation we applied for the ISO 9001 certification. The certifying body evaluated us in July, and granted us the Certificate in October. The Certificate was delivered to us on the joyful occasion of the visit of Mr. Busquin, EC Commissioner responsible for Research, to Petten on December 10th. The certificate is however not our final target; we are proceeding with the utilisation of the Excellence model of the European Foundation for Quality Management (EFQM), and started a comprehensive Self-Assessment exercise.

Important work of all actors involved (from the JRC, from the Commission and from our partners), but essentially efforts deployed by our staff in the Institute led to these achievements. I take this opportunity to express my admiration for the competence and change capabilities of our staff. Thank you for everything we have been able to achieve together.

KARI TÖRRÖNEN



CONTENTS



Institute for Advanced Materials
iam
PETTEN
GEEL
BRUSSELS
KARLSRUHE
ISPRA
SEVILLE

INTRODUCING IAM

Focal point for Industry and support to the European policy-making process through research, knowledge and understanding in the scope of advanced and conventional materials as well as advanced engineering for a safer environment and reduced emissions in energy production and transport.

IAM is one of the eight Institutes of the Directorate General Joint Research Centre (JRC) of the European Commission. It is located on the site of Petten (the Netherlands).

IAM works on technologies for reduction of emissions from industrial applications (power plants, waste incineration) and transport (vehicles, non road sectors, aero engines). IAM also works on technologies to ensure nuclear and industrial (mainly petro-chemical) safety.

IAM also manages the High Flux Reactor of the European Commission. This facility produces radioisotopes for diagnosis and treatment and supports research on industrial and nuclear safety and nuclear applications in medicine.

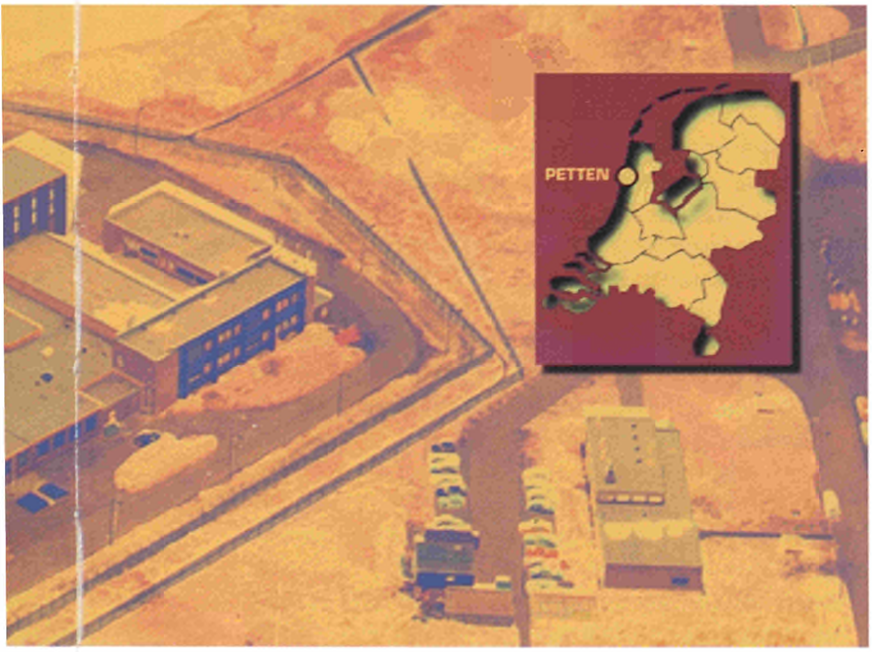
MISSION

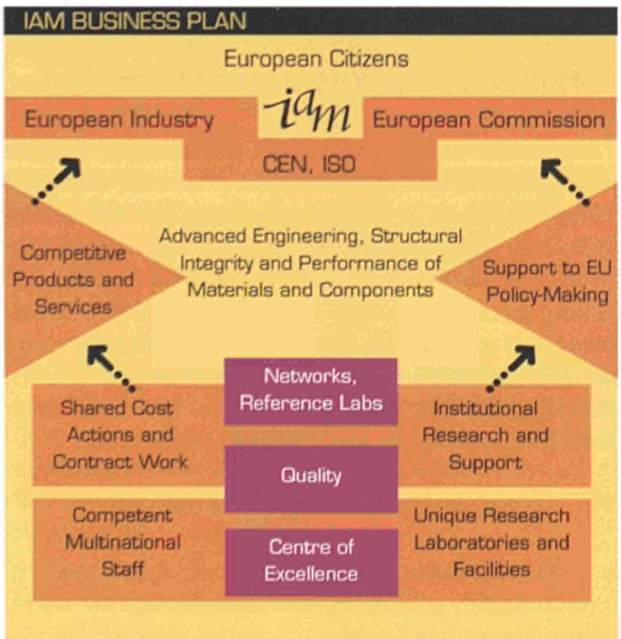
The Mission of the Institute for Advanced Materials (IAM) is to support the sustainable development and competitiveness of European industry through research on the structural integrity and performance of materials in components and processes in areas of concern to the public. The prime applications are in the sectors of energy, transport and chemical processes. The Institute manages the High Flux Reactor (HFR) for the benefit of the European nuclear industry and supports nuclear applications in medicine.

USERS OF IAM

The end-users of IAM services are ultimately European citizens who profit from an improved, safer and less polluted living environment.

The primary beneficiaries of IAM are the Commission and European Industry. The first gains an increased credibility of its policy-making process and the latter takes advantage of a legislative framework better adapted to sustainable and competitive growth.





IAM-PILLARS OF COMPETENCE			
Emission reduction technologies	Structural integrity assessment	Materials science and engineering	Irradiations and neutron beam applications
Internal combustion engines	Integrity assessment	Performance evaluation	Materials ageing
→ Vehicle and engine testing	→ Modelling → Experimental validation → Non-destructive techniques	→ Testing → Characterisation → Modelling	→ Residual stres assessment → Neutron radiography
Waste incineration			Nuclear fuel performance
LIFE TIME AND LIFE CYCLE ASSESSMENT			
Gas turbines technologies	Nuclear safety	Data management	Health care applications

The main Directorates General and Commission Services benefiting from IAM's work are:

- Energy and Transport DG
- Enterprise DG
- Environment DG
- Health & Consumer Protection DG
- External Relations DG
- Enlargement DG
- Common service for External Relations.

Direct users include Commission services and European Industry, standardisation bodies, Member State laboratories and research organisations, universities, international forums (e.g. VAMAS, ESIS) and other interested parties.

THE WORK OF THE INSTITUTE

IAM conducts fundamental and technological research and development into advanced materials, structural components and advanced engineering relevant to their industrial applications in all targeted sectors in its Mission. IAM also develops characterisation techniques and testing methodologies for industrial and structural materials and components. Finally, IAM contributes through international networking to research projects improving the dissemination of information on materials, structural integrity aspects and advanced engineering.

With respect to all targeted sectors in the Mission,

1. IAM contributes to European industrial, environmental and safety policies and standards through pre-normative research and networking in materials science, materials engineering and advanced engineering.
2. IAM stimulates innovation in industrial applications through basic and technological research on advanced industrial materials.
3. IAM brings together the fragmented research and resources of European organisations and disseminates information throughout Europe by co-operation through networks and joint projects on key issues in the fields of materials, structures and advanced engineering.

The work of IAM also addresses health care issues in nuclear applications of medicine through development of diagnostic and therapeutic techniques.

AREAS OF COMPETENCE

The areas of competence of IAM are the fields of research where IAM has developed core aptitudes by know-how, expertise and understanding of issues.

The main areas of competence include:

Materials science and engineering
- Materials characterisation and performance evaluation for industrial applications
- Life time assessment
- Materials data management.

Structural integrity assessment
- Integrity assessment of components through non-destructive techniques and experimental validation
- Life time assessment
- Qualification of inspection.

Industrial/medical irradiations and neutron beam applications
- Materials and nuclear fuel irradiations and irradiations behaviour evaluation
- Component integrity and residual stress assessment
- Health care applications of neutron beams.

IAM-ORGANIGRAMME					
Institute Director K. Törrönen					
Assistants to the Director F. Franck C. Chemaly			Quality Manager L. Debarberis		
Clean Technologies	Energy Production and Conversion	Safety of Industrial Components	High Flux Reactor	Scientific and Technical Support	Management Support
J.P. Hirvonen	J. Bressers	R. Hurst	J. Guidez	E. Bullock	M. Cundy
(CLT)	(EPC)	(SIC)	(HFR)	(STS)	(MAS)

Combustion engine technologies (under development)
- Emission reduction technologies
- Life time assessment.

ORGANISATION

IAM has organised its work around six units. Scientific competencies are grouped within four generic scientific units and one scientific support unit.

The generic scientific units group a range of competencies relevant to the following specific issues:

- Safety of Industrial Components (SIC)
- Clean Technologies (CLT)
- Energy Production and Conversion (EPC)
- High Flux Reactor and Nuclear Applications (HFR).

The scientific activities of IAM are organised along projects, which are managed and carried out within the scientific units. Responsibility and overall co-ordination of each project is assigned to a unit, based on the required competence and the central issue addressed by the project.

The HFR of the EC is managed by IAM in a dedicated unit. Operated by NRG (a subsidiary of ECN and KEMA), the HFR carries out irradiation work in support to nuclear safety projects and develops diagnostic and therapeutic techniques (through production of medical radio-isotopes and development of therapeutic neutron beams).

A Scientific and Technical Support unit (STS) pools resources, tools and competencies required across the Institute for the execution of projects. Services performed by the STS unit include microstructural analysis and studies, development of dosimetry and imaging tools (in support to nuclear applications in medicine), workshop, informatics support, documentation, reproduction and publication services.

In addition to the five scientific units, a unit for Management Support handles all staff, financial, legal, contractual, purchasing and infrastructural matters.

THE FUTURE

Materials are a key technology driving industrial efficiency, environment protection and citizen safety from hazards.

IAM combines this competence with structural integrity and advanced engineering focussing on safe and clean technologies.

Rapidly changing needs on the industrial market as well as new demands for citizen welfare generate fresh requirements, which demand a steady stream of new materials or novel conditions of application for existing ones. In view of this continuous innovation, the policy-maker needs independent advice to ensure protection of the environment and citizen safety from hazards without hampering industrial competitiveness and efficiency.

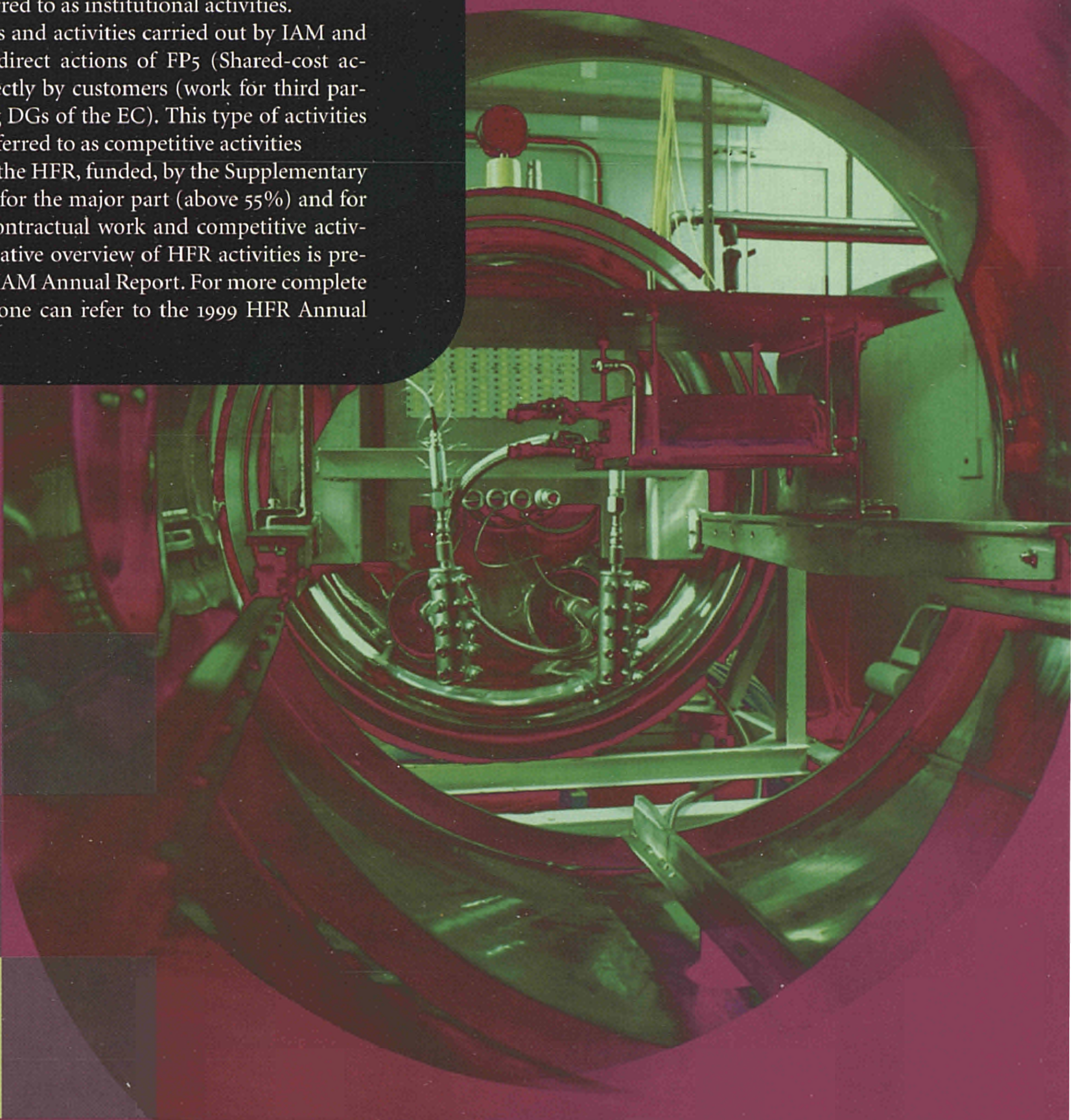
AM aims to fulfil this need in the EU context within its area of competence. In the coming years, IAM plans to achieve the position of focal point on materials-related issues for the European energy and transport sectors (including related industries).

The HFR of IAM will increase its role in nuclear applications of medicine. This will be achieved by maintaining its leading position in irradiation of radio-isotopes and expanding its visibility to serve as a unique European facility for conducting Boron Neutron Capture Therapy (BNCT) trials.

OVERVIEW OF IAM SCIENTIFIC ACTIVITIES IN 1999

The scientific activities of IAM can be split in three categories based on their funding source:

- Research activities funded by the direct actions of the Fifth Community Framework Programme (FP5) for research and supporting the actions of Directorates General (DGs) of the EC. This type of activities is hereafter referred to as institutional activities.
- Other projects and activities carried out by IAM and funded by indirect actions of FP5 (Shared-cost actions), or directly by customers (work for third parties, including DGs of the EC). This type of activities is hereafter referred to as competitive activities
- Operation of the HFR, funded, by the Supplementary Programme* for the major part (above 55%) and for the rest, by contractual work and competitive activities. An indicative overview of HFR activities is presented in the IAM Annual Report. For more complete information, one can refer to the 1999 HFR Annual Report.



* The Council adopted the Supplementary Research Programme for a four-year period (1996-1999) to be implemented by IAM for the European Atomic Energy Community. Three countries support the supplementary programme: the Netherlands, Germany and France.

INSTITUTIONAL ACTIVITIES

Overview

In 1999, first year of the FP5 (1999-2002), the research activities of IAM contributed to the following programme lines:

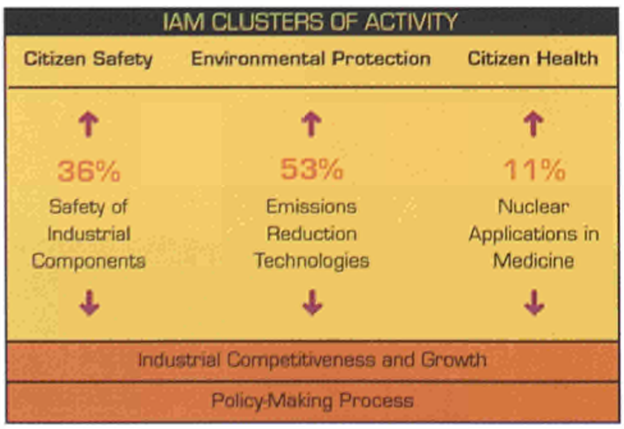
- Serving the Citizen (EC Programme)
- Enhancing Sustainability (EC Programme)
- Nuclear Fission Safety (Euratom Programme).

The following 12 projects were carried out for a total budget of 25.2 MEuro:

- Serving the Citizen (EC Programme)
  - BNCT: Boron Neutron Capture Therapy
  - MERECH: Characterisation of Medical Radiographic Equipment
  - EPERC: Design, Manufacture and Inspection of Pressure Equipment
  - HYDANET: Hydrogen Damage Prevention and Networking
- Enhancing Sustainability (EC Programme)
  - EPG Fossil: Efficient Power Generation: Advanced Fossil Power Plant
  - EPG Turbine: Efficient Power Generation: Gas Turbines
  - SAFTS: Safety and Reliability of High Temperature Systems Waste Incinerators
  - TEMAT: Technologies for Emission Abatement from Transport and Non-road sectors
  - ECRIT-Air: Emissions Reduction in Air Transport
- Nuclear Fission Safety (Euratom Programme)
  - ENIQ: Inspection Qualification
  - AMES: Materials Ageing Evaluation
  - NESC: Evaluation of Structural Components.

These projects have been internally clustered according to the three main policy issues tackled by IAM:

- Safety of Industrial Components (Nuclear and non-nuclear) for Citizen safety
  - EPERC: Design, Manufacture and Inspection of Pressure Equipment (non-nuclear)
  - HYDANET: Hydrogen Damage Prevention and Networking (non-nuclear)
  - ENIQ: Inspection Qualification (nuclear)
  - AMES: Materials Ageing Evaluation (nuclear)
  - NESC: Evaluation of Structural Components (nuclear)
- Emission reduction technologies for Environmental Protection
  - EPG Fossil: Efficient Power Generation: Advanced Fossil Power Plant
  - EPG Turbine: Efficient Power Generation: Gas Turbines
  - SAFTS: Safety and Reliability of High Temperature Systems Waste Incinerators
  - TEMAT: Technologies for Emission Abatement from Transport and Non-road sectors
  - ECRIT-Air: Emissions Reduction in Air Transport
- Nuclear Applications in Medicine for Citizen Health
  - BNCT: Boron Neutron Capture Therapy
  - MERECH: Characterisation of Medical Radiographic Equipment



Citizen Safety

The Directive of the EC on Pressure Equipment (PED 97/23/CE) was incorporated in Member State's national laws in November 1999 and will become mandatory in May 2002. The main purpose of the PED is to eliminate technical barriers to trade by harmonising national laws across the EC, regarding design, manufacture and safe operation of pressure equipment. The European Pressure Equipment Research Council (EPERC) co-ordinates research efforts at European level to conduct relevant scientific R&D supporting new technical standards. Technology transfer ensures that results are returned to the pressure equipment industry.

The project for Hydrogen Damage Prevention through Networking (HYDANET) aims at creating a focal point to co-ordinate research efforts on hydrogen damage and prevention: due to the presence of hydrogen in a large spectrum of industrial activities, research efforts are presently scattered. The objective of the project is to gather and create the data necessary for safe industrial development and operation of components susceptible to hydrogen damage. This project also supports the implementation of using hydrogen as an energy vector in transport.

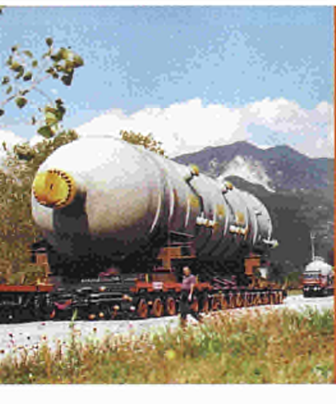
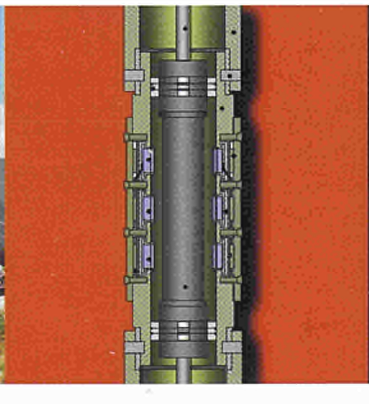
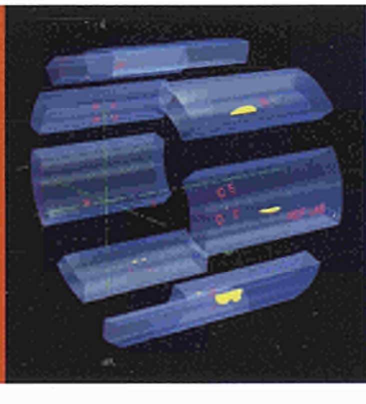
The networks for structural integrity of nuclear plants respond to the need for harmonised procedures and codes of practice for safe operation, sustainability and competitiveness. To this end, IAM carries our three projects, each operating a European network grouping key players from the European nuclear industry. The projects address important issues such as structural components integrity (NESC–Network for Evaluation of Structural Components), materials ageing (AMES–Ageing of Materials Evaluation and Studies) and qualification of inspection (ENIQ–European Network for Inspection Qualification). These networks integrate fragmented R&D work and contribute to broaden the knowledge base through joint undertaking and execution of projects at European level. Results achieved within the networks support a long term Commission strategy for the sustainability of nuclear energy as they are used in the context of Codes & Standards in Europe or for the harmonisation of practices in general.

Emission Reduction Technologies

Reducing emissions from power generation requires the implementation of innovative materials systems and construction designs allowing higher service temperatures, which lead to reduced fuel consumption, increased efficiency and reduced emissions. A number of technologies are applied or under development in the frame of fossil based power generation; given its resources and expertise, IAM has selected two main areas of focus:

- Advanced Fossil Fired Power Plant (EPG Fossil)
- Land-based gas turbines (EPG Turbine).

The Advanced Fossil Fired Power Plant continues to account for a significant proportion of electricity production. It is estimated that up to 5% improvement in efficiency, bringing such plant to levels of above 50% efficiency can lead to average reductions in carbon emissions of some 20% (up to 40% for the most offending plant). The EPG Fossil work programme focuses on critical compo-

nents in steam raising systems, specifically heavy section steam piping and superheater tubing, but also heat exchanger tubing for coal gasification and fluidised bed combustion plant.

Land-based gas turbines for power generation will see their role rapidly increasing in the future due to the potential efficiencies reachable in combined heat/power application and combined fuel cell/gas turbine operation. The objective of the EPG-Turbines project is to increase service temperatures of land-based gas turbines in order to enhance efficiency and reduce emissions by improvement of advanced engineering materials and surface treatments and comprehensive understanding of in-service degradation mechanisms enabling reliable lifetime prediction and plant management.

Although technical requirements are fundamentally different, the issue is the same for gas turbines in aero engines: increased inlet turbine temperature will allow for increased efficiency and reduced emissions. A project is thus been carried out at IAM on Emission Control and Reduction in Air Transport (ECRIT-Air). The main objective of the ECRIT-Air project is to contribute to the abatement of carbon-emissions from aero-engines, stemming from EU commitments taken further to the Kyoto Protocol. The project will provide the scientific and technical infrastructure of a reference laboratory for testing the suitability of advanced materials systems to operate at higher temperature than currently used materials in the hot-gas path of aero-engines.

The project on waste incineration addresses the environmentally problematic issue of domestic and industrial waste treatment: controlled incineration is a promising alternative to landfill sites dumping and open air burning; however, plant reliability remains limited by the degradation of components resulting from high temperature corrosion. The Safety And Reliability of High Temperature Systems (SAFTS) project tackles the issue by means of an integrated approach involving the development of standardised laboratory test methods simulating conditions found in waste incineration plants, and linking these studies to exposures in the advanced experimental incinerator system (ISI) at Ispra. A further step will be a comparison of materials performance derived during these combined studies with that observed on probes of candidate alloys exposed in an industrial waste incineration plant.

