Nuclear Science

Objective

To increase Member State capabilities in the development and application of nuclear science as a tool for their technological and economic development.

Atomic and Nuclear Data

The Agency maintains extensive nuclear, atomic and molecular databases that are available to all Member States through both on-line and traditional services. Improvements to on-line sites in 2008 have resulted in easier browsing and retrieval capabilities for these databases.

Such data are used, for example, in the design of advanced fission reactors like those being considered by the Generation IV International Forum (GIF) and the Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). Their design requires much more comprehensive cross-section databases than were previously needed. The Agency therefore launched a new CRP in 2008 to assess, evaluate and assemble a nuclear data library for advanced systems (the Fusion Evaluated Nuclear Data Library (FENDL-3)).

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The Agency also launched a new CRP to characterize the size, composition and origins of dust in fusion devices. The resulting information will be compiled in a database and made available to Member States. Existing fusion devices generate dust particles during operation, and the possibility of an excessive accumulation of dust is a significant safety concern. A major requirement for ITER and subsequent fusion machines will be the reduction and control of such dust.

By the end of 2008, all providers of analytical services based on ion beam techniques had adopted the new Ion Beam Analysis Nuclear Data Library (IBANDL), formulated under the Agency's auspices, as a standard reference database. Both web based and CD-ROM versions are now available to users in Member States.

In cooperation with the ICTP, the Agency organized two training workshops in 2008 entitled 'Nuclear Structure and Decay Data: Theory and Evaluation' and 'Nuclear Reaction Data for Advanced Reactor Systems'. The Agency also held an on-site training course on 'Modelling and Evaluating Nuclear Reaction Data for Transport Calculations'.

Research Reactors

Improving utilization

The Agency promotes regional collaboration to improve the utilization of small and medium size research reactors. In 2008, the Agency organized a technical meeting on strategic planning for research reactor utilization in the Mediterranean region, leading to the creation of the Mediterranean Research Reactor Users Network (M-RRUN). Research reactor coalitions were also formed in Eastern Europe, the Caribbean and Central Asia. In addition to these geographically defined coalitions, one topically oriented research reactor network was also established, on 'Residual Stress and Texture Analysis for Industrial Partners' (STRAINET).

In 2008 there were severe shortfalls in the production of vital medical and industrial radioisotopes, particularly molybdenum-99, owing to the frequent unavailability of some of the research reactors used for production. This highlighted the fragility of the molybdenum-99 supply chain, which relies on a small number of large and ageing research reactors, and the importance of better collaboration. In response, the Agency published *Optimization of Research Reactor Availability and Reliability: Recommended Practices* (IAEA Nuclear Energy Series No. NP-T-5.4) and *Homogeneous Aqueous Solution Nuclear Reactors for the Production of Mo-99 and Other Short Lived Radioisotopes* (IAEA-TECDOC-1601). The first publication compiles lessons learned from the operating experience of diverse heavily utilized research reactors and recommends specific operations and maintenance practices to optimize performance. The second presents the state of the art of homogeneous aqueous solution reactors (AHRs), including past and ongoing activities in China, France, the Russian Federation and the USA, and identifies specific