Transport by cars and non-road sectors have a significant impact on environment, particularly in terms of emissions. Reducing emissions from cars requires not only improved engine properties, but also enhanced fuel and oil properties. Using its experience developed in the past 20 years in the field of combustion engine technologies, IAM is conducting an ambitious research project on Technologies for Emission Abatement in Transport (TEMAT). This project will aim at the validation and development of emission abatement technologies by setting up a European Reference Engine and Vehicle Laboratory on Emission Reduction Technologies, by performing supporting research and by developing the necessary expertise to achieve interaction between industry and the Commission.

Citizen Health

Boron Neutron Capture Therapy (BNCT) is a promising and exciting form of therapy which can be used in replacement of conventional radiotherapy for treatment of degenerative diseases such as cancer and diabetes. The objective of the project is to provide a BNCT facility in Petten and develop the necessary related competence and experience. This facility will be accessible to researchers in the frame of European actions in BNCT treatment and/or via co-operation and collaboration agreements.

The project for Medical Radiographic Equipment Characterisation (MERECH) aims at protecting medical operators and patients in the exploitation of medical X-rays. The objective is to develop procedures for the easy on-

site verification of the effectiveness of X-ray equipment and adapt dosimetry tools for easy on-site X-ray equipment characterisation. It uses the X-ray Reference Laboratory of IAM and related extended experience in radiographic work.

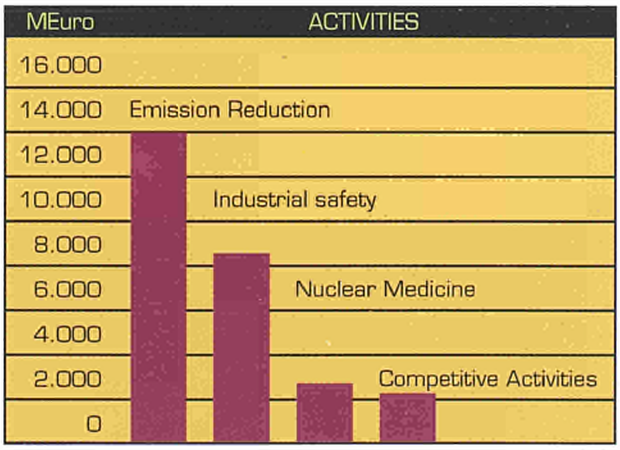
A detailed report on scientific progress achieved on the above 12 projects is provided in the second part of the present document.

COMPETITIVE ACTIVITIES

Suitably targeted competitive activities furnish IAM with a better understanding of issues of relevance to industry and to the political agenda. The development of industrial confidence in IAM's capability as well as maintaining of IAM's capacity to provide impartial support to Community policies are therefore strengthened by competitive activities. Additionally, they increase IAM's knowledge base by incorporating new expertise and know how. Interaction with industry also allows IAM to validate and benchmark its expertise and competitiveness.

Work performed in competitive projects essentially supports DG's needs for research (basic or pre-normative) in the frame of Shared-Cost Actions (SCA), Concerted Actions (CA), Thematic Networks (TN) and Other Competitive Activities (OCA). Upon specific request, IAM also carries out Work for Third Parties (TPW) involving mostly use of unique expertise or facilities.

During 1999, IAM has signed 14 contracts for a total value of 3.08 MEuro. The relatively low number of contracts signed is due to the fact that 1999 was the first year of FP5 and from 42 SCA proposals made in 1999 only two were already signed. Furthermore, IAM has carried out work on over 58 competitive projects (gained during 1999 or earlier) for a total value of 2.24 MEuro.



TRANSITION OF INSTITUTIONAL ACTIVITIES FROM FP4 TO FP5

During the FP4 (1995-1998), research activities of IAM contributed to the following programme lines:

- Industrial Technologies and Materials Technologies (EC Programme)
- Non-Nuclear Energy (EC Programme)
- Nuclear Fission Safety (Euratom Programme)
- Controlled Thermonuclear Fusion (Euratom Programme).

The contribution of IAM to the Industrial Technologies and Materials Technologies programme encompassed research on the performance of advanced materials, on surface engineering, and on Non-Destructive Evaluation (NDE) techniques for the inspection of industrial structural components. This work was carried out in support to the European Industry (particularly energy and transport), using IAM's scientific expertise, specialised competencies and unique facilities. It included strategic research, assessment and evaluation of materials, coatings and components, development and validation of testing methods, catalysing and promoting the breakthrough of novel materials and testing methods and pre-normative and standardisation activities. This line, which accounted for over 50% of IAM's activities in FP4, allowed to develop a number of competencies in the fields of materials performance, advanced engineering and structural integrity. These competencies have been geared to specific industrial applications in most of IAM's projects in FP5 (namely MERECH, EPERC, HYDANET, EPG-Fossil, EPG-Gas Turbines, SAFTS, TEMAT and ECRIT-Air).

The contribution to the Non-Nuclear Energy programme consisted of research on materials technologies for the more efficient and cleaner generation of fossil fuel energy (including automotive power). This was achieved by development and assessment of materials for improvement of the thermal efficiency of heat engines and reduction of exhaust emissions. Additionally, work was carried out to develop materials for better thermal insulation of combustion chambers and materials prolonging the operating life of catalytic converters by giving better protection against thermal deterioration. The relative importance of this activity was slightly reduced between FP4 and FP5 as it was integrated in the frame of TEMAT, IAM's contribution to emissions reduction from transport.

The contributions to the Nuclear Fission Safety programme were essentially research projects in and management of European networks on the issues of inspection qualification (ENIQ), materials ageing (AMES) and evaluation of steel components (NESC). Scientific activities carried out by IAM within the networks included research and testing of structural components in the frame of collaborative studies and practical exercises leading to definition of best practices and harmonisation of European and international standards. These activities developed into the three institutional projects on nuclear safety (namely ENIQ, AMES & NESC) and their relative importance was increased between FP4 and FP5.

The contribution to the Controlled Thermonuclear Fusion programme (Technology and Safety) included strategic research in support of the European programme in the areas of fusion materials (development and characterisation of low activation materials, setting up of a data bank) and tritium technology (studies on tritium permeation and recycling aspects). This very important issue in FP4 was discontinued in FP5. The materials related competencies are now used in the Institute for Health and Consumer Protection (IHCP) for research projects on bio-materials; the tritium and hydrogen related competencies are exploited by the Environment Institute for research projects on the use of hydrogen as a fuel.

During FP4, IAM carried out research and support activities on bio-materials (Industrial Technologies and Materials Technologies programme) and materials in renewable energies (Non-Nuclear Energy programme). These activities have been transferred to other JRC Institutes (namely IHCP and EI) since July 1998.

HFR SUPPLEMENTARY PROGRAMME

The HFR of the EC at Petten is managed by IAM and funded, for the major part, by the Supplementary Programme but also by competitive activities (SCA and TPW).

Besides traditional work for the nuclear R&D and industry, a large part of HFR activities is dedicated to medical applications. On the basis of contractual relationships, the reactor is now a major contributor to the production of medical radioisotopes for the European radio-pharmaceutical industry. The BNCT project, which involves the HFR but is funded by FP5 is presented in the present report. Other activities of the HFR are presented separately in a dedicated report.

STANDARDS, CODES AND INDUSTRIAL PRACTICES

IAM's involvement in standards, codes and industrial practices stems directly from its mission and that of the JRC. Standards drafting and amendment as well as reaching consensus on industrial issues are direct deliverables from IAM's institutional projects and projects carried out in the frame of SCAs (i.e. over 50% of IAM's competitive projects).

Standards contributions must be considered in a different manner than harmonisation of practices. Standards related activities are carried out based on the needs or requests of the standards organisation and lead to the basis for a policy. Harmonisation of practices are carried out within the frame of industrial networks where all relevant players work together to agree on issues at stake.

NORMALISATION AND STANDARDISATION

During 1999, IAM used its competencies to conduct projects in support to various standards organisations and bodies such as CEN, ISO, ASTM, VAMAS and ESIS.

Activities Supporting CEN

IAM has been a major thrust in the establishment of the JRC-CEN cooperation agreement signed early 1999, which is aimed at providing a framework for activities in support of standardisation within institutional JRC projects. IAM actively participates in the prenormative research (PNR) group of CEN-STAR (Standards and Research) where PNR issues identified by the different technical committees of CEN are discussed and prioritised, and where the standards-impact of results from EU-sponsored PNR projects (within the SMT programme) are evaluated.

IAM provided CEN with assistance in drafting of new standards and amendment of existing standards at review stage within CEN TC184/WG3 and CEN TC 184/SC1.

In 1998, IAM participated in a CEN-solicited project (CERANORM) for standardisation of mechanical tests for advanced technical of monolithic ceramic materials (latest amended draft document: CEN TC184/WG3/N338*). After the conclusion of the project, plans were

* TC184: Advanced Technical Ceramics.
WG3: Test Methods for Monolithic Ceramics.
SC1: Test Methods for Continuous Fibre Reinforced Ceramics.

formulated to conduct Round-Robin tests in support to the validation of the oxidation test method. The project has been initiated and Round-Robin testing has been conducted during 1999. Results will be presented to CEN in 2000.

Another SMT project (TESTCORR) in which IAM participated aimed at producing a "Code of Practice" for discontinuous corrosion testing of metallic materials in high temperature gaseous atmospheres. The final phase of the project, which ended in 1999, involved the definition of laboratory-based, industrially relevant test parameters, particularly the test environments (oxidation, petrochemical, flue gas/gas turbine, coal gasification and waste incineration), which were used in a series of reference experiments. The results of the reference tests, which will be conducted by the 10 partners, were included as annex in the draft Code of Practice submitted to CEN TC262.

Additionally, an IAM-developed Code of Practice for the determination of the misalignment-induced bending in uniaxially loaded test pieces has become a Working item in CEN TC 184/SC1.

Activities Supporting ASTM

With respect to ASTM, IAM assured the liaison between CEN TC 184/SC1 and ASTM C28.07 which both deal with standardisation of testing methods for continuous fibre reinforced ceramics.

Support was also provided in 1999 to ASTM through participation of one of IAM's Reference Laboratories in a Round Robin Test for miniaturised specimen testing.

Activities Supporting ISO

IAM has been requested to provide comments on documents of ISO TC 206 (Fine Ceramics) and has carried out the co-ordination of a European contribution in drafting of a standard on thermo-mechanical fatigue within the framework of ISO TC164/SC5/WG9.

Activities Supporting VAMAS and ESIS

In the frame of pre-normative research, IAM interacts essentially with VAMAS (Versailles Agreement on Materials and Standards) and ESIS (European Structural Integrity Association).

IAM had two representatives on the VAMAS steering committee and acted as participant and EU observer in the VAMAS TWA 3 (ceramics and composites). Participation to VAMAS activities also include a VAMAS-CEN round robin on quantitative microstructural analysis of ceramic materials and the recent VAMAS TWA 20, involving all major European, American and Japanese neutron diffraction facilities. The VAMAS TWA 20 aims at the preparation of a code of practice for residual stress measurements based on neutron diffraction.

Involvement within ESIS is mainly carried out through its Working Area (TWA) 6 on ceramics in which IAM is co-chairman and active participant (e.g. participation to the ESIS TC 6 round robin on fracture toughness of ceramics by the Single Edge V-Notched Beam technique). Furthermore, IAM is member of the ESIS TWA 11 concerned with High Temperature Materials Testing, which will hold an international seminar in Petten in 2000.

Other 1999 Activities

In addition to the above-mentioned activities, IAM has carried out work in 1999 for two other SCAs funded by the SMT programme of the Research DG (DG RTD– former DG XII), aiming at carrying out standards research. These SCAs contribute to standards or codes of practice for:

- Examination procedures for austenitic steel welds based on ultrasonic inspection.
- Dosimetry in BNCT.

THE INSTITUTE NETWORKS

IAM currently operates and manages four international networks on structural integrity of components in the frame of its institutional activities. These networks group all major players in the relevant European industry and bind them together by a Club-type agreement to carry out work under the supervision of a Steering Committee. The objective is to reach consensus on, elaborate and harmonise industrial codes of practice to secure safe operation without hampering industrial efficiency. Furthermore, the networks channel expert advice and recommendations to the Commission allowing it to take the best interests of the European industry into account in the policy-making process.

The networks AMES, ENIQ and NESC, each focussing on a specific aspect of structural integrity of reactor components, support nuclear fission safety, which are responsibilities of the Transport and Energy DG (DG TREN–former DG VII and DG XVII) and the Environment DG (DG ENV–former DG XI).

The EPERC network was primarily set-up for the non-nuclear industry but it has also found applications within the nuclear sector.

Two new networks planned for work on hydrogen damage prevention and on thermal barrier coatings could not be set up in 1999.

For MERECH a series of contacts and exchanges with the main European X-ray equipment manufacturers, universities and hospitals were undertaken with the aim of building-up a network of experts and users. It was decided not to set up this network, owing to funding constraints.

AMES

The AMES network groups over 25 members from several European countries, bringing together main capabilities on Reactor Pressure Vessels (RPV) materials assessment and research. The objective is to provide a forum for exchange of information and understanding as well as to establish and execute projects on neutron irradiation effects on reactor materials in support of designers, operators, regulators and researchers.

An important milestone of AMES was set in June 1999 by the signature of the EPLAF agreement between the Russian Ministry of Atomic Energy and the European Commission. EPLAF (European Plant Lifetime Assessment Forum) represents the key action of AMES to support EU enlargement towards NIS and CEEC, with the aim of prepare a strategy for new TACIS/PHARE projects in the field of nuclear power plant ageing.

Additionally, a successful conference organised jointly with the International Atomic Energy Agency (IAEA) took place in Petten in March on non-destructive methods for monitoring of ageing.

ENIQ

The ENIQ network groups over 40 different industrial participants (utilities, manufacturers, qualification bodies and vendors).

In addition to participants from Belgium, France, Sweden, Finland, Germany, Spain, Italy, UK, Netherlands, Denmark, ENIQ has extended its membership towards Eastern European countries since 1998 by having full participation from utilities in Czech Republic, Slovakia and Hungary.

The publications of ENIQ illustrate the consensus achieved at European level for issues related to the ENIQ's frame of activities. The Recommended Practice 4, 5 and 6 issued in 1999, which contain respectively recommended contents for the qualification dossier and guidelines for the design of test pieces and the conduct of open and blind test piece trials, represent consensus at European level for implementation of the ENIQ Methodology.

ENIQ is also involved in the European Non Destructive Evaluation Forum (ENDEF) and the European Nuclear Training Forum (ENTF) of the Energy and Transport DG (DG TREN – former DG XVII). Eight meetings were held in 1999 which generated three reports. One of the reports, containing guidelines for detailed project proposals to improve in-service inspection in WWER and RBMK reactors illustrates a consensus achieved at European level and supports the European industry for implementation of in-service inspection in Eastern Europe.

An enquiry will be launched to verify the feasibility of a European recognition scheme of inspection qualification. The enquiry will involve both regulators and industry.

NESC

The Network for Evaluation of Structural Components (NESC – originally, Network for Evaluation of Steel Components) has approximately 90 members working together to improve knowledge and information exchange on the entire process of structural integrity assessment.

During 1999, the main effort was on completing the evaluation of the NESC 1 spinning cylinder project. The numerous technical task groups produced their final reports complemented by reports of the Evaluation Task Force. In this frame, IAM played a key role in the destructive analysis and the evaluation of inspection data. An international seminar will be organised in March 2000 to promote the findings of the NESC 1 project to industry, national regulators, policy-makers and codes and standards bodies.

In complement to NESC 1, the NESC 2 project, which was launched in October 1998, focusing on shallow cracks, is now well underway, thus strengthening the network for the future. Preparatory work for the NESC 3 project focussing on steel piping systems in light water reactors has started in 1999, further to a Research DG (former DG XII) sponsored pilot-study.

Furthermore and in direct relation to NESC, IAM acts as technical co-ordinator of a Thematic Network funded by Research DG (former DG XII) on plant life assessment (PLAN). This TN groups over 45 partners (universities, research centres, SMEs and large companies) of all Members States and has been expanded since 1998 towards nine Central and Eastern European Countries in the frame of the INCO programme.

EPERC

The non-nuclear network EPERC provides support to the implementation of the European Pressure Equipment Directive (PED) issued by Enterprise DG (former DG III). EPERC is in its fourth year of activity and its membership grew to 157 signed organisations, totalling approximately 350 persons representing 14 countries (160 persons from 13 countries in 1998).

A number of activities have been initiated in 1999 in the four Technical Task Forces (TTFs) of EPERC which were set up and launched in 1998 (further to a survey on industrial needs) and officially recognised by 4 of the important CEN Technical Committees relating to pressure equipment (TC 54*, TC 267**, TC 269†, TC 74‡). To the four existing TTFs on fatigue design, high strength steel, harmonisation of inspection programming, and flanges & gaskets, a new Technical Task Force was launched in February on service integrity and life extension.

The proceedings of a conference on Inspection Qualification have been published in March and the related network bulletin (EPERC Bulletin No. 2 on "European Approach to Pressure Equipment Inspection") was refereed by the Executive Group of EPERC and issued in September.

EPERC has assisted Enterprise DG in the establishment of its PED Website into which the Website of EPERC will be integrated, thereby illustrating the relevance of EPERC and the support it provides to the implementation of the Directive.

Additionally, an agreement for collaboration has been achieved between EPERC, the American PVRC (Pressure Vessel Research Council) and the Japanese Research Council. This is an important step in the worldwide recognition of EPERC activities. The official framework collaboration agreement is under preparation.

A meeting was held in June to explore the possibilities and needs for expanding activities to pressure equipment used to power vehicles using alternative fuels. As a result, a survey on R&D needs will be carried out in 2000.

Other challenges for 2000 include the extension of technical activities to pressure equipment used for the carriage of dangerous goods in support to the New European Transportable PED (TPED 99/36/EC).

Hydrogen Damage Prevention

Further to industrial needs and requests, a competence has been developed at IAM on hydrogen damage during 1997 and 1998. The objective was to launch, set up, manage and operate a network on hydrogen damage prevention (HYDANET) at the start of FP5.

Work in 1999 therefore focussed on preparing IAM for its role as reference laboratory by developing high-temperature facilities and carrying out testing activities required for a better understanding of hydrogen attack phenomena.

Thermal Barrier Coatings Network

Further to an exploratory research project on Thermal Barrier Coatings (TBC) and a workshop in 1997 to survey industrial needs, all major European gas turbine manufacturers (aeroengine and stationary) indicated firm support for an initiative of networking and co-ordination of research activities at the European level. A second Workshop, targeted at users has taken place in Petten in 1998 to finalise the preparatory stage. The club agreement, terms of operation and financial structure had been agreed upon as well as the "research package" (direction of research, technical work involved and typical deliverables).

* Unfired pressure vessels.
** Piping.
† Boilers.
‡ Flanges and their joints.

IAM IN 1999: KEY FIGURES

■ STAFFING OF THE INSTITUTE

The distribution of IAM staff in December 1999 compared to 1998 was as follows:

	Dec 99	Dec 98
Statutory Staff		
Scientific staff	56	(57)
Technical staff	52	(53)
Skilled staff	29	(29)
Administrative staff	30	(30)
Sub-total Statutory Staff	**167**	**(169)**
Temporary Staff		
Grant holders	8	(9)
Visiting scientists	3	(5)
Trainees	0	(1)
Auxiliaries	0	(3)
Sub-total Temporary Staff	**11**	**(18)**
Total IAM	**178**	**(187)**

At the end of 1999, the Institute had 167 statutory staff plus 11 temporary staff (PhDs, post-doctoral and industrial fellows, seconded experts) based in Petten and financed by the Institutional programme, Competitive activities, and a small fraction of the HFR supplementary programme.

The drop as compared to 1998 arose from a number of departures, which were not replaced.

■ FINANCING THE INSTITUTE

IAM is funded through the following sources:

- Institutional research programmes (EC and Euratom FWP, including support activities).
- Competitive activities.
- Supplementary research programme (only for HFR activities and related staff).

IAM's expenditure along the programme lines is shown in the table below.

In addition to the institutional programme line, the competitive work executed in 1999 generated revenue supporting an additional 17 scientific and technical staff.

Activities	MEuro
Emission Reduction	14.058
Industrial Safety	8.554
Nuclear Medicine	2.634
Institutional	**25.246**
Competitive Activities	2.244
Total	**27.490**

■ HIGH FLUX REACTOR-KEY FIGURES

During 1999, the HFR of IAM has maintained its position in medical radio-isotopes production with roughly 70% of the market share of radio-isotope production in Western Europe (cyclotron radio-isotope production excluded).

Main items to be mentioned for 1999 include the maintaining of the level of production of isotopes for medical applications, the number of operational days (293) and the approval of the complementary programme in December.

The HFR has hosted 118 visits in 1999, totalling 1229 participants, amongst others, Mr. J.P. Pronk (Dutch Minister for Housing, Spatial Planning and the Environment), Mrs. A. Jorritsma-Lebbink (Dutch minister for Economical Affairs), a delegation of the Dutch Ministry for Foreign Affairs and Mr. P. Busquin (EC Commissioner for Research). The most important success however, came from the requests to visit the HFR at and after the annual open day. As a result of the increasing demand, it was decided to organise an open day each cycle (i.e. about each month) during the year 2000.

In the future, the HFR will increase its role in nuclear applications of medicine. This will be achieved by maintaining a leading position in irradiation of medical radio-isotopes and expansion of HFR visibility to serve as a unique European facility for conducting Boron Neutron Capture Therapy (BNCT) trials.

MANAGEMENT GOALS AND ACHIEVEMENTS IN 1999

■ CONTINUOUS UPDATE OF STRATEGY FRAMEWORK

IAM's marketing plan was reviewed thoroughly in 1999 in view of the various changes of IAM's orientation in the Fifth Framework Programme. A document was issued in March 1999, defining a strategic approach for IAM towards competitive activities and distributed to IAM's senior management, project leaders and JRC headquarters.

This document served as the basis for the update of the Strategy 2000+ to take into account the restructuration of the JRC in FP5. After many developments, this document was released to IAM's senior management and JRC's headquarters in June 1999. This document, which is subject to regular updating, defines a "road-map" for IAM towards FP6.

■ TOTAL QUALITY MANAGEMENT

ISO 9001 Certification

On December 10, 1999 IAM achieved its first milestone in its effort towards Total Quality Management (TQM): in the presence of Philippe Busquin, EC Commissioner Responsible for Research, IAM was awarded an ISO 9001 Certificate encompassing all its activities. IAM is the first JRC Institute to be fully ISO 9001 certified.

The audit took place in July, generating five corrective action requests and two observations. Upon reception of IAM's proposals for corrective action in October, DNV, the certifying body, decided to issue a positive advice for certification.

The core of the work on quality during 1999 focussed on the implementation of the corporate procedures, which were distributed the previous year. Formalisation of general administrative procedures has been finalised and twelve internal audits took place in the first part of 1999 (each unit was audited twice) in preparation of the certification audit.

Total Quality Management (TQM)

In 1999, work regarding Quality Policy and Strategy Implementation Plan has essentially focussed on the preparing to the new ISO 9001-2000 standard and adapting to the TQM frame according to the European Foundation for Quality Management (EFQM) Excellence Model. Working documents with revised corporate procedures have been prepared for approval in mid 2000 and implementation later that year. The primary key process of IAM will remain management of R&D projects.

Contribution to a JRC-wide Quality System

The JRC-wide effort towards TQM, in which IAM played a key-initiating role, continued in 1999. Main actions included the training of JRC top management, definition of a quality strategy, statement of a quality policy and issuing of a project management manual. IAM's role was central to the preparation of the two latter documents. Meetings of the JRC Quality Group continued leading to the preparation of quality training policy, a staff satisfaction survey and customer satisfaction questionnaire. Additionally, the Quality Manager of IAM was invited to participate in the EFQM assessment of another JRC Institute (namely ITU) and a JRC internal audit.

Plans for 2000 and Beyond

Main plans for 2000 include the re-assessment of the calibration plan and implementation of the EFQM Excellence Model within IAM by a self-assessment exercise.

MAIN FACILITIES

■ DESCRIPTION OF MAIN FACILITIES

45 MW High Flux Reactor

The HFR is one of the most powerful multi-purpose research and test reactors in Europe. Activities include:

- nuclear fission and fusion energy research,
- providing neutron beams for analytical applications (e.g., neutron activation analysis, neutron radiography) and further research (solid state physics, materials science, medical therapy),
- producing radioisotopes for scientific, industrial, medical and agricultural purposes.

Testing Evaluation and Modelling of Mechanical Performance Laboratories (TEMMP)

The TEMMP laboratory is involved in testing, evaluating and modelling of mechanical performance of metallic alloys, ceramics, ceramic matrix composites, materials with metallic coatings and with thermal barrier coatings, dissimilar materials with joints and dual alloys under air, vaccuum and inert environments. Aspects covered are:

- mechanical testing and fracture mechanics testing of materials,
- joining of dissimilar materials,
- property-microstructure correlations,
- interface properties,
- development of methods and equipment for *in-situ* monitoring of damage,
- damage and failure mechanisms,
- modelling of mechanical behaviour,
- lifetime assessment, life prediction.

Component Integrity Testing Laboratory (CITE)

The CITE laboratory is a facility comprising 8 concrete test cells for testing components and test-pieces of power plants and petrochemical plants under simulative conditions (elevated temperatures, high pressures, toxic and explosive environments) for creep, fractureand thermal fatigue through:

- mechanical loading through internal pressure, load and thermal fatigue,
- creep and thermal fatigue crack growth testing of components containing defects,
- hydrogen attack-creep interactions in high pressure hydrogen,
- integrity assessment of welded components,
- modelling of deformation behaviour and lifetime assessment and prediction.

Non Destructive Evaluation Laboratory (NDE)

The NDE Laboratory features a wide range of machines and techniques for the integrity assessment of components. Two major techniques are available, namely ultrasonic testing and X-ray radiography. The latter is located in a dedicated bunker including a 2MeV Linear Accelerator, 3 X-ray machines respectively from 200, 300 and 450 kV, one micro-focus X-ray device of 200 kV for research and industrial radiography. The ultrasonic equipment is composed of an extensive range of sensors and analysis apparatus.

Environmental Testing Laboratory (ETL)

The ETL is a laboratory primarily dedicated to high temperature corrosion testing of materials in complex environments, containing noxious and/or explosive gases, tailored to simulate in-service conditions of target industries. Tests are performed both with and without applied loads, on metallic, ceramic or composite materials at elevated temperatures generally in simulated engine, power generation or chemical process environments. Examples from recent programmes are comparative testing of new and advanced corrosion resistant alloys for the energy conversion sector, oxidation/corrosion degradation studies of candidate ceramic matrix composites for application in proposed ultra-high temperature heat exchangers and environmental degradation mechanisms of state-of-the-art ceramic catalyst supports from the automotive transport sector.

NEW MAIN FACILITY

European Reference Vehicle and Engine Testing Laboratory on Emission Reduction Technologies

This laboratory is the main investment of IAM in the future. By tackling the ambitious TEMAT project, IAM needed to develop a Reference Laboratory to test and validate emission reduction technologies for vehicles and engines. This laboratory will include facilities for engine and full-scale vehicle testing (light duty vehicles) and will operate with two 48" chassis dynamometers in the temperature range from -30°C up to +40°C. The facility will be equipped with a transient engine test bed for light duty vehicles. It is aimed that the facility becomes European Reference Vehicle and Engine Testing Laboratory for Emission Reduction Technologies. The laboratory will be used to support Commission's programs on emission reduction for improved air quality. It will also be available for industrial partners in their R&D activities in testing and validating of emission reduction technologies.

The first part of the facility for engine testing, originally designed to perform degradation measurements, such as wear tests on engine components, was constructed and commissioned in IAM Ispra in 1998 and moved to Petten and recommissioned in 1999. A stationary engine test bed and the necessary equipment for *in-situ* monitoring of the engine condition was installed. The facility, as it is now can measure the degradation by wear and corrosion through Thin Layer Activation analysis (TLA) in collaboration with IHCP in Ispra, which has a cyclotron available for activation. The degradation of critical components can be associated to a change in emission characteristics as determined by simultaneous measurements. Gas analysis equipment according to state of the art specifications for pre-, mid- and post-catalyst transient measurements was purchased. Both regulated and non-regulated emissions can be measured.

UTILISATION OF MAIN FACILITIES

Detailed figures are appended for utilisation of three major facilities in IAM, namely HFR, ETL and CITE. The objective here is to maximise the use of the facilities whilst remaining within the limits of safe operation. The HFR featured a record 293 operation days in 1998. The CITE Lab featured an average occupation of more than 50% (including preparation and experimentation). The percentage of usage the TEMMP Laboratory during 1998 is approximately 45%. Maintenance and refurbishing accounted for over 25%. 30% of the equipment was not used because of structural shortage of technician-operator manpower.

HFR Utilisation	1996	1997	1998	1999
Operation days per year	291	285*	285	293
% Occupation of irradiation positions	85	82	75	70

* In 1997 in-service inspection took place and reduced operation days.

ETL Utilisation	1996	1997	1998	1999
Operation days per year	351	350	354	354
% Occupation predicted (active positions)	50	75	85	90
% Occupation actual (active positions)	65	90	90	90

Utilisation CITE	Usage* 1998	Usage* 1999
Cell 1	45%	10%
Cell 2	52%	86%
Cell 3	22%	0%
Cell 4	37%	50%
Cell 5	52%	57%
Cell 6	65%	88%
Cell 7	84%	94%
Cell 8	67%	42%
Average	53%	53%

* Calculated on the basis of days.

IAM PARTNERS AND CUSTOMERS IN THE FRAME OF COMPETITIVE ACTIVITIES

IN BRIEF

Suitably targeted competitive activities nourish IAM's capacity to give impartial support to Community policies by incorporating new expertise and know how, validation and benchmarking.

IAM collaborates through competitive activities with a wide range of companies, research institutes and universities in Europe across the many technological sectors concerned with advanced materials and measurement technologies.

Project selection takes into account the present and future needs of the political agenda, the existing expertise and the strategic priorities at IAM, while closely respecting the subsidiarity principle.

Competitive projects carried out by IAM in 1999 are split into four categories:

- Shared Cost Actions (SCA).
- Third Party Work (TPW).
- Competitive Support to the Commission (CSC).
- Other Competitive Activities (OCA).

SHARED COST ACTIONS

During 1999, IAM was involved in 42 proposals for SCAs following calls for tender for the Biomedicine and Health, COPER, Energy and Environment, Nuclear Fission Safety, Growth, Quality of Life, Tacis, Training and Mobility.

From these 42 proposals, 2 were signed in 1999 for a funding of 0.46 MEuro (excluding matching funds), 21 were already accepted for a total funding of 7.16 MEuro and 10 are still awaiting a decision for a total amount of 1.2 MEuro. The current ratio (over 50% approved with still 10 proposals pending) compares quite favourably with all previous ratios (40% in 1996, 54% in 1997 and 60% in 1998).

Work in 1999 was carried out on 32 SCA projects, using a wide range of IAM's competences and facilities and for a total amount of 1.36 MEuro.

THIRD PARTY WORK

IAM supplies many European industrial companies with expertise in advanced materials technologies through Third Party Work.

During 1999, IAM worked on nine projects for seven customers in six countries (five member states). Work in these projects amounted to 180 kEuro and involved studies, evaluation and technical assistance.

IAM also signed six contracts for TPW in 1999 for a total value of 151 kEuro. The 6 contracts involve five customers from four countries (one non-member State). Additionally, four contracts have been signed, totalling 1.24 MEuro, for HFR activities (i.e. not related to FP5).

SUPPORT TO EUROPEAN COMMISSION SERVICES

Enterprise DG

Work was carried out in 1999 for the Enterprise DG on six Competitive Support to the Commission projects, for a total value of 263.5 kEuro.

Three projects were carried out for the Value programme (former DG XIII.D) on the following topics:

- Software for implementation of alignment measurements.
- New coatings for next generation catalytic converters for automobile exhaust gases.
- Brake linings from ceramic matrix composites.

Two competitive support proposals, accepted by the Enterprise DG in 1997 and signed in 1998 for a total value of 950 kEuro, are related to design by analysis and harmonisation of inspection in support to the Pressure Equipment Directive.

A Competitive Support to the Commission project which had started in January 1997 (for 250 kEuro) was finished during 1999, and consisted in providing support to the Auto-Oil II programme on car emission technologies. Work in 1999 on this project involved 65 kEuro.

Enlargement DG and SCR

The support to Enlargement DG and SCR is provided in the frame of IAM's Other Competitive Activities.

Since 1998 three JRC institutes are collaborating with the Twinning Programme Engineering Group (TPEG) in establishing the annual Masterplan and are in charge of writing the Terms of Reference. They are also responsible for the complete follow-up of the projects granted in the frame of Tacis and Phare programmes for nuclear safety. This role of the JRC in Tacis/Phare fits very well with its new mission. The JRC is thus still very much involved in what is going on in the nuclear industry with regard to Central and Eastern European Countries (CEECs) and the New Independent States (NIS) without being a competitor.

IAM is a leading institute in these activities of high strategic importance for the JRC.

Two contracts were signed in 1999 for a total amount of 2.47 MEuro: on-site assistance to the Tacis programme and the Phare workplan. Work was already initiated on this latter project as well as on two other projects (namely technical assistance to the Tacis workplan and assistance for the Tacis programme in Russia) for a total value of 3.31 kEuro.

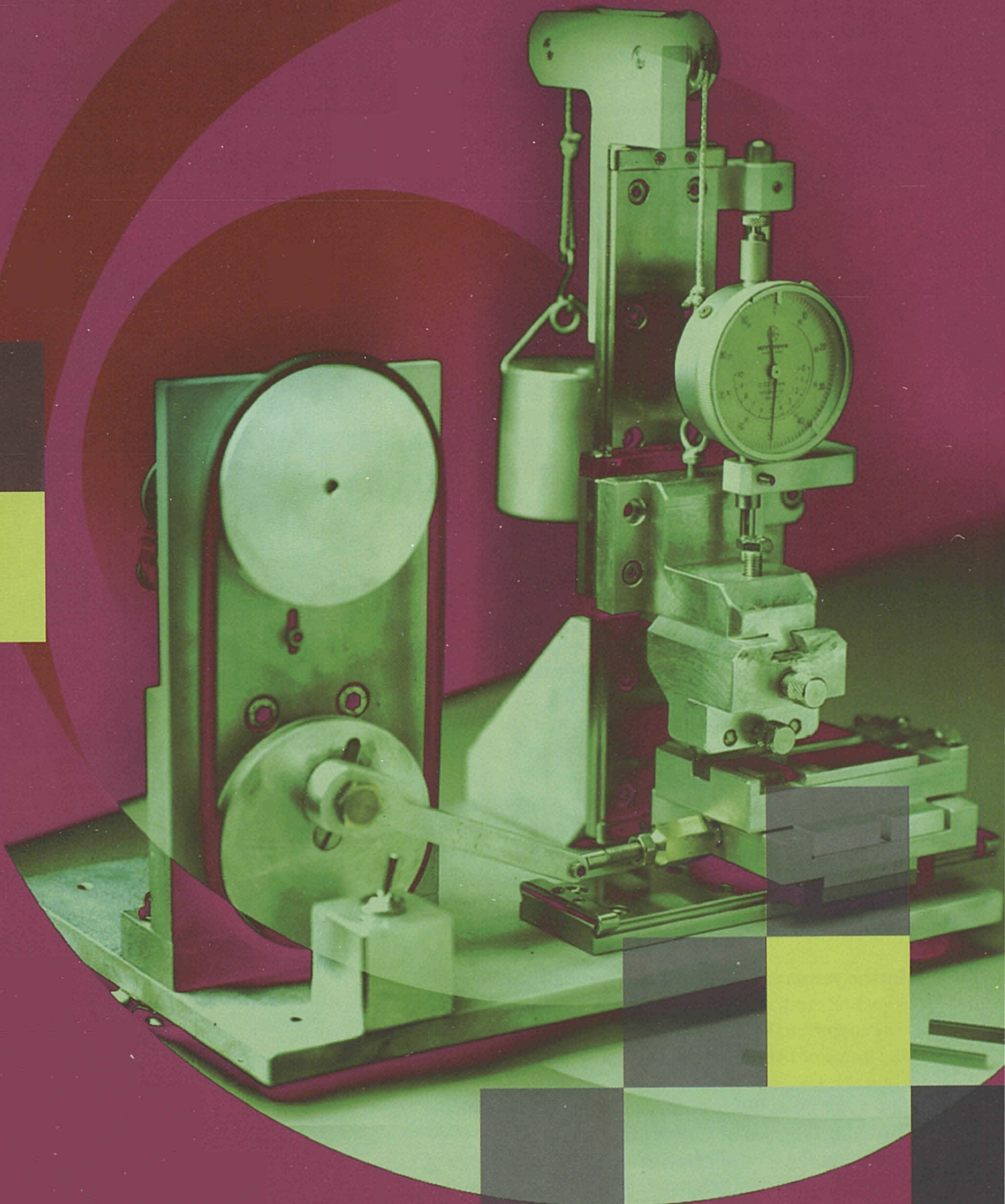
VALUE OF COMPETITIVE ACTIVITIES SIGNED

The indicator of performance is the volume (in MEuro) of competitive actions signed.

IAM Petten	1995	1996	1997	1998	1999
SCA (50%)	0.42	0.90	1.81	1.51	0.46
CSC	0.10	0.56	2.14	1.08	0*
TPW	0.35	0.20	0.98	0.30	0.15
OCA	0	0.10	0.58	1.13	2.47
Total IAM (excl. HFR)	**0.87**	**1.76**	**5.51**	**4.02**	**3.08**

* From 1999 on the possibility of income from Competitive Support to the Commission was not any more available due to changes in the financial regulations. Nevertheless, ongoing work in 1999 and beyond has still to be finished.

22



EXECUTIVE SUMMARY

Boron Neutron Capture Therapy (BNCT) is a therapy that can be used in replacement of conventional radiotherapy for treatment of degenerative diseases such as cancer and diabetes. It is based on the ability of the isotope ^{10}B to concentrate around specific tumour cells and capture thermal neutrons upon irradiation, thereby producing highly energetic particles destroying neighbouring cells. The objective of the project is to provide a BNCT facility in Petten, support clinical trials, improve treatment planning and develop the necessary related competence to operate the facility.

Highlights of the achievements in 1999 include:

- Renewal of critical components in the liquid argon system of the facility.
- Completion of the second cohort of five patients in the clinical trials of BNCT for glioblastoma using BPA.
- Improvement of treatment procedures leading to more efficient task flow and allowing, on one occasion, to treat two patients on the same day (worldwide premiere in BNCT).
- Approval of a SCA to perform clinical trials of BNCT using BSH.
- Implementation of improved sub-routines/macros to facilitate pre- and post-processing routines.
- Development and use of improved patient positioning procedure during treatment.
- Development of a program to accept the input of PET images, which could form part of the treatment planning procedure in future trials.

BACKGROUND

Pre-clinical research and clinical activities on BNCT have continued to flourish at the HFR. BNCT is based on the ability of the isotope ^{10}B to capture thermal neutrons to produce two highly energetic particles, i.e. a He (α particle) and Li ion, which when produced selectively in tumour cells, opens an effective new modality for cancer treatment. Work on BNCT at Petten has already experienced more than 10 years of effort, leading to the start of the first clinical trial on BNCT in Europe, in October 1997.

PROJECT OBJECTIVES

For the first time, the BNCT project became part of the JRC's Institutional Research programme, giving it a sounder base on which to develop its research activities.* Four prime objectives were proposed, each with a number of sub-tasks:

Objetive 1: BNCT Facility

- The BNCT facility had some critical components in the liquid argon system renewed, making the overall operation of the facility more reliable.
- As part of the Institute's drive towards Total Quality Management, the BNCT project was singled out to represent the HFR with respect to both independent Quality and Scientific Audits. In previous years, and as part of the procedure to obtain permission and licensing from the Dutch Authorities to perform clinical trials on patients at a nuclear research reactor, the BNCT project had already set up its own Quality system, which was necessary with respect to Good Clinical Practice.

Objetive 2: Trials Support

- Continuation of the Current Clinical Trial of BNCT for Glioblastoma.

The clinical trial of BNCT for glioblastoma using BPA progressed in 1999 with the treatment of 5 patients in a second cohort. This cohort of patients received a 10% increase in radiation dose to the first cohort.

▲ *Patient positioned in front of the radiation beam during treatment.*

* Work on BNCT started in 1994 in the frame of Shared Cost Actions in Biomed I and Biomed II programmes and projects funded under the Enterprise DG (former DG XIII.D) Competitive Support to the Commission line.

The outcome of the first cohort, in which 10 patients were treated, was as expected. The life expectancy was no worse than alternative treatment, whilst the quality of life of these patients was arguably improved. No overall conclusion may be drawn until the study has been fully completed.

During the treatment of the second cohort, the procedures developed and used in the first cohort had been slightly modified to improve the study. With this improvement, which enabled the staff to perform their tasks more efficiently, it was possible during one of the treatment weeks to treat 2 patients per day, which had never been performed before worldwide in BNCT. Of the 5 patients that were treated in the second cohort, 3 came from Germany, one from France and one from Austria.

- Proposed New Clinical Trials

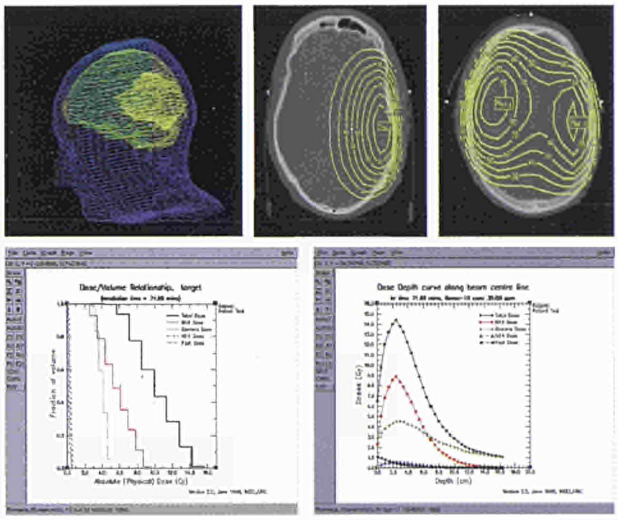
Within the "Quality of Life and Management of Living Resources" programme in the 5th Framework Programme, an application to perform two new clinical trials in support of boron imaging development was successful. The work will begin in 2000. The 2 trials have the objectives to study the toxicity of BSH, by means of increasing the boron concentration in blood and therefore in the tumour, which would increase the dose to the tumour whilst maintaining the same irradiation time or alternatively, maintaining the dose to the tumour but by reducing the irradiation time (and therefore reducing the non-boron dose components to healthy tissue. The second trial will perform BNCT for brain metastases of malignant melanoma using the boron compound, BPA. This trial is intended to be prepared in common with the EORTC BNCT Study Group as well as the EORTC Melanoma Co-operative Group. The Principal Clinical Investigator will again be Prof. Dr. Med. Wolfgang Sauerwein of the University of Essen. Participating hospitals and institutes are Universities of Münster, Reims, Essen, VU Amsterdam, Nice, Graz and München. The close co-operation with NRG Petten, who operate the facility, remains an integral part of the BNCT work at Petten.

Objetive 3: Treatment Planning

- Improved sub-routines/macros to facilitate pre- and post-processing routines during treatment planning were implemented, whilst improvements and validation continue.
- A QA/QC protocol was proposed, in line with Good Clinical Practice.

Objetive 4: Research Activities

- Improvements to the patient positioning procedure were developed and used during the treatment of patients in the current glioblastoma trial.
- A new program was developed to accept the input of PET images, which could form part of the treatment planning procedure in future trials.
- A new cubic phantom was constructed to perform cell culture irradiation experiments as part of a combined microdosimetry and beam calibration exercise, which will be performed in 2000.
- Some probing studies were launched to ascertain if the BNCT facility could be used for other types of NCT treatment, e.g. using gadolinium, and other types of diseases, e.g. diabetes.



▲ *Example of the 3D reconstruction of a patient's head, and the resulting treatment planning procedure, indicating isodose curves and Dose/Volume and Depth calculations.*

EUROPEAN DIMENSION

Recognition of the continued work at Petten resulted in participation in many seminars, colloquia and progress meetings at numerous institutes throughout Europe. Highlights included:

- An invitation to the MARIA reactor in Warsaw to advice Polish radiotherapists and nuclear physicists in their aim to implement BNCT in Poland.
- Conference to Launch the European Union's Fifth Framework Programme for research, Essen/Germany, 25-26 February 1999.
- Participation in an IAEA Technical Meeting in Vienna in support of BNCT development. The Petten project reported on its expertise in Quality Assurance and Safety.
- In November, JRC was invited to report to the Advisory Committee on Cancer Prevention, who advise and develop policies within DG SANCO/F/2.

The BNCT trial and the facility at the HFR continued to attract many visitors, both professionally and to the public. Scientific and Medical experts from many countries visited Petten throughout the year, including clinicians from Hungary, Poland, Japan, USA, Libya and Taiwan.

EXECUTIVE SUMMARY

MERECH addresses the unnecessary received radiations of X-ray medical devices on human patients. Therefore, one of MERECH's major objectives was to identify technologies for exposure reduction. During the first year of operation the experimental activity of MERECH was set up to analyze the influence of the different technical factors on the dose released for a given image quality. Several studies were carried out, one of those being a review report on main research findings, significant data generated and methods developed. Also many necessary and useful contacts were established. Unfortunately, the management of IAM decided to terminate the project despite its promising start for reasons mentioned further below. MERECH will be terminated in the course of 2000.

BACKGROUND

MERECH is a new project of the IAM and covers the Medical and Health Application Research Area of the JRC. It addresses the problem of the unnecessary doses absorbed in case of medical X-ray examinations by patients for the same radiographic procedure and for the same image quality in European hospitals and diagnostic centres. In fact, radiographic equipment is used for several purposes with variable effectiveness from equipment to equipment and from institution to institution and is not always used in an optimal manner. Furthermore, X-ray equipment dose relevant regulations in Europe differ greatly.

Within this context MERECH supports European legal initiatives on patient radiation protection from medical radiation exposures (Council Directive 97/43/Euratom). In particular MERECH contributes to limit the X-ray dose received by individuals while enhancing diagnostic image quality through the development of characterization methods for medical X-ray equipment.

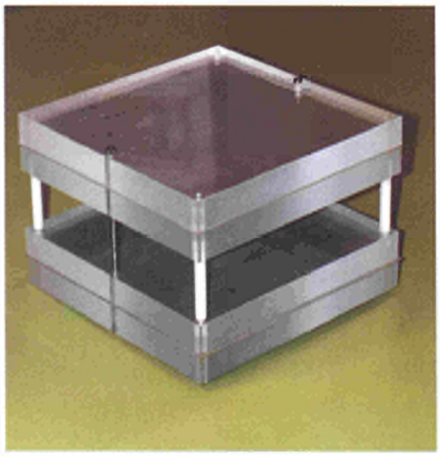
PROJECT OBJECTIVES

The MERECH main objectives in relation to the most common X-ray examinations are then to:

- optimize and harmonize procedures for X-ray equipment qualification,
- adapt dosimetry tools,
- identify technologies for exposure reduction,
- launch and manage networks of users, specially hospitals and Member States regulatory authorities, for the execution of benchmark exercises,
- disseminate the information, support of customer DGs (enterprise, research, radiation protection).

MAJOR ACHIEVEMENTS IN 1999

MERECH started in 1999. The major efforts were addressed to establishing contacts, building up know-how and setting up a laboratory. An external scientific audit, conducted under the supervision of the JRC Headquarters, stated that the technology was "in its mature technological age" and that IAM was "entering a very 'closed' market where industry had a long standing experience". Although the favourable reaction from leading industry groups was noted, the scientific audit team was uneasy in supporting this specific project. In light of this advice and of the difficult integration of MERECH in IAM's workprogramme as a whole, the management of IAM decided to terminate the project despite its promising start. MERECH will be terminated in the course of 2000. The expertise, manpower and credits available for the project will be used in the coming years on other IAM projects.



▲ *MERECH laboratory: typical diagnostic facility for chest radiography* [top], *and chest phantom for dosimetry calibration studies* [bottom].

Laboratory Set-up

A state-of-the-art review in medical X-ray was carried out in order to define the layout of the X-ray medical laboratory. This lead to the main achievement during 1999, the first year of operation, which was the preparation and set-up of the X-ray medical laboratory, integrated in the existing JRC X-ray facility. A second important outcome of the review was a dedicated experimental plan.

Technologies for Exposure Reduction

The experimental activity of MERECH is planned to analyze the influence of the different technical factors on the dose released for a given image quality. After an intensive literature review carried out by IAM staff those can be listed as follows:

- Geometric Characteristics of the X-ray beam.
- X-ray exposure Parameters.
- Beam Quality.
- Dose Measurements.
- Film/Screen–combinations.
- Film/Screen characteristics.
- Film Cassette.
- Anti Scatter Grids.
- Film Processing.

Network Establishment

The laboratory activity has been backed-up by the development of a series of contacts and exchanges with the main European X-ray equipment manufacturers, universities and hospitals with the aim of building-up a MERECH network of experts and users.

Information Dissemination and Contacts

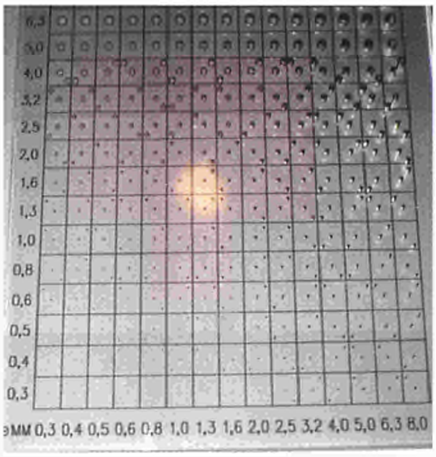
Advanced discussions have been carried out with the DGs of major concern. Key support for MERECH has been identified from DG Enterprise and efforts were made to introduce MERECH to the European Federation of Manufacturers of Electro-Medical Equipment (COCIR). DG Environment support was gained and MERECH had been presented to its national working group on medical X-ray. MERECH was also presented to DG Research and the 'Concerted Action' group DIMOND on medical radiology.

SCIENTIFIC ACHIEVEMENTS

Due to the starting phase MERECH is in, practical experiments could not yet been carried out in 1999. Nevertheless, a review report on main research findings, significant data generated as well as methods developed available in literature was started. In addition, the need for a drafting a report describing dosimetry equipment required for the experimental activity was felt. The report was started and is in its first phase.

OBJECTIVES FOR 2000

As laid out earlier the project MERECH will be run down within 2000.



▲ *Contrast-detail phantom to determine the image quality* [top], *and instrumentation for quality assurance in diagnostic radiology (left pinhole camera, centre and above dose measurement device and ionization chambers)* [bottom].

EXECUTIVE SUMMARY

The project EPERC is aimed at the industrial sector of pressure equipment. The objectives of the project are to foster co-operative research and development linked to problems of design, construction and in-service activities and to operate the network EPERC.

Major achievements in 1999 include:

- Membership in EPERC has grown to 157 signed organisations (≈350 persons).
- A new EPERC TTF (TTF 5) on service integrity and life extension has been launched in February 1999.
- Establishment of a European industrial survey to identify R&D needs.
- Support to DG Enterprises continued in 1999 with three new projects:
  - pressure components fatigue design,
  - advanced methodologies to exploit high strength steels for pressure equipment manufacturer,
  - knowledge based system to reduce design conservatism.
- Several publications, bulletins and newsletters have been published.
- On the request of EPERC Technical Task Forces a number of additional technical activities meeting the requirement of the PED were conducted by IAM in the following areas:
  - benchmark calculations to demonstrate the potential of the proposed CEN procedure for fatigue life assessment of Unfired Pressure Vessels,
  - regulatory and fabrication limitations to use high strength steels,
  - Round Robin Table on Time of Flight Diffraction (test pieces, inspections, etc.),
  - new alternative method for flange gasket joint design based upon numerical analysis and experimental validation and finally fugitive emissions control.

BACKGROUND

In May 1999 the European Pressure Equipment Directive (PED 97/23/EC) was adopted by the member states. It will be mandatory the 29th of May 2002. The Directive will be implemented through a series of European standards and harmonised practices.

The European Pressure Equipment Research Council

EPERC is a European network grouping over 150 organisations (industry, national research centres, inspection bodies and governmental institutions). The network was set-up with the objective of supporting both the Pressure Equipment industry and the EC policy for the development of safety measures to protect the citizen in the field of Pressure Equipment. As all European Networks at IAM, EPERC is a platform for the industrial sector to establish and conduct the relevant R&D priorities, to identify and stimulate funding of these R&D priorities and to return the results to the industry by means of improved technology transfer activities.

All EPERC technical actions (Technical Task Forces – TTFs) aim at performing research for improving safety/reliability/efficiency and environmental protection while maintaining sustainable growth. Until end 1998, the TTFs were as follows:

TTF 1	fatigue design,
TTF 2	high strength steel for pressure equipment reduction,
TTF 3	harmonization of inspection programmes in Europe,
TTF 4	flanges and gaskets.

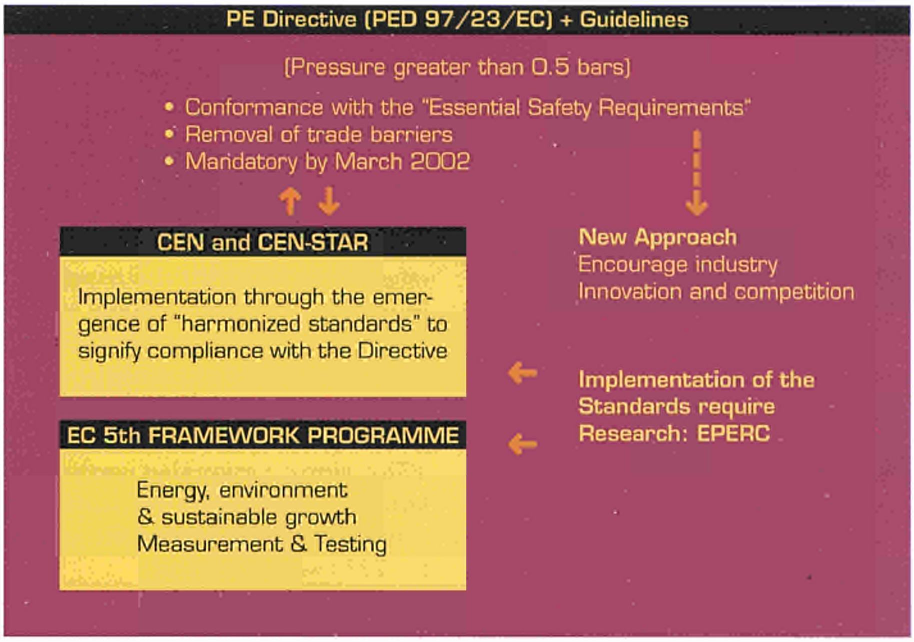
EPERC is providing added value to conduct relevant scientific R&D to support new technical standards. A link is maintained between EPERC and the following CEN technical committees:

TC 54	Unfired pressure vessels,
TC 267	Industrial piping and pipelines,
TC 269	Shell boilers and water tube boilers,
TC 74	Flanges and their joints,
TC 138	Non-Destructive Testing,
TC 121	Welding.

PROJECT OBJECTIVES

The project EPERC (European Pressure Equipment Research Council) of IAM is aimed at the industrial sector of pressure equipment. The objectives of the project are to foster co-operative research and development linked to problems of design, construction and in-service activities and to operate the network EPERC through the following actions:

- To manage the activities, on a day by day basis, under the guidance of the Steering Committee, handle the network secretariat and operate the four Technical Task Forces (TTFs) of EPERC.
- To assemble the Reference Laboratory of the network, based on JRC and on the national laboratories of excellence in the different technical fields of action developed by EPERC TTFs.
- To liase with the services of the Commission (for



EPERC), with the Committee for European Standardisation (CEN) in view of a possible contribution of EPERC to codes and standards and with the national members representing the national pressure equipment associations or individual institutions (for the Steering Committee).

- To help for the technology transfer (Website).

MAJOR ACHIEVEMENTS IN 1999

Achievements in 1999, as related to the project objectives, can be summarised as follows:

Network Operation

As a result of the technical actions, membership in EPERC has grown to 157 signed organisations (≈350 persons) by the middle of 1999. IAM, as operating agent, provides a co-chairman for each TTF with responsibility for preparing proposals, co-ordinating the task programme and implementing the task schedules.

IAM has also expanded the strategy of EPERC on its leading position in the field of Pressure equipment.

A new EPERC TTF (TTF 5) on service integrity and life extension has been launched in February 1999. It will focus on plant operation aspects including component integrity, residual life assessment, repair and effect of material damage in the component integrity and residual life.

Further to an IAM proposal, it was decided in 1999 to establish a European industrial survey to identify R&D needs and to create a new technical task force on alternative fuel storage tanks (TTF 6) in the course of 2000. An exploratory meeting was held the 1st of June 1999 with relevant industries active in the field (vehicle manufacturers, gas industry and tanks manufacturers). Storage tanks is a crucial issue for using alternative fuels (e.g., Natural gas, Hydrogen) to power vehicles in the sector of transport.

IAM management is also considering merging the projects EPERC and HYDANET for a more efficient use of resources. Instead of launching a dedicated network, for hydrogen damage, IAM could use the EPERC platform where hydrogen related issues would be tackled in specific and dedicated TTFs. This decision is pending the approval of the Steering Committee.

Network Reference Laboratory

Actions were taken to strengthen the facilities of the IAM Reference Laboratory for component integrity testing & evaluation and for non-destructive evaluation, which provide the technical and scientific basis to support EPERC research activities.

Liaison

In the frame of the Pressure Equipment Directive, the co-operation with DG Enterprises and the ensuing contracts has led at the end of 1999 to successful conclusions in the areas of:

- promoting the use of Design by Analysis aiming at giving guidelines for applying DBA to typical pressure vessel structures under a variety of loading conditions,

- harmonisation of inspection procedures based on Non-Destructive Examination (NDE) techniques.

Support to DG Enterprises continued in 1999 with three new projects:

- pressure components fatigue design,
- advanced methodologies to exploit high strength steels for pressure equipment manufacturer,
- knowledge based system to reduce design conservatism.

Technology Transfer

Much research work is never fully used by industry without proper technology transfer. EPERC was also established with the objective of addressing this issue. Actions have involved the creation of Technical Bulletins and Newsletters. Main publications in 1999 include:

- EPERC has assisted DG Enterprise in the establishment of a Pressure Equipment Web Site into which the web site of EPERC will be integrated (http://eperc.jrc.nl).
- 2nd EPERC Bulletin: "European Standards Approach to Pressure Equipment Inspection" has been published at the end of November 1999.
- 4th EPERC Newsletter has been issued in May 1999.
- Proceedings of the EPERC Workshop on Inspection Qualification, March 1999, EUR 18691 EN.
- Invitation made by CEN to participate at the International Conference on Pressure Equipment in Europe (September 1999, Brussels).

SCIENTIFIC ACHIEVEMENTS

On the request of EPERC Technical Task Forces a number of additional technical activities meeting the requirement of the PED were conducted by IAM in the following areas:

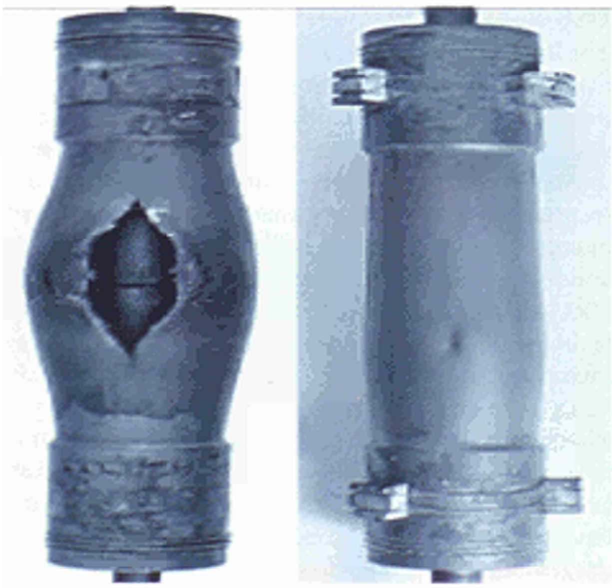
- benchmark calculations to demonstrate the potential of the proposed CEN procedure for fatigue life assessment of Unfired Pressure Vessels,
- regulatory and fabrication limitations to use high strength steels,
- Round Robin Table on Time of Flight Diffraction (test pieces, inspections, etc.),
- new alternative method for flange gasket joint design based upon numerical analysis and experimental validation and finally fugitive emissions control.

OBJECTIVES FOR 2000

1. Extend the technical activities of EPERC to "transportable" pressure equipment and possibly hydrogen damage related issues:
   - Pressure equipment used to power vehicles using alternative fuels (e.g.: Natural gas, Hydrogen).
   - Pressure equipment used for the carriage of dangerous goods (New European Transportable Pressure Equipment Directive–TPED 99/36/EC).
2. Establish a framework collaboration agreement with the American Pressure Vessel Research Council and Japanese Research Council.

HIGHLIGHTS

- A workshop entitled "Is there a need for qualification of manufacturing NDT inspections in the pressure equipment industry?" was organized by EPERC. There was a general consensus amongst industrial participants that inspection qualification may be useful in the specific cases:
  - use of new non-standard techniques not covered by existing codes and standards such as for example the case of the inspection of gas pipe line,
  - applications where no codes/standards are available,
  - cases where the consequences of inefficient NDT may be catastrophic.
- Extension of EPERC technical activities to alternative fuel (Hydrogen, Natural Gas) storage tanks for vehicles.
- Unique partnership between EPERC (R&D) and standardization bodies, manufacturers, end-users, notified bodies national authorities.



▲ *Selected example: IAM Reference Laboratory high pressure Test conducted up to failure.*

EXECUTIVE SUMMARY

The establishment of a European Network as focal point on hydrogen interaction with materials is the major objective of this project.

Work has been mainly carried out to prepare a successful Network launch, and to prepare the IAM for its role as Network Operating Agent, in particular identifying and developing the necessary basic key activities/infrastructure for Room Temperature (RT) hydrogen embrittlement studies, and continuing the efforts in the High-Temperature (HT) research field.

Major achievements are the following:

- Preparation of an official Network document.
- Purchase of suitable equipment for the RT laboratory.
- Identification and set-up of key facility for the evaluation of hydrogen uptake, permeation and transport in metals and alloys.
- Uniaxial creep testing in hot high-pressure hydrogen on currently used and new generation steels was conducted and the stability of their microstructure in hydrogen was assessed.
- Extensive test campaigns have been carried on the combined effects of stress and hydrogen attack.

PROJECT OBJECTIVES

The long term objective of the project is the establishment of a European Network (HYDANET) as a focal point of competence for the interaction of hydrogen with materials and in particular to deal with the detrimental effect of hydrogen (hydrogen damage) on the materials and components behaviour. The Network will be supported by a Network Reference Laboratory (NRL) and IAM will act as a Network Operating Agent and as NRL Co-ordinator. It will support implementation of hydrogen as an energy pathway for clean technologies providing inputs for safe handling of hydrogen.

The main actions for 1999 concerned the execution of the preliminary actions for a successful Network launch, and the preparation of the IAM for its role as Network Operating Agent and Co-ordinator of the NRL. The activities were focussed on: identifying and developing the necessary basic key activities/infrastructure for Room Temperature (RT) hydrogen embrittlement studies, and continuing the efforts in the High-Temperature (HT) research field. There, the most important issue is that of "hydrogen attack", a potentially catastrophic phenomenon affecting hot-hydrogen large-scale reactors (hydrocrackers).

MAJOR ACHIEVEMENTS IN 1999

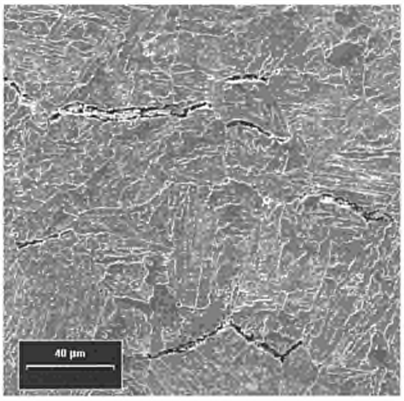
Network Establishment

The first HYDANET Newsletter has been prepared in a draft form and was forwarded to the key players in the field (industries, research centres, universities, regulatory bodies, etc.).

Consolidation for Participation in the Network Reference Laboratory

Suitable equipment for the RT laboratory has been purchased, and the key fields of activity have been identified. The work will be based on electrochemical techniques to study and measure hydrogen entry in metals and alloys. Priority will be given to the following methods:

- Potentiostatic double-step method for measuring hydrogen atom diffusion and trapping in metal electrodes. The technique involves generating hydrogen atoms at constant cathodic potential, then stepping to a more positive value and recording the anodic current and charge associated with the removal of hydrogen atoms from the electrode.
- Hydrogen Permeation Technique, ASTM Standard G148-97. The technique involves locating a metal membrane between the hydrogen charging and oxidation cells. Hydrogen atoms generated on the charging side are recombined on the oxidation side, so that a hydrogen flux through the membrane is measured.

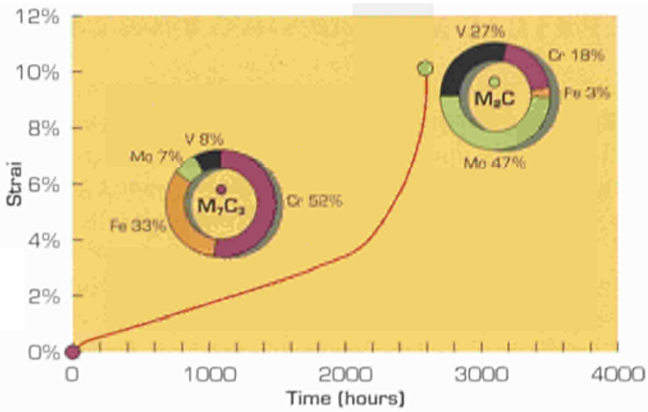


◀ *H_2 damage microstructure: hydrogen-induced cracking of a commercial ferritic steel.*

The existing facilities for HT testing have been implemented. This was either with the purchase of new devices (autoclave for small-scale experiments) or by upgrading the existing setup/design of the remote control/data acquisition system. Therefore, the HT hydrogen laboratory now consists of rigs for uniaxial and multiaxial creep, creep crack growth and stress-free reference testing in hydrogen at high temperatures and pressures.

An EU-co-financed research project (BE 1835–PREDICH) in which IAM is involved was completed. The project was aimed to assess and predict the behaviour of welded components, made from new steel grades, and to reach code acceptance under conditions in which hydrogen-assisted and creep degradation are acting simultaneously.

In this frame, uniaxial creep testing in hot high-pressure hydrogen on currently used and new generation steels were conducted, and the stability of their microstructure in hydrogen was assessed. The results achieved have been delivered to the project co-ordinator and will form part of the final report. The relevant knowledge will be disseminated, following the guidelines which will be set by the project co-ordinator.



▲ *Evolution of predominant carbides in a commercial ferritic steel after ageing in hot-high pressure H_2 under creep load (σ=150 MPa).*

range from steels for conventional use in large-scale pressure vessels to materials used in hydrogen containment and storage for medium-small-scale applications.

SCIENTIFIC ACHIEVEMENT

Extensive test campaigns have been carried on the combined effects of stress and hydrogen attack, either for steels currently used for hot-high pressure hydrogen reactors or for new generation steels. Relevant data on materials performance have been collected, and the damage mechanisms have been investigated in detail. Effort has been put in the specific application of consolidated techniques of microstructural investigation of materials (SEM/TEM/EDS) to hydrogen damage related studies. Correlations have been outlined between the degradation of mechanical properties of materials and the evolution of their fine microstructure, namely the structure, distribution and composition of reinforcing phases (grain boundary carbides). Mathematical modelling of the behaviour of tubular components internally pressurised with hydrogen at high temperatures has been developed.

OBJECTIVES FOR 2000

The most important issue for the year 2000 is the official Network launch, which will be accompanied by extended participation to scientific and technical conferences in order to promote the related activities.

The decisions taken relevantly to the RT-laboratory will be converted into active research starting from the May-June 2000. In this respect, relevant research lines have been identified, namely a first selection of materials to be investigated has been made. Materials to be tested will range from steels for conventional use in large-scale pressure vessels to materials used in hydrogen containment and storage for medium-small-scale applications.

HIGHLIGHTS

The research activity on the interaction of hydrogen with stress has created at JRC/IAM a sizeable knowledge. In particular:

- The role of stress on hydrogen attack has been clearly demonstrated.
- Analysis of the damage during tube testing revealed the possible occurrence of a highly specific damage mechanism (hydrogen-assisted cracking) which is potentially very detrimental for the integrity of plants/components.
- TEM carbide analysis on extraction replicas on hydrogen exposed materials has been identified as a potential way of achieving a breakthrough in damage assessment/lifetime estimation.

This had led in 1996 to the submission of applications for two patents which were relevant for innovative designs potentially exploitable in the hydrogen-related industry. One of them is expected to be officially published in the European Patent Bulletin in the year 2000. The same knowledge is now being converted into publications on scientific/technical journals. It is expected that a valuable input will be given in the field, with potential interest for the upgrade of codes and standards. For instance, the design of hydrocrackers is currently based on the so-called "Nelson Curves", which not only are derived purely from industrial experience and failure case studies, but do not account for factors such as the stress conditions, weldments, thermo-mechanical history, etc.

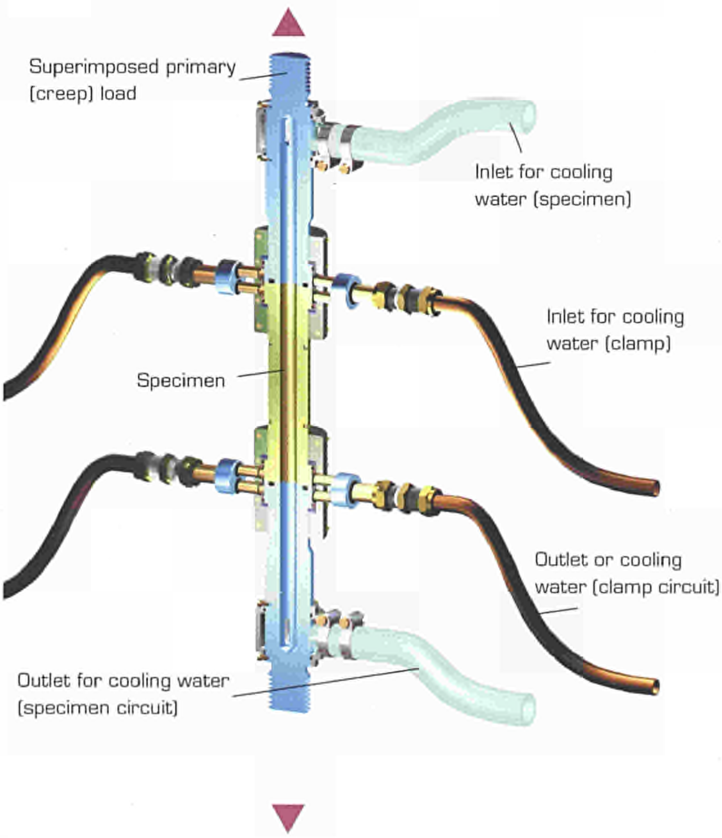
EXECUTIVE SUMMARY

The stated objectives of the project are to develop unique materials evaluation and component testing tools for:

- verifying advanced life assessment models for operating power plant components,
- verifying condition monitoring methods for operating power plant components,
- assessing the suitability of currently unused advanced materials employed in high efficiency, lower emission plant usually operating at higher temperatures.

The achievement of these goals centres on the successful development of models which can characterise the mechanical performance and environmental resistance of candidate alloys and weldments and consequently accelerate their introduction either in new or refurbished plant. These models have to be derived from dedicated experiments on the alloys to provide information on creep, fracture and corrosion resistance behaviour, and their interactions. For acceptance by plant designers and operators, such lifetime prediction models need to be verified using complex benchmarking experiments, which simulate the operation of actual plant components.

Considerable progress has been achieved during the first year of the project, in spite of some delay in material selection, and has concentrated on preparation of suitable test equipment, preparation for material selection through networking activities and data base investigations, preliminary model development and full participation in external networks.



MAJOR ACHIEVEMENTS IN 1999

Test Facility Development

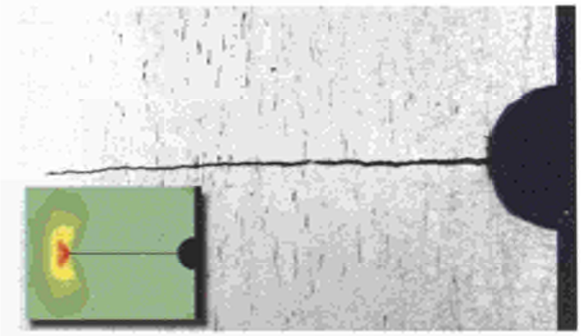
In terms of the preparation of additional specialist facilities for assessing materials behaviour under closely simulated plant conditions, a total of 8 creep machines have been improved and dedicated for testing in aggressive environments. A laboratory autoclave has also been adapted and re-commissioned for use with complex chlorine-containing gas mixtures that include sulphur and carbon-containing species. For the more complex benchmark type testing, the design of a rig for subjecting pipes to bending loads at elevated temperatures, in order to simulate the complex loading of plant components, has been completed. The most highly stressed parts of power plant steam piping are the welds where the stresses produced by internal pressure are accompanied by system stresses arising from the thermal expansion of the piping or insufficient functioning of the pipe hangers. In the past only small size tubes could be tested under internal pressure and axial loading in our laboratories, as pipes require axial load beyond practical possibilities. Therefore replacing the axial loading by bending offers an effective and inexpensive way to increase the axial stress in a pipe to such a level that a circumferential weld would fail with the same mechanism as a pipe under plant conditions. Similarly, to take into account thermal stresses another facility for assessing the combined action of high temperature creep and thermal fatigue on notched pipes is constructed and already in operation testing austenitic steel components.

MATERIAL SELECTION

In order to ensure that this project lies at the heart of the industrial interest it is linked into prominent external networks. Due to some delayed decisions within these networks, an important milestone for EPG-Fossil, that of material selection was delayed by some months. However the first alloys have now been selected. The underlying idea was to select only very few high efficiency plant materials which would be fully characterised in terms of their creep and thermal fatigue resistance and steam oxidation and fire side corrosion properties. Two "core materials" were selected as the martensitic steel P92 (9% Cr-1.8% W) the current top of the range alloy for steam temperatures up to 625°C and, as austenitic steel, NF709, because of its status as a reference material in the industry driven COST 522 and THERMIE projects. A decision about a suitable Ni-based alloy has been

◄ *The loading system for studying creep effects on thermal fatigue crack growth.*

delayed in order to wait for results from the above mentioned networks, along with the decision as to the most appropriate weldments to be introduced in the project, representing the most vulnerable part of the plant components. Some additional alloys are to be introduced for specific applications such as 12% Cr steel, T122, for better steam oxidation and fireside corrosion resistance for boiler tubing. For components that will be subjected to aggressive coal gasification environments a second austenitic material AC66 was selected. A preliminary investigation of available data on all these materials has been conducted in the Alloys Data Bank, with limited results but which conversely indicates that work is required on these materials. The Data Bank is preparing to store the data produced in the project and to introduce the necessary evaluation programmes.



▲ *Stresses at the crack tip of a crack grown in a component wall grown by thermal fatigue from a starter notch.*

MODEL DEVELOPMENT

The development of integrated life time prediction models in preparation for the availability of data on the selected materials has been concentrated on thermal fatigue crack growth of cracked 316 stainless steel components, (already commenced in the previous programme for nuclear applications) and multiaxial creep behaviour of welded ferritic alloy tubes. An example concerns the use of finite element analysis to predict the stresses around a growing crack and hence the rate of crack growth under thermal loading for comparison with the growth of a crack from a circumferential defect machined into the wall of cylindrical component a defect cycled between 80° and 600°C.

The continuum damage mechanics model proposed to characterise creep behaviour in base metal and welded components relies for appropriate benchmarking on the development of appropriate NDT techniques to characterise the component damage in situ. The route towards successful inspection for defective or service damaged components, has been collated into a definitive report for austenitic weldments and work has commenced to find the most appropriate techniques for ferritic and austenitic alloys and weldments.

NETWORK ACTIVITIES

Within the linked networks and projects, the component testing matrix has now been defined for all partners including IAM within COST 522 "Low Emission – Ultra Efficient Power Generation Systems" as has the corrosion testing plan within the Plant Ancillary Group of COST 522. JRC is co-ordinating the Common Activity CA5 group for Modelling of Component Behaviour and Residual Life where the multiaxial properties of the advanced steels are characterised by special component tests for ferritic and austenitic steels which have been developed for use at future power plants with increased thermal efficiency and reduced emissions. These new materials have been aimed at live steam conditions up to 650°C and JRC will perform tube tests under internal pressure and axial loading on NF709 as its contribution. Simulated coal gasification environment tests have already commenced on materials selected in a bilateral project by EPRI and IAM. Two Si-enriched 12%-Cr model alloys (1%- and 2%-Si) and three commercial steels have been compared in a gas mixture, simulating the process atmosphere of a dry-feed entrained slagging coal gasifier. The tests were carried out at two temperatures (550° and 400°C), under non-equilibrium conditions, for up to 1200 hours, and included fly ash deposits and periods simulating plant down-time. Gravimetric data on non-ash coated specimens after 1200 h at 550°C indicated a corrosion resistance for the 2%-Si model alloy close to that of the high Cr/Ni Alloy 800H material whereas weight gains of the other two commercial alloys, HCM12 and P91 were a factor of 10 higher. Highest corrosion rates were observed with the 9%-Cr, P91 material. In contrast, at 400°C, the effect of chlorides in the fly ash appeared greater, thereby increasing the corrosivity of the environment. As a consequence, the lower, 1%-Si-containing material could no longer be considered to be "very corrosion resistant"; its performance was closer to that of the lower-alloy, 9%- and 12%-Cr materials, without silicon additions. Under these more severe conditions, 1%-Si in the alloy appears to be below the critical level needed to provide significantly improved performance for 12%-Cr materials. Increasing the Si content to 2%, however, promoted a considerable improvement in resistance to attack, even under the more severe conditions at 400°C.

Creep tests on bimetallic welds from the European Creep Collaborative Committee (ECCC) network have also commenced. Testing of P91-P22 dissimilar metal weld where, under certain conditions, a special carbon diffusion problem may occur when chromium will move from the low chromium steel to the 9%-Cr steel creating a carbide free zone in the low alloy steel with a reduced creep strength.

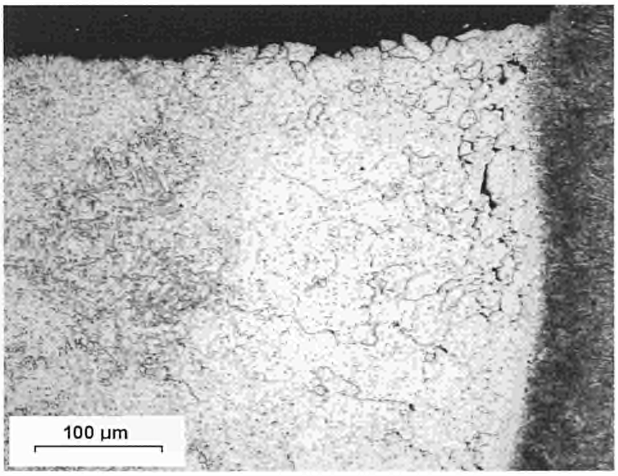
The materials selection exercise for the Thermie Shared Cost Action (SCA) Advanced 700 C Power Plant project commenced at the beginning of the year both in the IAM laboratories and those of partners. In parallel an intensive literature search and preliminary experimental programme has been focussed particularly on nickel base alloys for their corrosion resistance in coal fired boiler atmospheres which has led to a number of reports and publications.

In order to further extend the collaborative reach of the project some considerable effort was devoted to the preparation of SCA proposals to the Vth FWP Competitive and Sustainable Growth call of June. It is understood that two of these, "Prediction of life-time behaviour for C/C-SiC tubes in high and ultra-high temperature heat exchangers" (HITHEX) which is a watch and alert aspect of the current project for very high temperature applications and "Integrity of repair welds in high temperature plant operating under steady and cyclic conditions" are approved for funding.

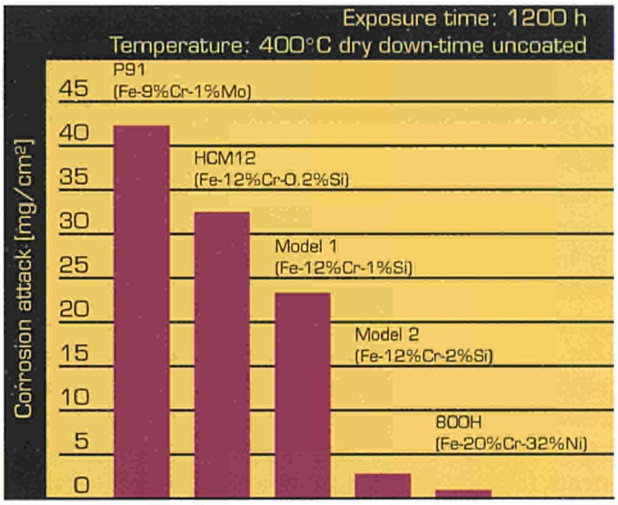
EXPLOITATION OF RESULTS

Although the project has been running for less than one year and there is no data yet available for the selected core materials, there are already deliverables available to Network partners concerning other alloys for high temperature power plant application, particularly within ECCC and COST 522 along with specific SCA networks such as Thermie USC 700 and Thermie ELCOGAS a demonstration plant for coal gasification. Not only have these industry driven Networks been constructive in influencing material selection but also JRC could contribute its own expertise in particular in deciding on component testing programmes but also giving guidance in terms of potential corrosion resistance of some candidate materials based on long experience in this field.

Dissemination of information is also considered as a high priority in the project with already a number of publications made and the Data Bank figuring in networks to enable data to be made available to interested organisations.



▲ *Decarburised zone and creep damage in P22 weld metal.*



▲ *Beneficial effect of Silicon on resisting corrosion attack in chloride containing fly ash.*

GAS TURBINES FOR EFFICIENT POWER GENERATION

In the recent IPTS (JRC Seville) report "Technology options for the Kyoto Carbon emission targets and European competitiveness", the gas turbine combined cycle technology for electricity generation scores high on the scale of technology options to meet Kyoto targets in the EU. Indeed, nearly 65% of the total anticipated growth of the electric power capacity in the EU between 1992 and 2030 is expected to be covered by gas turbine combined cycle (see fig. below). Today, the issues driving the market of gas turbine manufacturing are enhanced energy conversion efficiency/reduced emissions and cost effectiveness. On the user side, cost of operation is the issue in the power generating industry. Reducing greenhouse gas emissions through achieving higher levels of efficiency, and lowering the cost of operation through extending the life of components are the main objectives of the "Efficient Power Generation-Gas Turbines" project. The project objectives are achieved by means of R&D on advanced material systems, by means of harmonisation of testing methods and standards, through the setting up and operation of networks, and by providing technical support to EU policies.

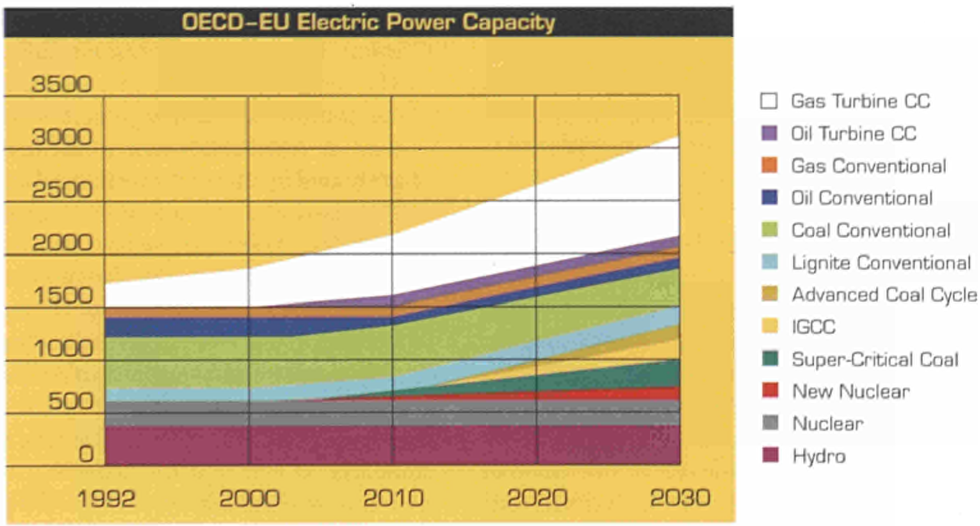
MAJOR ACHIEVEMENTS IN 1999

- Development and implementation of new test facilities and novel measurement methods.
- Implementation of the R&D part of the project, first experimental and modelling results.
- Contribution to standardisation of testing.
- Setting up of networks.

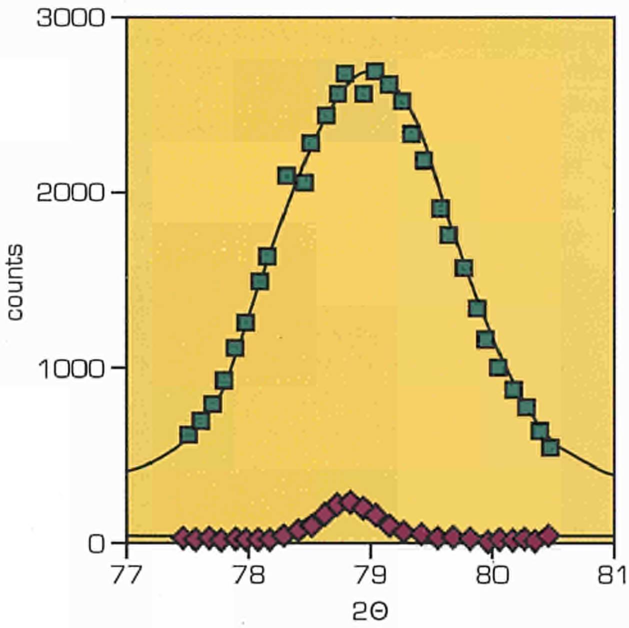
The use of innovative materials systems that support higher turbine inlet temperatures is the main route forward to meeting the market push for higher efficiency and reduced specific fuel consumption. Validation of the applicability of advanced materials calls for *adequate facilities for testing* of material properties. Progress in this area in 1999 included:

- Putting into service of a new universal mechanical testing rig. A market survey for the upgrading of existing testing rigs was made, and upgrades ordered.
- Implementing an induction heating technique coupled with a "special" material susceptor for testing of the mechanical performance of Thermal Barrier Coated materials under near-to-service conditions. Another heating technique using radiant lamps has been evaluated and solutions for its shortcomings are pursued.

*Projected evolution of energy conversion systems (*IPTS Report, *No. 38, Oct. 1999).* ▼



- Tailoring of Acoustic Emission (AE) as a non destructive procedure for the *in-situ* measurement of damage that develops during mechanical testing.
- Optimising of the Large Component Neutron Diffraction Facility (HB4) and of the Combined Powder and Stress Diffractometer (HB5) at the High Flux Reactor. HB4's double monochromator offers a wide range of selectable neutron wavelengths which allows for high resolution measurements based on second order neutrons (fig. below). This option has been extensively and successfully tested in 1999. For HB5 a new position sensitive neutron detector has been purchased that is expected to reduce sampling time by one order of magnitude.



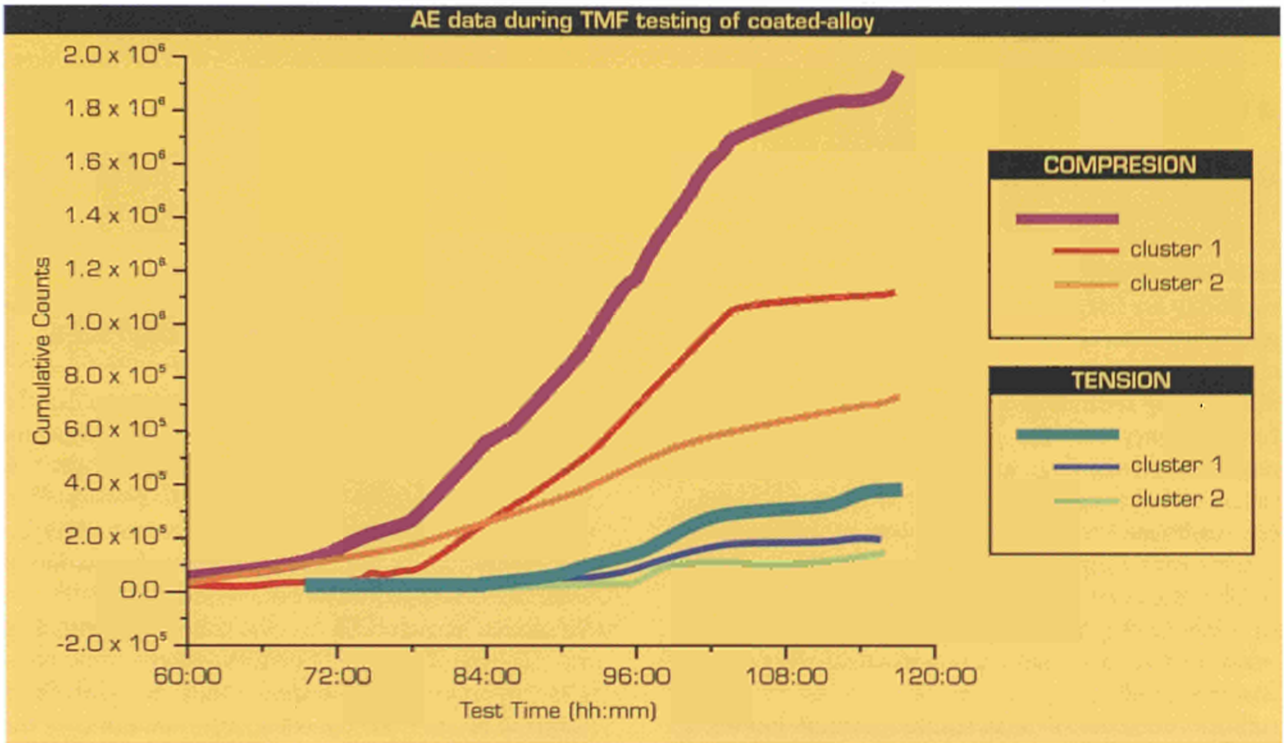
▲ *Multi-detector and double-monochromator performance employing first (large peak) and second order neutrons (small peak), the second order neutrons render superior fir accuracy in shorter testing time.*

The actual *R&D part of the project* is directed at evaluating the properties of a selection of innovative materials, at achieving a comprehensive understanding of the degradation mechanisms of these materials under service conditions, and at translating of that knowledge into reliable life prediction models. The objective is to validate the selected materials for their use in gas turbine components, and to contribute to lowering of the cost of operation of turbines. The project "Efficient Power Generation-Gas Turbines" focuses on materials for application in the Hot Gas Path (HGP) of the turbine, in particular on coated materials for blades and vanes and on dual alloys for discs. Coated materials include oxidation resistant coatings applied to extend blade/vane lives, and Plasma Sprayed Thermal Barrier Coatings (PS-TBC) to enable higher turbine inlet temperatures, and hence higher efficiency. Achievements in the reporting period are:

- A literature database on protective coatings and TBCs has been set up and is continually expanded. Currently it contains over 1400 entries, including literature publications, Ph.D. theses and patents. The database will be made available to outside parties as a service.
- As a precursor to the detailing of R&D tasks, critical literature surveys concerning various aspects of TBCs have been prepared or are being finalized. Surveys specifically address life prediction, residual stresses generated upon plasma spraying, oxidation and corrosion, and damage monitoring.
- A methodology for treating AE data via pattern recognition procedures is under development. The AE data are correlated with specific operating damage mechanisms as identified either by post-mortem fractographic analysis or by *in-situ* video imaging, in order to create a reference database. This will enable the AE technique not only to detect but also to characterise the damage upon testing. An example of data clustering is shown in the fig. on p. 37 for data collected during thermo-mechanical fatigue testing of a single crystal nickel-based alloy coated with an oxidation resistant MCrAlY-type coating.
- Mechanical properties under near-to-service conditions of nickel-based alloy CM186 in Single Crystal and Directionally Solidified forms, and covered with a protective coating, were assessed.
- Residual stresses in PS-TBCs due to quenching and cooling after annealing have been numerically investigated. The numerical simulation includes splatting (impact of partially molten spherical TBC powder droplets upon NiCrAlY), solidification and pore formation. Recent experimental results verify the importance of the usually neglected quenching stresses. Furthermore, the analysis provides microstructural characteristics of the Plasma Spray process (pore formation). The tensile quenching stresses are superimposed on the compressive cooling stresses and the results are used as initial conditions in the modeling of stresses generated by thermal-mechanical cycling.
- The classical and the unified viscoplastic constitutive equations were tested against accuracy in reproducing TMF data of Rene 80. Furthermore, the non-linear behavior of the ceramic topcoat of the TBC system was studied. In this context, the role of yield and failure loci in tension and compression has been investigated.

The availability of harmonized testing and measurement standards is essential for achieving success when applying new materials systems in the power generating sector. The project contributes to achieving the goal of *standardization of testing procedures* by performing pre-normative R&D and by coordinating the EU efforts in the areas of:

- thermo-mechanical fatigue testing. Preparations for the organization of a workshop dedicated to coordinate the EU input into the drafting of a TMF testing



▲ *AE cluster analysis.*

standard within the framework of the International Standards Organization Working Group ISO/TC164/ SC5/WG9 are underway,

- measurement of residual stresses by means of neutron diffraction in the framework of VAMAS (Versailles Agreement on Materials and Standards).

IAM's *R&D activities* in the project area *are embedded in various networks*, including:

- in COST 522, IAM leads the activity on protective coatings for gas turbine blades and vanes,
- in VAMAS, IAM represents the European Commission in the Steering Committee,
- within the context of this project and project "ECRIT-air", IAM is setting up the pro-active network "TBCs-in-service", targeted at pooling fragmented European R&D resources in the field of thermal barrier coatings research, and involving gas turbine manufacturers, users and coating companies.

DISSEMINATION OF RESULTS

The development and application of advanced material systems is a major enabling factor in the process of achieving higher energy conversion efficiency and of reducing greenhouse gas emissions. However, for competitiveness' sake the cost aspect associated with the implementation of novel material systems in manufacturing and in operation of energy conversion equipment needs consideration. The present project provides IAM with the expertise required to technically support the Commission in achieving the goals of competitive and sustainable growth, and of the reduction of emissions in the area of gas turbines for power generation. In that respect, a wide spectrum of sources ranging from technical reports in the printed press to Worldwide web sites were consulted, and a library of information sources that is to form the basis for technical support documents to various DGs was established and is continually expanded.

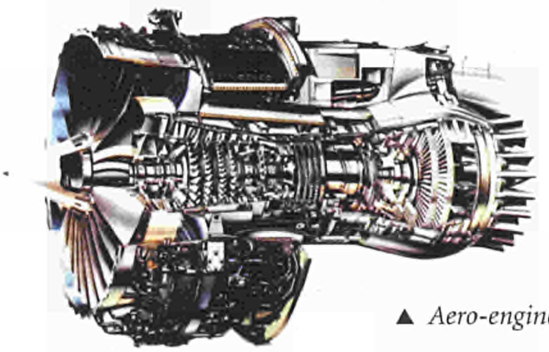
The scientific and technical results of the project are disseminated in the form of publications in learned journals, at conferences and in monographs. So far, twelve scientific papers have been published in 1999.

Gas turbine manufacturers, power generation and materials manufacturing industries apply the research results generated by the project to guide material selection and to optimize materials for better performance and increased turbine efficiency. The expertise accumulated within the framework and the unique equipment are often called for by industrial partners that invite IAM to perform Third Party Contract (TPW) work and to lead/participate in Shared Cost Actions (SCA). In 1999, ongoing competitive work related to the project included six SCAs and one TPW contract. One new SCA and an Expression of Interest (EoI) in the area of standardization were approved, while a total of ten SCAs, TPWs and EoIs have been submitted or are under preparation for submission later in 1999 or early 2000.

BACKGROUND

Improvements in aero-engine technology are estimated to have a potential for a ~25% reduction of fuel consumption over the next twenty years. Lightweight materials and material systems with higher temperature capability are the main route to achieving this potential, and to reducing emissions from aircraft. Project ECRIT-air (Emission Control and Reduction in Transport) aims at achieving technological solutions for the increase of fuel efficiency and the abatement of greenhouse gas emissions of aero-engines by means of:

(i) in-house R&D targeted at advanced materials systems with a higher temperature capability and reliability than materials systems currently in use,
(ii) the development and implementation of harmonized data bases and pre-normative research and standards drafting,
(iii) the creation of a scientific/technical knowledge platform and of advanced testing facilities as a service to the EU aeronautics industry,
(iv) embedding R&D activities in pro-active European network(s) directed at pooling fragmented R&D resources.



▲ *Aero-engine.*

The project focuses on two material systems for application in the hot gas path of the aero-engine:

(i) Thermal Barrier Coated systems deposited by Electron Beam Physical Vapour Deposition (EB PVD TBCs) increase the temperature capability of blades by some 100-150°C (fig. on p. 39, top), leading to higher efficiencies and reduced greenhouse gas emissions.
(ii) Continuous Fibre Reinforced Ceramic Matrix Composites (CFCCs) for combustion chambers that enable reductions in NOx emissions.

In 1999 progress was achieved in the following areas:

- developing of advanced testing facilities and measurement practices,
- implementing of the R&D programme; achieving first results,
- prenormative research and standardization,
- anchoring of the project in relevant networks,
- starting up of the Technology Watch and Alert function in support of EU policies.

DEVELOPMENT OF NOVEL TEST FACILITIES AND MEASUREMENT PRACTICES

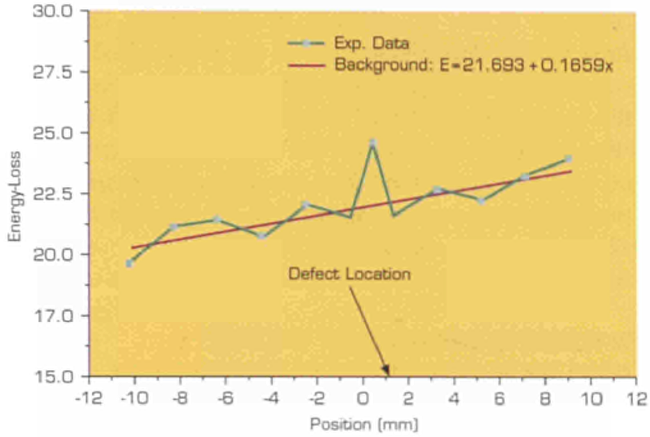
Dedicated test facilities/methods are required to evaluate the properties and performance of advanced material systems. In the case of EB-PVD TBCs achievements include:

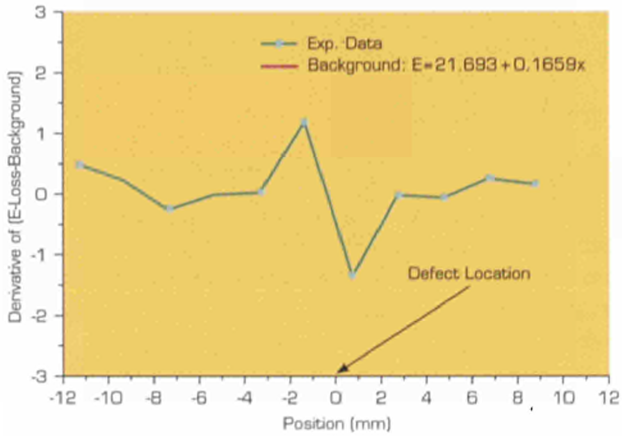
- Commissioning of parts of the ultrasonic (US) instrumentation for the Non Destructive Evaluation of interface delamination in TBC systems.
- Numerical simulations to evaluate the potential of various techniques for the measurement of thermo-physical properties, including (i) the Laser Flash Technique to account for the advantages and limits of the thermal diffusivity measurements in TBCs, (ii) the Laser Ultrasonic Technique for establishing its feasibility to characterize microcracked porous TBCs, (iii) micro and nano-indentation to find out its potential towards measuring of the local mechanical behaviour of coating and interface layers, (iv) vibrational analysis for stiffness and damage characterization.
- Design and preliminary performance evaluation of a transverse high temperature extensometer to access the anisotropic mechanical response of CFCCs.
- Design of an novel type of equipment for the measurement of the through-thickness tensile strength of plate- or shell-like CFCC products.
- Based on previous in-house experience and on a critical literature review, the specifications for a non-intrusive camera system for the *in-situ* observation of deformation and damage in CFCCs during high temperature mechanical testing have been established.
- A software method to determine fibre diameters, fibre diameter distribution, and fibre volume fraction of CFCCs has been optimised.

RESEARCH RESULTS

The focal points of the R&D project tasks are to assess material properties, to map out damage mechanisms, to investigate the potential of various NDE techniques towards measuring delamination damage in TBC systems, and to draw up mechanism-informed life prediction models. Progress in the reporting period is outlined below:

- Critical literature reviews have been prepared concerning (i) thermo-physical properties and NDE of TBCs, (ii) non-contacting displacement measurement

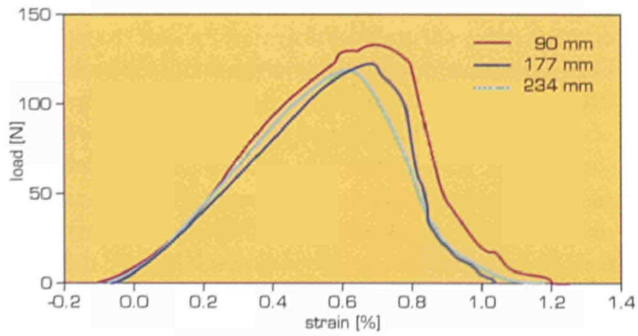




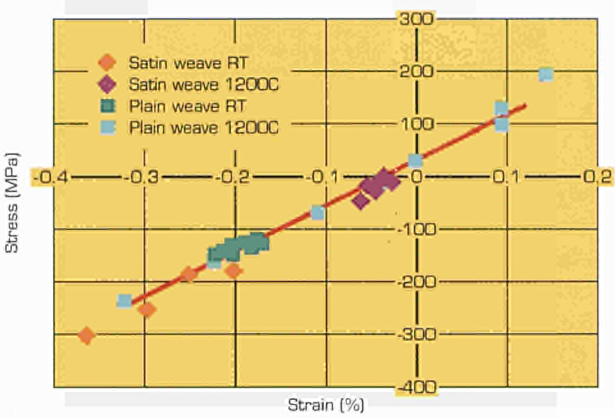
▲ *Energy of the ultrasonic pulse at different locations on the coating surface* [left]*; first derivative of the pulse energy along the coating surface* [right].

methods for CFCCs, (iii) creep models and models for the oxidative degradation of SiC-based fibres which are the most commonly used fibres to reinforce CFCCs.

- A CFCC reference data base has been set up and currently contains 250 papers which are relevant to the mechanical, thermal and environmental behaviour of this class of materials.
- Exploratory NDE tests by means of ultrasonic waves on a sample of a TBC coated system with an artificial delamination of width equal to 1 mm show promising results. The figure at the top of this page illustrates results obtained by means of interferometric detection of the ultrasonic waves generated by a piezoelectric transducer in the near surface region of the sample. Each data-point in this figure corresponds to an observation carried out at a specific location on the layer surface. Such a location is identified by its distance from the defect. The data of the figure at the top illustrate the increase of the loss of energy by the ultrasonic pulse at the observation points considered in this investigation. While a progressive decrease of the energy is expected because of the scattering-induced attenuation of the propagating wave, a clear increase of the energy loss is observed when the pulse is reflected by the defect. This figure also illustrates the behavior of the first derivative of the energy once the background has been subtracted from it. The presence of the defect becomes even more evident.
- The temperature and stress fields that develop in damage-free TBC systems during thermomechanical loading were calculated by means of a Finite Element model, accounting for the presence of cool-down residual stresses. The influence of interfacial topology and of the thickness of the thermally grown oxide layer on the stresses was examined in the vicinity of rough interfaces. In a parametric study the effect of creep, and the sensitivity of the analysis results to variations in the used material property values are investigated. Failure criteria derived using fracture mechanics principles have been used to predict crack initiation. The analysis predicts that failure initiates at bond coat asperities, and the probability of crack initiation increases with the increase of interfacial roughness and TGO thickness.
- Experimental work on CFCCs has focussed on the tensile behaviour of ceramic fibre bundles and on the fracture toughness and subcritical crack growth of ceramic nanocomposites SiC/Si_3N_4 at high temperature. Tensile test results on Hi-Nicalon fibre at three different gauge lengths are shown in the figure at the bottom of this column, superimposed in a single graph by using the compliance correction developed at IAM. Weibull parameters that characterise the statistical distribution of fibre strength for a given gauge length are derived from the non-linear part of the curves.
- The mastercurve approach for the evaluation of the tensile response of CFCCs has been extended to allow the determination of the *in-situ* fibre and matrix strength, i.e. the strength of the composite constituents as incorporated in the composite. It is shown that the waviness of the fiber reinforcement affects the matrix cracking stress, but that the *in-situ* fiber strength properties are not influenced by the type of the weav
- CFCC modelling concerned the effect on the scatter in time-independent mechanical response of variability in the axial residual stress state in different CFCC test specimens, and on how this scatter can be translated in the establishment of a behavioural model. A representation of this scatter is given in the figure on p. 40 for a C-fibre reinforced SiC-matrix composite tested at room temperature and at 1200° C.



▲ *Load versus strain for three bundle tests. Legend indicates gauge lengths of specimens.*



▲ *Variability in axial residual stress state in C/SiC composites with different reinforcement architecture.*

- The Alloys-Data Bank has been adapted to the need of the institutional projects "ECRIT-air" and "EPG-gas turbines". The following upgrades were performed: extension of the databases structure to store information of the TBC coating layer (production, chemical composition, etc.); references to microstructural images; option for entering multiple thermal and thermo-mechanical fatigue tests in one step; graphical data output options.

PRE-NORMATIVE RESEARCH AND STANDARDIZATION

Contribution to standardisation activities covered:

- translation of the IAM-initiated Code of Practice for the measurement of misalignment into a CEN working item and draft standard,
- discussion and balloting of ISO and ASTM standards (ceramics fracture toughness, CFCC tensile test, fractography...),
- drafting and discussion within CEN of IAM test procedure for cold-end high temperature fibre bundle tests; rewriting of draft standard for the determination of elastic properties of CFCCs by ultrasonic method.

NETWORKING

IAM has been a major thrust in the establishment of the JRC-CEN cooperation agreement signed early 1999, which is aimed at providing a framework for activities in support of standardisation within institutional JRC projects. IAM actively participates in the prenormative research (PNR) group of CEN-STAR (Standards and Research) where PNR issues identified by the different technical committees of CEN are discussed and prioritised, and where the standards-impact of results from EU-sponsored PNR projects (within the SMT programme) are evaluated.

Members of the project team lead Technical Working Area (TWA) 6 on ceramics and participate in TWA 11 concerned with High Temperature Materials Testing of the European Structural Integrity Association (ESIS). Within the framework of VAMAS (Versailles Agreement on Materials and Standards) the project participates in the discussion round directed at the organisation of TWA 3 (ceramics and composite ceramics).

DISSEMINATION OF RESULTS AND EXPLOITATION OF KNOW-HOW

The present project, being part of the JRC Emissions and Global Change clusters, provides IAM with the expertise required to technically support the Commission in achieving the goals of competitive and sustainable growth, and of the reduction of emissions by aircraft. Within the framework of the Technology Watch function of the project, a library of information sources concerned with environmental issues in air transport, ranging from technical reports in the printed press to Worldwide web sites, is established and continually expanded. This library forms the basis for the drafting of technical documents in support of EU policies.

The scientific and technical results of the project are disseminated in the form of publications in learned journals, at conferences and in monographs. Twenty one scientific papers have been published in 1999.

A patent proposal for a high temperature ceramic fibre bundle test facility under inert gas conditions using a novel cold-end gripping method has been submitted. A newly developed compliance correction allows to fully exploit the experimental advantages of the cold-end gripping method and to determine the fibre elastic modulus for temperatures up to 1400°C. By testing fibre bundles of different heated lengths the parameters of the statistical distribution of fibre strength and of fibre failure strain can be determined.

Aero-engine and materials manufacturing industries apply the research results generated by the project to guide material selection and to optimize materials for better performance and increased aero-engine efficiency. Because of its expertise and of the availability of unique equipment, IAM is often invited to perform Third Party Contract (TPW) work and to lead/participate in Shared Cost Actions (SCA). In 1999, competitive work related to project ECRIT-air is ongoing in four SCAs and two TPW contracts. One Expression of Interest (EoI) in the area of reference data bases was approved, while two orders for TPW were received. Two SCAs and an EoI have been submitted for approval, as well as quotations for several TPW contracts. Three more SCAs are under preparation for submission early 2000.

TECHNOLOGIES FOR EMISSION ABATEMENT IN TRANSPORT AND NON-ROAD SECTORS (TEMAT)

The overall objective of the project is to support the development and application of legislative actions by the Commission on air quality. IAM aims to support this initiative through the set-up of the European Reference Vehicle and Engine Testing Laboratory on Emission Reduction Technologies.

The main achievements in 1999 include:

- Layout and planning of a complete facility has been carried out throughout the year to tailor it to the EC's demands and to make it rather unique in the EU.
- A market survey of gas analysis equipment was carried out.
- A stationary engine test bed and the necessary equipment for *in-situ* monitoring of the engine condition was taken over from JRC's Ispra site and transferred to IAM.
- Discussions on future collaboration and mutual use of facilities were initiated with the Dutch Research Centre TNO, with the European Council for Automotive Research and Development (EUCAR), and with the Oil Companies' European Organisation for Environment, Health and Safety (CONCAWE).
- The analysis of the results of a questionnaire dealing with alternative fuels was carried out by IAM staff.
- IAM has initialised the set up of a European Network, which aims towards identification and assessment of the potential of innovative technologies in emission abatement.
- A survey had been started to identify the most promising emission reduction technologies for meeting future legislative requirements.

BACKGROUND

Legislative actions by the Commission are tightening the rules on emissions from transport and non-road sectors for coming decades. In co-ordination with national institutions, car manufacturers, oil industry and other Services of the Commission, IAM aims to support this initiative through the set-up of the European Reference Vehicle and Engine Testing Laboratory on Emission Reduction Technologies. This facility will support research and technical infrastructure for testing, network co-ordination and performance analysis of emission reduction technologies. Results will mainly be used by the Directorates General involved in legislation, while a close collaboration with industry guarantees that industrial competitiveness issues are taken into account.

PROJECT OBJECTIVES

The overall objective of the project is to support the development and application of legislative actions by the Commission on air quality. They tighten the rules on emissions from transport systems and non-road sectors for the coming decade and require comprehensive techno-economic responses of the involved industries, authorities and the public. The support takes place through the following contributions of the IAM:

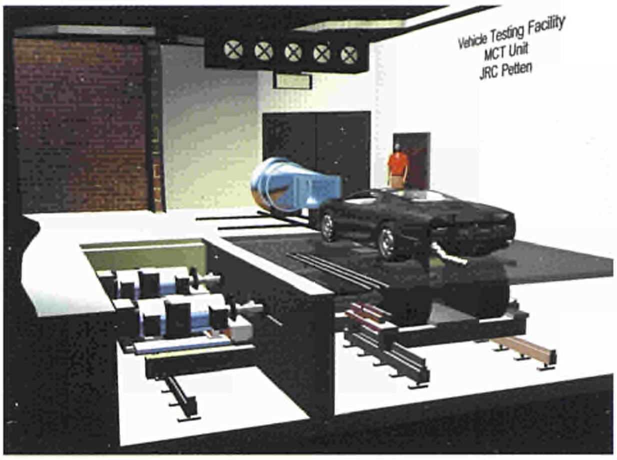
- Set-up of a European Reference Vehicle and Engine Testing Laboratory on Emission Reduction Technologies which will include a facility for full-scale vehicle tests from past, present and future fleets.
- Support to the current Auto-Oil II Programme, and its successor Clean Air For Europe (CAFE).
- Participation (or co-ordination) in various European Networks:
  - Particulate matter (in collaboration with EI in Ispra).
  - Network on emission reduction technologies that are not commercially available with potential applications to combustion engines.
- Novel Techniques:
  - Activation analysis of particulate matter at the prompt gamma facility of the HFR.
  - Thin layer activation analysis on performance of critical engine components.
  - Characterisation of new and improved materials for use in catalytic converters, filters, particulate traps and other critical components, and the performance of such materials in components.

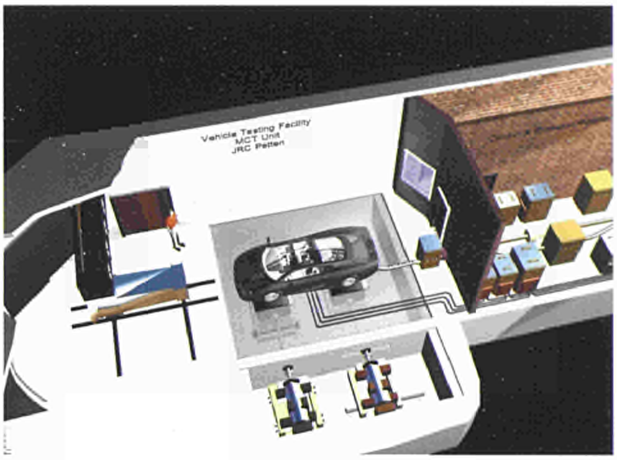
MAJOR ACHIEVEMENTS IN 1999

European Reference Vehicle and Engine Testing Laboratory on Emission Reduction Technologies

A laboratory will be set up, which includes facilities for engine and full-scale vehicle testing (light duty vehicles). The aim of this laboratory is to relate the emission parameters to the characteristics of the source of such emission (vehicle technologies, catalysts, oil and fuel quality, combustion and performance of critical components).

The necessary layout and planning of a complete facility has been carried out throughout the year. A market survey and close contacts to industry associations have been used to tailor the facilities to the EC's demands and to make it rather unique in the EU.



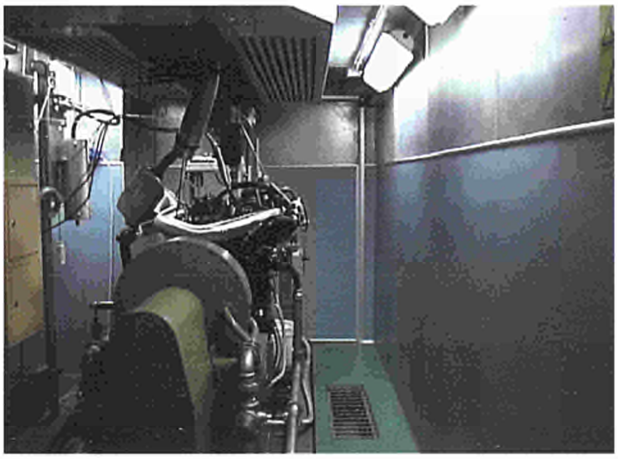


▲ *Two views of the full-size vehicle testing facility.*

The Full Scale Vehicle Testing Facility for Light Duty Vehicles will operate with two 48" chassis dynamometers in the temperature range from -30° C up to +40° C. The Engine Testing Facility will be equipped with a transient engine test bed for light duty vehicles.

A market survey of gas analysis equipment was carried out by IAM staff, which led to the acquisition of equipment according to state of the art specifications for pre-, mid- and post-catalyst transient measurements. Both regulated and non-regulated emissions can be measured.

A stationary engine test bed and the necessary equipment for *in-situ* monitoring of the engine condition was taken over from JRC's Ispra site and transferred to IAM. This facility can be used to measure the degradation by wear and corrosion through Thin Layer Activation analysis (TLA) in collaboration with IHCP in Ispra, which has a cyclotron available for activation. Afterwards the degradation of critical components can be related to a change in emission characteristics as determined by simultaneous measurements.



▲ *Engine test bench.*

The emission part of the TEMAT project is closely related to activities in the JRC's Environment Institute (EI). In this context, a JRC strategy document was prepared together with the EI on emissions from vehicle transport and related JRC activities.

Additionally, discussions on future collaboration and mutual use of facilities were initiated with the Dutch Research Centre TNO, with the European Council for Automotive Research and Development (EUCAR), and with the Oil Companies' European Organisation for Environment, Health and Safety (CONCAWE). The discussions with TNO, where IAM played an initiating and leading role, led to the preparation of a Memorandum of Understanding (MoU) between JRC and TNO. Under the responsibility of IAM, discussions were carried out with EUCAR and CONCAWE for the signing of a joint MoU with the JRC in early 2000. Further to its signature, this MoU would set the ground for the first research collaboration between the two industrial research organisations.

Support to AUTO- OIL II Working Group 2

The Auto-Oil II program was designed to provide policy makers with an objective assessment of the most cost-effective package of technical and non-technical measures necessary to reduce emissions from the road transport sector to a level consistent with the attainment of the new air quality standards being developed for adoption across the European Union. Auto-Oil II will provide the scientific input for the Commission's activities on a wide range of possible measures including future vehicle and fuel quality standards and related measures. The work programme of Auto-Oil II is divided into seven Working Groups (WG), each one with its own mandate. The mandate of Working Group 2 (WG2) on "Vehicle Technology" is to determine the potential and costs of motor vehicle emission control technologies and their interaction with fuel quality to meet the emission limits envisaged for application in the year 2005. The IAM was appointed by the European Commission (DG Enterprise) within the framework of the Auto-Oil II programme under the Working Group 2 (WG2) to undertake a study of costs and effects of different vehicle technologies with the aim of reducing emissions from motor vehicles. The purpose of the study was to provide the European Commission with an objective assessment of possible measures that could be adopted from the automotive technology side to contribute in achieving the required air quality standards. Part of the questionnaire dealing with alternative fuels compiled by IAM staff was distributed to the appropriate industries. The analysis of the results of this questionnaire will be presented by the official Auto Oil report currently being compiled by Commission Services.

Participation (or co-ordination) in Various European Networks

Based on its long history in Networking and Network Management the IAM has initialised the set up of a European Network, which aims towards identification and assessment of the potential of innovative technologies in emission abatement.

First contacts with the involved industry have been established. Positive replies lead to believe and Terms of References for a Network have been drafted, based on the successful model of the existing IAM Networks.

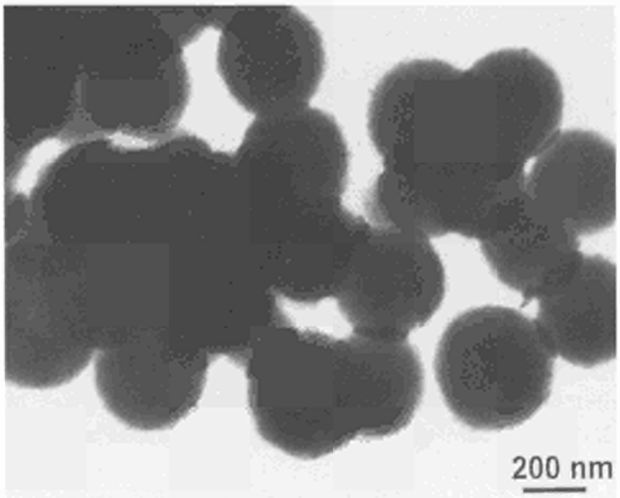
Novel Techniques

The biggest single contributor to emission abatement within the road transport sector is the 3-way catalytic converter, which reduces CO, NOx and unburned hydrocarbons from petrol engines by more than 90%. However, with increasing understanding of the effects of emissions on the environment, the focus of attention in emission reduction is now changing. Governments accept the reality of global warming and recognise that previously neglected emissions of CO_2 from the combustion of fossil fuels are the main cause of it. The lean-burn engine, of which the diesel is the best-known example, is targeted as the key technology for making a significant impact on the CO_2 problem in the short term. However, lean-burn engines have relatively high inherent NOx and particulate emissions and, unfortunately, the 3-way catalytic converter is ineffective for lean-burn engines and new abatement technology must be developed.

The objective of this work is to promote the further abatement of vehicle emissions through innovative technologies to meet the increasingly stringent targets set by EU legislation. It is an extension of work begun in the 4th Framework Programme on improved materials for 3-way catalytic converters.

The first major action was to make a survey to identify the most promising emission reduction technologies for meeting future legislative requirements. The possibility of developing improved catalytic materials based on perovskite and solid acid zirconia to reduce NOx to harmless N_2 was identified in the survey as an innovation in catalytic converter technology that should be pursued. Because the perovskites and zirconia required for the new technology are cheaper than the platinum currently used, catalytic converters have good prospects to remain the most cost-effective emission reduction technology if this new technology can be developed.

Experimental investigations, based on previous experience in producing alumina and ceria materials for catalytic converter applications, demonstrated that suitable zirconia powders can be produced by simple wet-chemical synthesis method—see figure below.



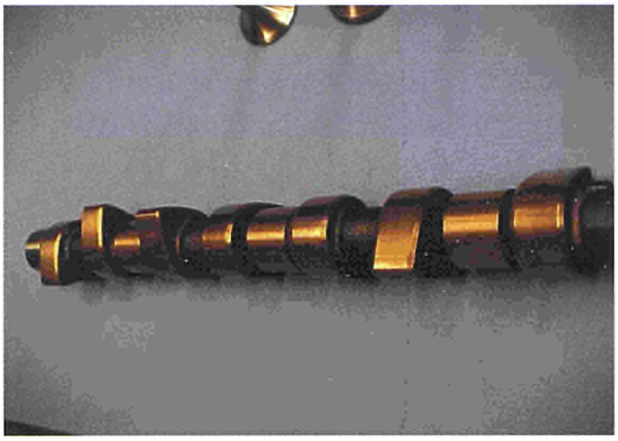
▲ *TEM image of particles of nanostructured zirconia from a sulphate precursor calcined for 1 h at 500° C.*

A sulphate precursor was used to obtain solid acid characteristics. Preliminary investigations were started into methods suitable for synthesising perovskites. The intention is to deploy these materials as a washcoat on existing cordierite honeycomb catalyst carriers. A preliminary configuration study of a state-of-the-art Flame Assisted Chemical Vapour Deposition unit for the deposition of washcoats was executed and a procurement phase for the construction of this equipment was initiated.

To assess the potential of innovative technologies in the reduction of emissions and improvement of fuel-efficiency of road and non-road vehicles is one of the objectives.

To realise this, an overview of the capabilities of current technologies in reducing wear and improving the efficiency of critical engine and other mechanical components of road vehicles and ships was carried out.

A Physical Vapour Deposition facility for the production of hard self–lubrifying composite layers (e.g. TiN/MoS_2, CrN/MoS_2) for a reduction of wear and friction was installed and commissioned. Coating of complex-shaped engine components is in progress. The next step is to test the coated components in an engine test bench by using Thin Layer Activation (TLA) method.



▲ *General view of physical vapour deposition coated crankshaft.*

SCIENTIFIC ACHIEVEMENTS

Since 1999 was the first year of this new activity, there is no substantial publication list. Nevertheless, some research was published on IAM's catalyst related activities, e.g. "Nanostructured Cerium Oxide: Preparation and Properties of Weakly-Agglomerated Powders".

OBJECTIVES FOR 2000

A Memorandum of Understanding (MoU) between EUCAR, CONCAWE and JRC (IAM) should be elaborated and signed. The specification of the vehicle testing facility should be finalised and the acquisition procedure for equipment be completed.

HIGHLIGHTS

Discussions were initiated with EUCAR (Strategic Association for Automotive R&D in Europe), ACEA (European Automobile Manufacturers Association), CONCAWE (Oil Companies' European Organisation for Environment, Health and Safety) and Europia (Association of Companies Owning and Operating Mineral Oil Refining Facilities in the European Union) which could lead to a common platform of these different industry groupings, where IAM could play a co-ordinating role.

EXECUTIVE SUMMARY

The objective of the SAFTS project is to improve the availability and reduce pollution of waste incineration systems. The technical contribution of IAM will be to develop/validate standard laboratory test methods to simulate waste incinerators operating conditions and to produce a database of best materials available for optimised waste incinerator applications. The European network on performance, reliability, and emissions reduction of waste incinerators (PREWIN) will play a central role in achieving the project objectives.

The scientific and technical progress achieved in 1999 includes:

- A preliminary report on literature on waste incineration conditions and materials.
- The identification, selection and procurement of the reference material to be used in the laboratory studies (namely Alloy 625).
- The definition of an initial "standard" laboratory test condition (as part of an SMT funded project).
- The adaptation and re-commissioning of a laboratory autoclave to be used with complex gas mixtures.

In terms of relations and networking, the following achievements can be cited:

- The kick-off meeting of the European network PREWIN in October with representation from industry, research centres and DGs of the Commission.
- The inclusion of the SAFTS project in the MoUs between Environment DG and JRC and between Enterprise DG and JRC.
- The support offered to a Finnish national program..
- The possible representation of the EC by IAM in the Biomass Combustion task (Bio-energy programme) of the International Environment Agency.

BACKGROUND

Currently, the treatment of domestic and industrial waste is a major environmental problem in Europe with pollution and contamination resulting from open air burning or dumping in landfill sites becoming increasingly unacceptable. As an alternative, controlled incineration will ensure not only a drastic reduction in the volume of waste but may also be adapted for heat recovery and electricity production, thereby reducing plant operating costs. At the moment, plant reliability and heat recovery are both strongly limited by the degradation of components resulting from high temperature corrosion. Optimised materials selection and the development of new and improved compositions must therefore be carried out to address this issue. This requires intensive testing and a study of materials behaviour under operating conditions accompanied by the development and validation of standardised laboratory test methods. The PREWIN network uses co-ordinate dispersed research activities and facilitates an integrated approach, which includes all relevant factors affecting performance, reliability and emissions of incinerators.

PROJECT OBJECTIVES

The overall objective of the 4-year SAFTS project is to improve the availability and reduce pollution of waste incineration systems. This is achieved by increasing their safety, efficiency and reliability via optimised materials technology.

The technical contribution of IAM is the following:

- Development of standard laboratory test methods for the simulation of waste incineration operating conditions.
- Validation of laboratory and pilot plant testing through exposure of material probes in commercial European waste incinerators.
- Production of a database of best materials available for optimised waste incinerator applications for use by materials suppliers, plant builders and operators.

As part of the SAFTS project, the European Network PREWIN (performance, reliability, and emissions reduction of waste incinerators) will be initiated and managed by IAM to co-ordinate activities. This network will group European industry, municipal facilities and research organisations and will both provide a bridge of information between industry and legislation and a platform for a concerted research effort. This latter aspect will be furthered though targeted collaborative studies and SCA.

All technical results associated with the network will constitute deliverables of the project. Conversely, the technical contribution of IAM will be delivered through PREWIN, In this sense, the success of the network will be one of the key objectives of the project.

SCIENTIFIC AND TECHNICAL PROGRESS

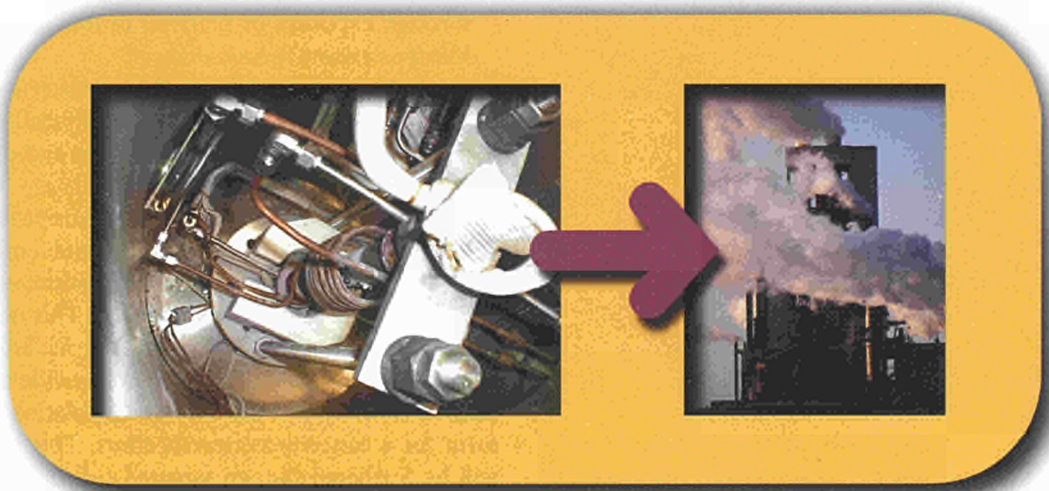
It is too early in the project to report laboratory test results. Progress and scientific work in 1999 essentially consisted in the definition of test conditions and preparation of the facilities.

A preliminary report on literature on waste incineration conditions and materials has been carried out. This state-of-the art literature review identified Alloy 625 as the principal corrosion resistant alloy used in waste incinerators and the key material to be used in the laboratory studies. This material has been adopted as a reference material and a commercial batch of it has been procured for the laboratory studies from a Spanish incinerator (TRM-Barcelona). Work has also begun on basic metal/deposit reactions pertinent to waste incineration.

Additionally, the conclusion of a related SMT funded project led to the definition of an initial "standard" laboratory test condition (see highlight).

A laboratory high temperature corrosion autoclave has been modernised and re-commissioned to be used with complex gas mixtures including sulphur, carbon and chlorine-containing species. This autoclave, which simulates waste incineration atmospheres, will play a key role in the objective of developing standard laboratory test methods.

Transfer of laboratory based data to industrially relevant parameters. ▼



Finally, a series of scientific seminars by leading experts at IAM has been initiated; one seminar took place in 1999 with industrial participants.

With respect to related competitive activities, three proposals have been submitted in 1999 and work was carried out on three projects.

A proposal on "ceramic composite corrosion" submitted to the TMR programme and a proposal on "cadmium elimination for future and existing applications" submitted to the Growth programme have been accepted for funding. Negotiations will take place in early 2000. The proposal on "cost effective intermediate temperature solid oxide fuel cells for micro combined heat and power systems" submitted to the energy and environment programme is awaiting decision.

NETWORKING AND RELATIONS WITH OTHER PARTIES

A preparatory meeting was held in June 1999 with 20 external participants. The purpose of the meeting was to canvas interest in forming a European Network on Materials Performance in Waste Incinerators (initially MAPWIN). A strong participation by industrial organisations coupled with positive responses both during and subsequent to the meeting led to a "kick-off" event, which took place in October 1999.

The network was renamed to PREWIN and four different tasks have been agreed upon:

- plant characterisation,
- materials property collection and analysis,
- repair methods and maintenance,
- emissions reduction.

The ground is now set for the European network PREWIN, which is expected to be fully operational by spring 2000 and include 30 to 40 partners (municipal facilities, components and materials manufacturers and research organisations).

To complement the approach, support was offered to a Finnish national program through accommodation of a Detached National Expert. Additional support through providing test services is under negotiation.

In order to gain access to the advanced unit at Alkmaar (the Netherlands), extensive discussions have been initiated and are still in progress with KEMA for plant exposures.

The discussions, which were held with waste incinerator plant operators and related research organisations in Spain, Portugal, The Netherlands and Finland, substantiate the European-wide dimension of the issue.

Also to be noted, IAM was proposed to represent the Commission in the task "Biomass Combustion" in Bioenergy program of the International Environment Agency (IEA). The matter is currently under discussion. The proposal stemmed both from IAM's relevant competence in the field and from the PREWIN network, which provides a good framework for such a representation.

Interested European Commission Services include the Transport and Energy DG, Environment DG and Enterprise DG. Particular interest was expressed by Transport and Energy DG, which is represented in PREWIN through its working group on "Energy from Biomass and Waste". Additionally, the SAFTS project has been included in the Memoranda of Understanding between Environment DG and JRC and between Enterprise DG and JRC.

PLANS FOR 2000

Slightly before the official launch of PREWIN in spring 2000, the following scientific tasks, which are the input of IAM to the newtork, will have been initiated:

- Corrosion testing with and without stress in mixed gases and deposits in the Environmental Testing Laboratory, simulating certain aspects of industrial processes.
- Modelling of industrial environments from data derived from industrial plant exposures and operating data.
- Data collection for input into materials performance database and subsequent analysis.
- Data evaluation for the establishment of degradation mechanisms.
- State of the art review of preventive (life extension) and corrective maintenance for waste incinerator components.

HIGHLIGHT

IAM participated in an SMT funded research project aimed at producing a "Code of Practice" for discontinuous corrosion testing of metallic materials in high temperature gaseous atmospheres. The project, which ended in 1999, was concluded by the definition of laboratory-based, industrially relevant test parameters. The definition test parameters particularly focussed on the test environments (oxidation, petrochemical, flue gas/gas turbine, coal gasification and waste incineration) to be used in a series of reference experiments. The results of the reference tests will be included in an annex in the draft code of practice to be submitted to CEN TC262.

EXECUTIVE SUMMARY

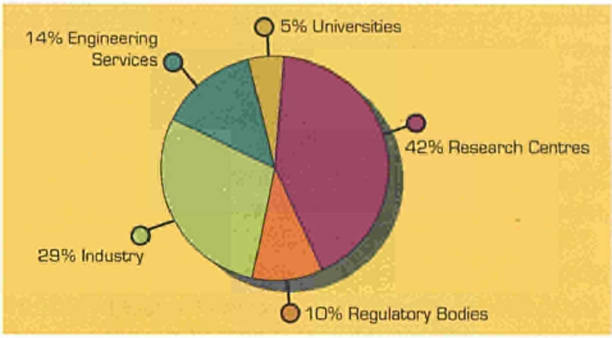
The AMES major objectives are to provide information and understanding on neutron irradiation effects in reactor materials and to establish and execute AMES projects.

For 1999 the following achievements are summarised:

- The central point of the AMES Network is the Operating Agent. This duty is carried out continuously be the IAM staff and is involving support to the Steering Committee members, dissemination of information, technical preparation of meetings, organisation of workshops, etc.
- Signature of the EPLAF agreement between the Russian Ministry of Atomic Energy and the European Commission.
- First irradiation of Model Alloys was successfully carried out in the HFR Petten by means of the LYRA facility.
- Through participation to the Concerted Action "AMES-NDT", progress has been made in calibrating STEAM (Seebeck-Thomson Effect on Ageing Materials).
- A feasibility study for the irradiation of concrete samples in the HFR was made and a proposal on the ageing of concrete in NPPs was prepared and submitted to the 5th FWP Nuclear Safety Programme.
- Important reference materials from the US and the NIS could be acquired and tested.
- AMES JRC Laboratory has participated in an ASTM Round Robin Test for miniaturised specimen testing.
- A Specialists Meeting was held jointly with the IAEA in Petten entitled "NDT Methods for Monitoring Degradation".

BACKGROUND

The AMES network was set up in 1993 to bring together the organisations in Europe that have the main capabilities on RPV materials assessment and research, with the objectives (a) to provide information and understanding on neutron irradiation effects in reactor materials in support of designers, operators, regulators and researchers, (b) to establish and execute AMES projects in this subject area, (c) to act as European Review Group, (d) to provide technical support to regulatory bodies, General Directorates of the EC and a base for development of common European standards, and (e) to participate in collaborative programmes with the New Independent States (NIS) and the Central and East European Countries (CEEC).



Besides that, the Network is promoting the integration of national programmes, validation of techniques, definition of European Standards, and validation and establishment of safe limits for mitigation measures.

AMES is supported by the General Directorates: TREN, ENVIRONMENT, RTD and SCR.

AMES has more than 25 members from the EU and two applicant countries (Hungary, Czech Republic). The composition according to branches can be seen above.

PROJECT OBJECTIVES

In order to fulfil the role of Operating Agent of the network AMES (Ageing Materials Evaluation & Studies), a basic know-how in the field has to be maintained and several tasks with subsidiarity and neutrality character have to be executed by the IAM. Therefore, the objectives of the AMES project have been subdivided in 4 tasks:

Task 1 Project Leadership,
Task 2 Direct R&D on Ageing,
Task 3 R&D to support AMES Strategy,
Task 4 Management and Co-ordination of AMES.

An additional objective required by Customer DG TREN is the further development of EPLAF (European Plant Lifetime Assessment Forum).

MAJOR ACHIEVEMENTS IN 1999

Project Leadership

During 1999 the AMES European Network entered its third strategy phase, defining the proposals for the 5th FWP. The Steering Committee collected, streamlined and elaborated the proposals from the members, initially designed to cover the strategy drivers and the areas of investigation identified in a "shopping list" in 1998. The result of this co-ordination was the set of proposals marked in yellow shown in the figure below.

Direct R&D on Ageing

In addition, the first irradiation of Model Alloys was successfully carried out in the HFR Petten by means of the LYRA facility. This experience has the aim of systematically studying the effects of P, Cu and Ni on the sensitivity of ferritic steel to irradiation embrittlement. The programme will use model alloys with parametric variation of the above mentioned chemical elements. The AMES laboratory has carried out the full characterisation of non-irradiated material in 1999.

By also participating to the Concerted Action "AMES-NDT", progress has been made in calibrating STEAM (Seebeck-Thomson Effect on Ageing Materials), a new non-destructive technique based on thermoelectric power for assessing material ageing. The thermoelectric power generated by the Seebeck effect is a property of the material that may be described as its ability, when coupled with another metal, to generate an electron flux when crossed by a thermal flux. Voltage drop values range from one to a few dozens of mV/K depending on temperature difference (DT), chemical composition and microstructure. STEAM can be correlated to the change in mechanical properties of the aged material.

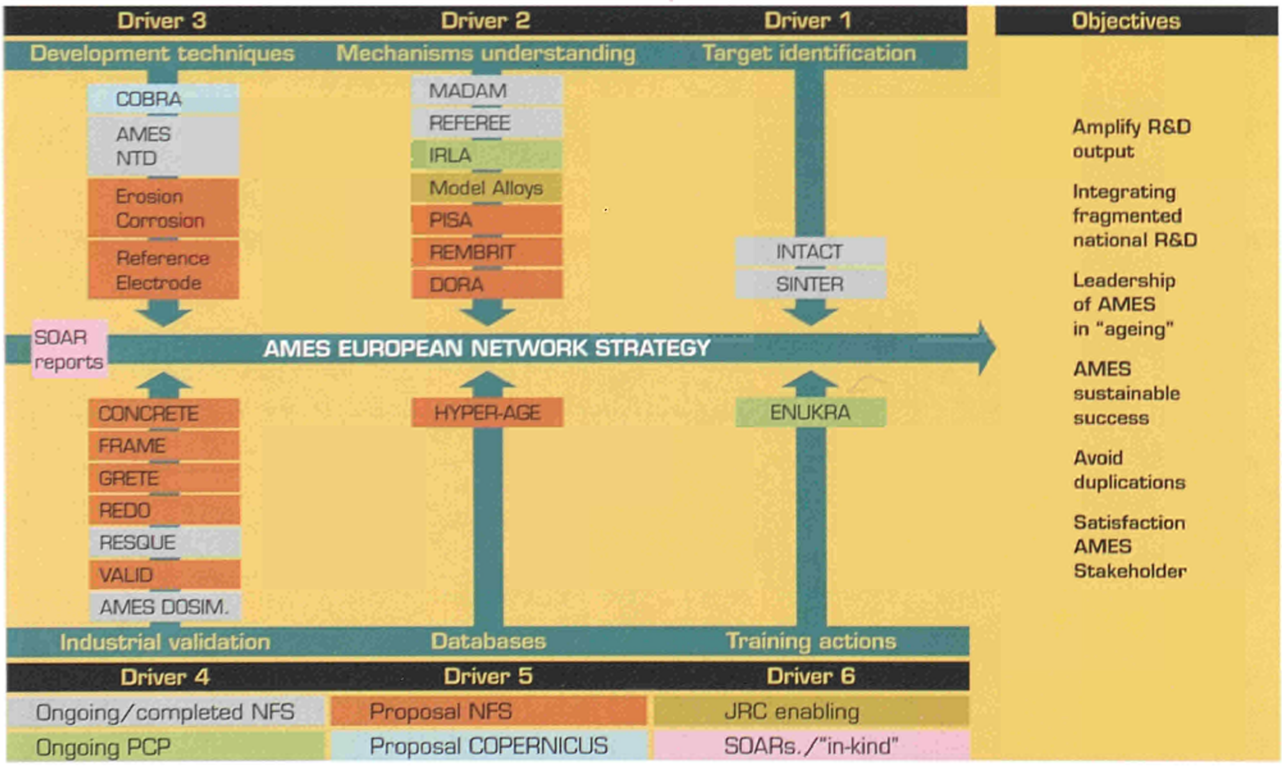
Moreover, a feasibility study for the irradiation of concrete samples in the HFR was made and a proposal on the ageing of concrete in NPPs was prepared and submitted to the 5th FWP Nuclear Safety Programme.

R&D to Support AMES Strategy

The AMES JRC laboratory has made a query amongst its contacts for the possibility to add further reference materials to its stocks. Important reference materials from the US and the NIS could be acquired and tested.

In terms of technical progress, the AMES JRC Laboratory has participated in an ASTM Round Robin Test for miniaturised specimen testing, where it carried out several tests and delivered a test report to the organisers.

▼ *AMES strategy towards the 5th FWP.*



Management and Co-ordination of AMES

The central point of the AMES Network is the Operating Agent. This duty is carried out continuously be the IAM staff and is involving support to the Steering Committee members, dissemination of information, technical preparation of meetings, organisation of workshops, etc.

With regard to technology transfer several actions have been undertaken. In March a Specialists Meeting was held jointly with the IAEA in Petten entitled "NDT Methods for Monitoring Degradation". The proceedings were prepared, edited and widely distributed. The event had about 90 participants from 25 different countries.

Two further workshops were organised and held during 1999 on non-destructive evaluation of ageing and on plant life assessment. Proceedings were prepared and distributed.

Relations with other international organisations in the area of nuclear safety are continuously maintained (IAEA: Life Management of Nuclear Power Plants, Expert Meeting on Irradiation Embrittlement, etc.; OECD: Principle Working Group 3).

SCIENTIFIC ACHIEVEMENTS

The figure below shows the first results obtained with one reference steel in untreated condition and after different heat treatments. STEAM results are plotted against hardness and transition temperature measured at 41 joule Charpy impact energy.

OBJECTIVES FOR 2000

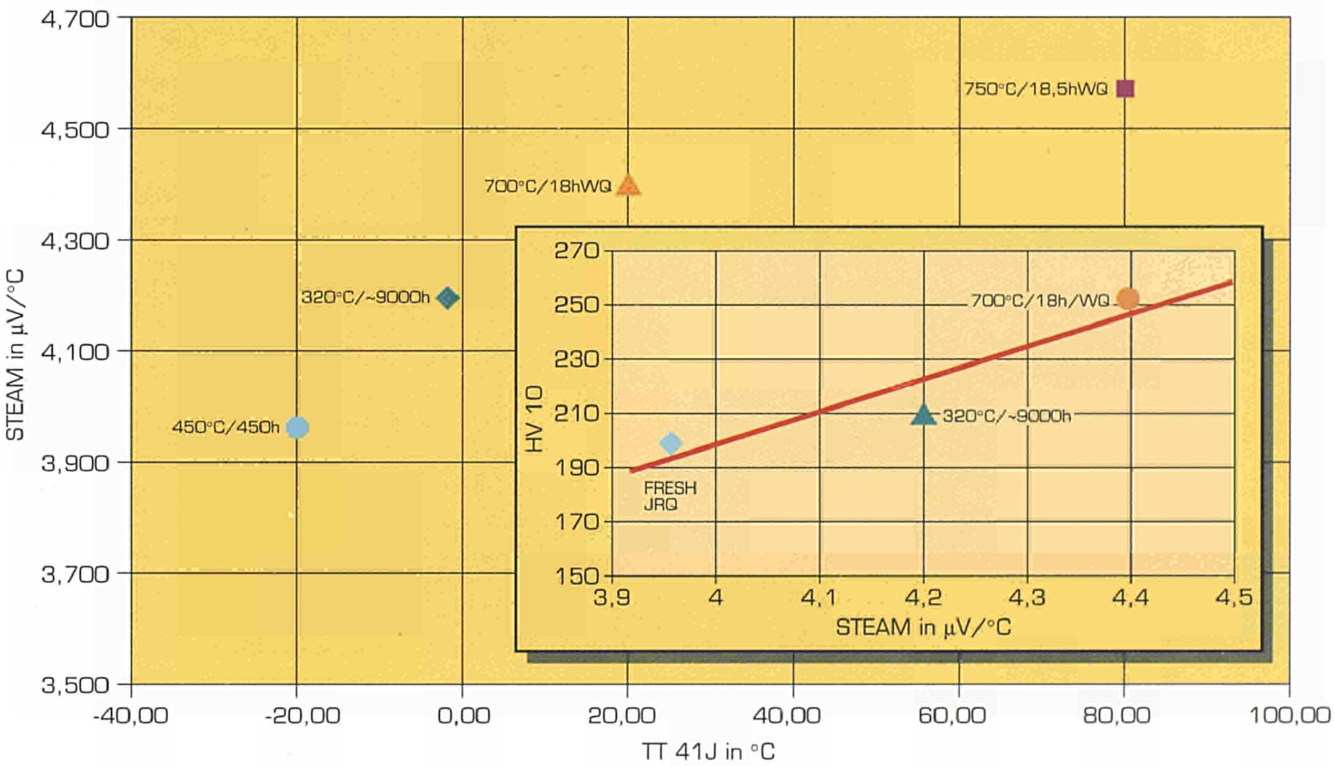
Mechanical testing of the irradiated specimens will be carried out in the year 2000, including application of the STEAM non-destructive technique developed in 1998.

A final report on model alloys, which are tested after irradiation will be prepared as well as a report on AMES common dosimetry experience.

HIGHLIGHTS

An important milestone was set in June 1999 by the signature of the EPLAF agreement between the Russian Ministry of Atomic Energy and the European Commission. EPLAF (European Plant Lifetime Assessment Forum) represents the key action of AMES to support EU enlargement towards the NIS and CEEC, with the aim to co-ordinate new Tacis/Phare projects in the field of nuclear power plant ageing.

Application of the STEAM technique to thermally treated steel. ▼



EXECUTIVE SUMMARY

The European Network for Inspection Qualification (ENIQ) was set up in 1992, grouping the European organisations having main capabilities in the field of inspection qualification to manage available resources and expertise at European level. The objectives of the project are to co-ordinate expertise and resources for the assessment and qualification of Non Destructive Evaluation (NDE) inspection techniques and procedures primarily for nuclear components, to develop qualification schemes and to work towards a harmonisation of codes and standards. Additionally, ENIQ has the objectives of setting-up a co-ordinated EU approach for ISI (In Service Inspection) and studying risk informed concepts and possible consequences for inspection qualification.

Main achievements for 1999 include:

- Publication (after approval by Steering Committee ENIQ) of 6 recommended practices and of the final report of the first ENIQ pilot study.
- Publication of an ENDEF report (JRC and Transport & Energy DG) containing guidelines for detailed project proposals to improve in-service inspection in WWER and RBMK reactors.
- Presentation of the results of first ENIQ pilot study to European regulators (Environment DG) who judged them to have contributed significantly to the harmonisation of the European approach towards inspection qualification.
- Decision to launch an enquiry in order to verify the feasibility of a European recognition scheme of inspection qualification involving both regulators and industry.

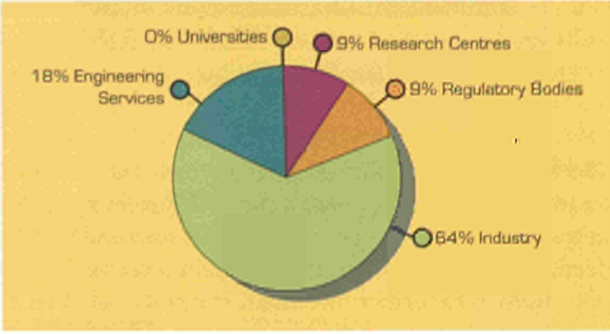
BACKGROUND

ENIQ was set up in 1993 and has the major objective to co-ordinate and to manage at European level expertise and resources for the assessment and qualification of NDE inspection techniques and procedures, primarily in the nuclear field. The primary focus is on the capabilities and limitations of the NDE techniques and procedures used as well as on qualification of ISI through performance demonstration and other processes.

The ultimate goal will be the supporting of international codes and standards bodies by making available state-of-the-art results, technical tools, expertise and performance/capabilities demonstration exercises that can be sponsored and managed at a European level.

ENIQ is supported by the General Directorates: ENERGY, ENVIRONMENT, RTD and SCR.

The ENIQ network groups over 40 different industrial participants (utilities, manufacturers, qualification bodies and vendors) from member states and three Eastern European countries.



PROJECT OBJECTIVES

During 1999, the ENIQ project had foreseen four major tasks in addition to the task of managing its dedicated network (ENIQ).

1. Gathering of information.
2. Development of qualification schemes.
3. Application and implementation of qualification schemes.
4. Risk based inspection.

▲ *ENIQ Reports.*

MAJOR ACHIEVEMENTS IN 1999

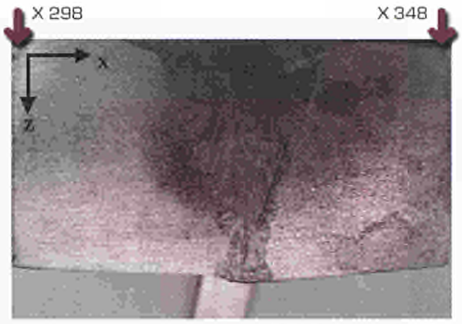
Overall progress in 1999 has been according to schedule for tasks 3 and 4. Substantial delay in task 1 (data base, neutron diffraction and effect of residual stresses), and some delay in task 2 (second pilot study and steam generators) had to be accepted as a result of the departure of key staff working on the project. In the following a more detailed overview of the progress is given related to the above tasks.

Gathering of Information

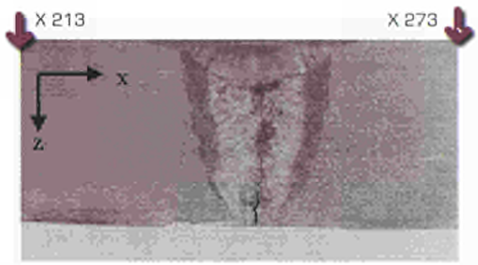
A project proposal devoted to the study of real and realistic defects was elaborated, proposed and accepted in the Nuclear Fission Safety Call of the EC's 5th Framework Programme.

Development of Qualification Schemes

The first pilot study on the feasibility of the European Methodology applied on austenitic steel piping has been concluded and assessed described in a comprehensive final report.



ENIQ Pilot Study Test Piece ENIQ 9. ▲



▲ *ENIQ Pilot Study Test Piece ENIQ 7.*

The way forward for the second pilot study was prepared by IAM staff and proposed to the ENIQ Steering Committee. The principle to go ahead was agreed and further details have to be elaborated. The main objective of this pilot study is to further investigate the potential of technical justification to reduce the number of full-scale trials in a qualification exercise.

Application and Implementation of Qualification Schemes

A strategy report for detailed project proposals to improve in-service inspection in VVER and RBMK reactors has been jointly published by JRC-IAM and DG TREN in the frame of ENDEF (European Non-Destructive Evaluation Forum).

Risk Based Inspection

The short-term European Network on risk informed in-service inspection (EURIS), funded through the Nuclear Safety programme of DG RTD (4th FWP) as a Concerted Action, has produced valuable material to be used through ENIQ. The aim is to study how risk based concepts could be used in order to target in a more efficient way the inspection efforts and use possible alternative mitigation methods both from an economical and safety viewpoint.

SCIENTIFIC ACHIEVEMENTS

All the above publications are at the centre of the two-fold contribution of ENIQ to the issue of inspection qualification. They are, on one hand, the illustration of the scientific added value of the network, and represent, on the other hand, a European consensus at industrial and policy level for common implementation of harmonised practices and methodologies.

OBJECTIVES FOR 2000

A detailed plan of the second pilot study will be worked out. In connection, a full-scale test piece (qualification test block) to be used for the first experimental part of the study will be purchased, in order to assess the value of the technical justification. Additionally, defects will be designed and fabricated in this test block. The corresponding technical justification will be elaborated.

The Steering Committee of the ENIQ network has decided to launch an enquiry in order to verify the feasibility of a European recognition scheme of inspection qualification involving both regulators and industry. This enquiry will be initiated in 2000.

The task on risk informed in-service inspection will be further pursued by drafting of a discussion document on this issue to be used for the elaboration of a frame document representing the position of the EU utilities on risk informed in-service inspection of nuclear power plants.

HIGHLIGHTS

1999 has been a positive year for ENIQ regarding publications, as it published recommended practices 4, 5 and 6 and the final report of the first pilot study (after approval by the ENIQ Steering Committee).

The contact with policy-makers and regulators is already well established. A number of meetings took place in 1999 with representatives of DG TREN to prepare the contributions to ENDEF and ENTF (European Nuclear Training Forum). One joint publication resulted for ENDEF (mentioned above) and two joint documents for ENTF are under preparation (namely Project Synopsis and Strategy Document on training of nuclear personnel in Eastern Europe.

Interaction with DG ENV happened in the frame of the meeting of the Nuclear Regulator Working Group on ENIQ pilot study (Brussels 22/6/99). The results of the study were presented to the regulators. They were received very positively and were judged to have contributed significantly to the harmonisation of the European approach towards inspection qualification.

Other contacts have been made with the Enlargement Service, the DG RELEX (former DG IA) and SCR in the frame of IAM's involvement in the Tacis/Phare support activities of JRC.

EXECUTIVE SUMMARY

The general objective of NESC is to undertake collaborative projects capable of validating the entire structural integrity process. Additionally, NESC should work towards best practice and the harmonisation of international standards and improve codes and standards for structural integrity assessment.

In 1999 NESC had the following main achievements:

- The NESC network was managed and co-ordinated by IAM as operating agent as the agreement prescribes.
- The highlight of 1999 has been the completing the critical evaluation of the NESC-1 spinning cylinder project.
- The NESC-2 project progressed rapidly in 1999. The focus is on shallow cracks, so that the results will complement those of the NESC-1.
- Plans for a third NESC project are been brought to an advanced stage.
- The commissioning of the tensile and fracture testing equipment was completed.
- Installation of a computer controlled multi-directional manipulator for electro-discharge machining .
- Entering the NESC materials characterisation data in the Institute's Alloys Data Bank has been initiated.
- IAM staff led the analysis of the inspection data from NESC-1.

BACKGROUND

Safe and efficient operation of nuclear power plant can be enhanced through better integration of the structural integrity assessment technologies. To meet this challenge, the JRC-IAM launched the Network for Evaluation of Structural Components (NESC) in 1992, and is maintaining and expanding its activities within FP5. The general objectives of the network are:

- to undertake collaborative projects capable of validating the entire structural integrity process,
- to work towards best practice and the harmonisation of international standards,
- to improve codes and standards for structural integrity assessment and to transfer the technology to industrial applications.

A 90-member network has been established in which operators, manufacturers, regulators, service companies and R&D organisations collaborate to perform large-scale experimental projects capable of serving as international benchmarks. Two such projects are currently running; these have been specifically designed to combine all aspects of structural integrity assessment including inspection, materials characterisation, fracture mechanics and instrumentation. NESC-1 (the spinning cylinder test) looks at the use of the integrated approach to provide a robust safety case for pressurised thermal shock (PTS) of an aged, defect containing, reactor pressure vessel. It is unique insofar as the inspection and fracture mechanics analyses have been carried out without exact knowledge of the defects, as is the case for operational plant. The test was performed in March 1997 and the evaluation of the results is now its final phase. NESC-II also features the PTS problem, but with the focus on the brittle fracture behaviour of shallow, sub-clad defects.

PROJECT OBJECTIVES

The NESC network strategy relates directly to efforts to maintain and increase the safety of operating nuclear plant and to promote the competitiveness of the EU power industry. The Institute's specific goals for NESC the 5th Framework Programme are to:

- complete of the NESC-I Project,
- provide data to support improved codes and standards for safe and efficient operation of critical nuclear power plant components,
- extend the JRC-IAM's technical competence (the Reference Laboratory) for supporting the NESC network projects,
- introduce new, industry-driven projects to the network.

MAJOR ACHIEVEMENTS IN 1999

Network Operation

The NESC network projects are performed by the following series of task groups, each co-ordinated by a JRC-IAM staff member and reporting to the Steering Committee:

TG1 Inspection,
TG2 Materials Characterisation,
TG3 Structural Analysis,
TG4 Instrumentation,
Evaluation Task Force,
Destructive Examination Advisory Group.

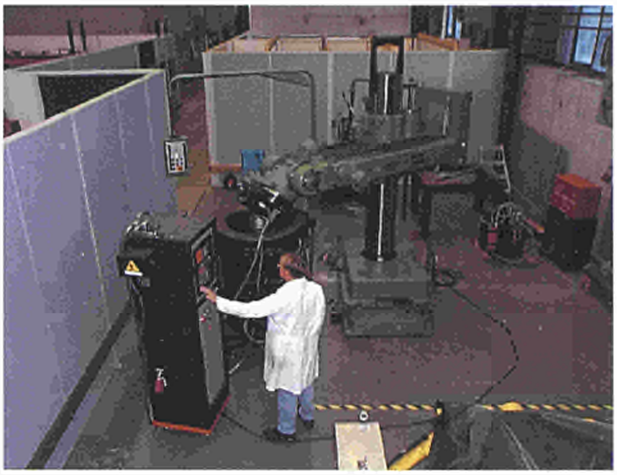
In 1999 the JRC-IAM organised regular meetings (fourteen) of these groups and provided the central contact point and archive service for exchange of documents and reports.

NESC Network Projects

A major step has been taken to completing the evaluation of NESC-1 Project, which is in its seventh year. The technical task groups on inspection, material characterisation, structural analysis, instrumentation and destructive examination have produced final reports. These were complemented by project evaluation task reports, which synthesise the results obtained on multi-disciplinary themes, e.g. sensitivity, codes and standards issues, relevance to plant transients, technology transfer etc. JRC-IAM has played a key technical role in this process. Institute staff have carried out the destructive analysis of the 20 artificial defects present in the test cylinder to establish their precise dimensions and extent of growth (where present). The JRC-IAM led the evaluation of the inspection data; this has generated important conclusions about NDE performance and suitability of reference defects. Finally the Institute has co-edited the overview report summarising all the results, which was released in draft form for network approval at the end of 1999.

Although only launched in 1998, the NESC-2 project progressed rapidly in 1999. The focus is on shallow cracks, so that the results will complement those of the NESC-1. A network partner successfully executed the two large-scale PTS tests. The Institute has co-ordinated the pre-test analyses conducted by the structural analysis group. Within the reference lab, NDE examinations were performed to check the size of the implanted defects.

Plans for a third NESC project are been brought to an advanced stage. This will focus on integrity issues in steel piping systems in light water reactors, in particular addressing the lack of current assessment codes for defect-containing dissimilar welds. This work follows on from a successful pilot study, which the EC sponsored in FP4.



▲ *Commissioning trials on the computer controlled multi-directional manipulator for implanting defects in full-size components.*

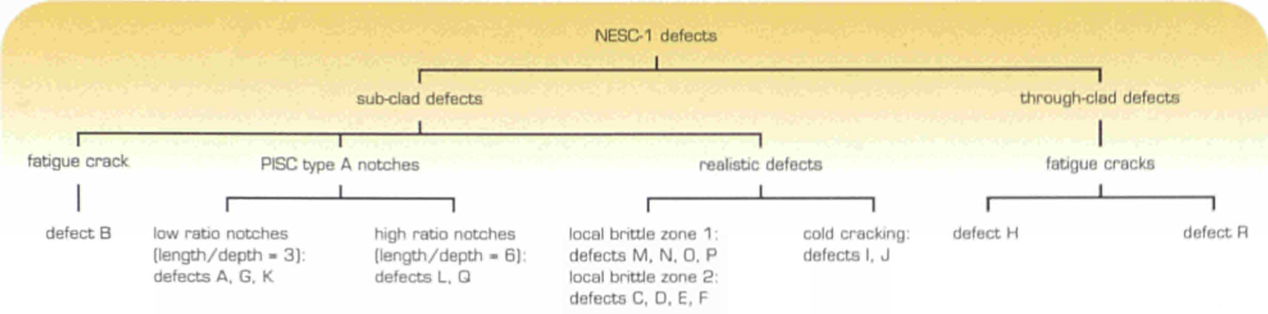
Reference Laboratory

1999 has seen a number of important developments aimed at reinforcing the competencies of the reference laboratory. The commissioning of the tensile and fracture testing equipment was completed, and included testing to support the assessment of the NESC-I cylinder material.

The capability to insert artificial defects in large, complex components has been extended with the installation of a computer controlled multi-directional manipulator for electro-discharge machining (figure above). For verifying the dimensions of defects, a new imaging system has been installed, which simplifies and improves the measurement accuracy.

The neutron diffraction technique has been successfully used to characterise residual stresses in a 25 mm thick bimetallic nuclear piping weld. This technique is unique in its ability to measure sectional as opposed to surface stress. The validity of the stress measurements is confirmed by stress equilibrium in the piping longitudinal direction and also through very good agreement with computational data furnished by network partners.

Finally the process of entering the NESC materials characterisation data in the Institute's Alloys Data Bank has been initiated. This will support the use of the NESC tests as international benchmarks for qualifying analysis procedures.



▲ *Overview of defects contained in NESC I cylinder.*

Dissemination of Results

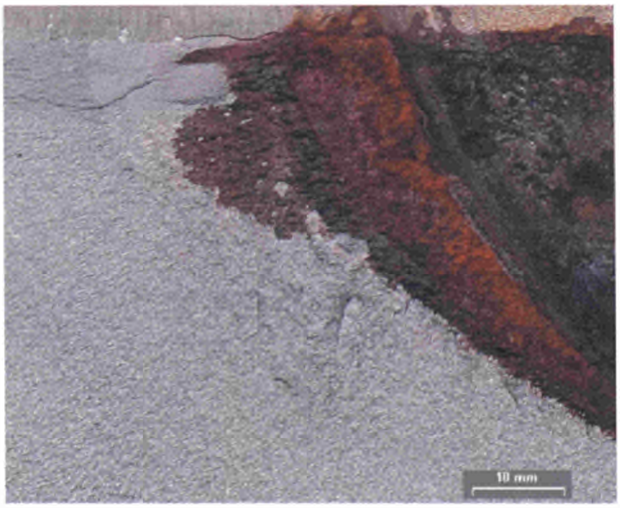
Effective dissemination of the NESC results is seen as critical to the overall success of the project. This functions on two levels:

a) As operating agent the JRC-IAM actively promotes the Network with papers and presentations to key seminars, conferences and other working groups. In 1999 such NESC presentations were made at the ASME Pressure Vessels and Piping Conference held in Boston in August, to the Structural Mechanical in Reactor Technology (SMiRT) Conference held in Korea, to the MPA Seminar held in Stuttgart. A poster presentation was also made to the European Commission's FISA conference held in Luxembourg at the end of 1999.

b) It is the network policy that detailed technical results from the NESC projects are only presented after internal peer review within the network task groups and Steering Committee approval. For NESC-1 this process is now at an advanced stage and the Institute has organised an international seminar under the title "Structural Integrity Assessment–How Safe is It?" for March 2000 to promote the findings to industry, national regulators, policy makers and codes and standards bodies.

■ SCIENTIFIC ACHIEVEMENTS

JRC-IAM, with the support of the network's Destructive Evaluation Advisory Group, successfully completed the destructive analysis of the NESC-1 cylinder to establish the precise position and dimensions of each of the 18 defects (figure above). This required each of the defect be isolated using a carefully planned, stepwise process. The Institutes facilities for ultrasonic and X-ray analysis were exploited to locate the exact defect dimensions and position before each cut. The 6-ton cylinder has now been reduced to more than 200 sections. Intensive fractographic investigations were carried out to establish the extent and mode of growth, which had occurred in the four largest defects during the pressurised thermal shock test. The large through-clad defect produced limited ductile initiation and tearing, followed by a significant local cleavage event at one end of the defect just below the cladding heat affected zone (figure below).



▲ *Destructive examination of a large defect from the NESC-1 cylinder showing the areas of crack growth that occurred during the test.*

The Institute also led the analysis of the inspection data from NESC-1. The inspections of the cylinder had been carried out in two phases: seven teams inspected the cylinder before the test and twelve after the test under blind trial conditions, i.e. without prior knowledge of the number or size of the defects present. The analysis of the data was both a complex and sensitive task. In particular, given the safety and commercial interests involved the JRC-IAM's proven competence in this field and independent status was critical factors. The data sets (almost 200) have been evaluated using the detailed procedures developed in previous studies for PISC and ENIQ, in which the anonymity of the teams is guaranteed. Over 100 separate analysis plots were produced. A generally positive picture has emerged (figure below), with improved detection and sizing performances than the results obtained in the comparable PISC II trials a decade earlier, demonstrating the lessons learned and the good progress made. Those errors that did occur could be traced to human factors rather than inherent limitations of the techniques themselves, underlining then need for well-written, unambiguous procedures both for data acquisition and data analysis, good quality control and training of the inspection personnel.

OBJECTIVES FOR 2000

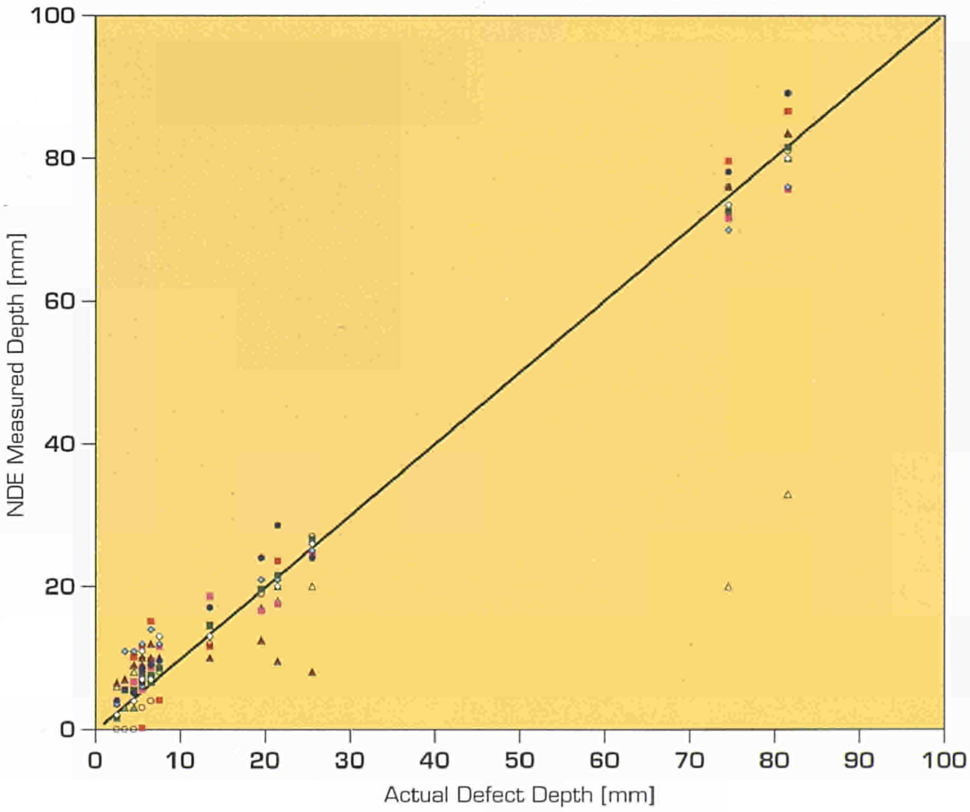
In terms of the current network projects, it is foreseen that in 2000 the Institute will finalise and publish the NESC-1 Overview Report. This will be presented at a dedicated international seminar to launch the exploitation phase with actions at national and international level to promote the project recommendations for improved working practices and codes and standards. For NESC-2, focus will be on completion of the post-test analyses and evaluation of the results.

Concerning new activities, a new project dealing with piping integrity will be launched and new partners will be encouraged to join the network from the candidate countries.

HIGHLIGHTS

The highlight of 1999 has been the completing the critical evaluation of the NESC-1 spinning cylinder project. Over 24 technical reports have been prepared, with Institute playing a critical role both in co-ordinating the work of the network partners and in providing scientific input to the evaluation of the inspection results and to analysing the crack growth observed at the more critical defects. This has culminated in a draft Overview Report designed to promote the results to industry, national regulators, policy makers and codes and standards bodies. In parallel the NESC-2 project has progressed rapidly. A network partner completed the planned large-scale pressurised thermal shock tests and the evaluation phase will be launched next year. Finally, preparations have been made for a third NESC project in the field of piping integrity.

An example of the results from the NESC-1 inspection round-robin; the participating teams were able to accurately measure the depth of all 15 defects, which ranged in depth from 5 to 80 mm. ▼



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.

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

15
LB-NA-19-597-EN-C

ISBN 92-828-9692-7

9 789282 896921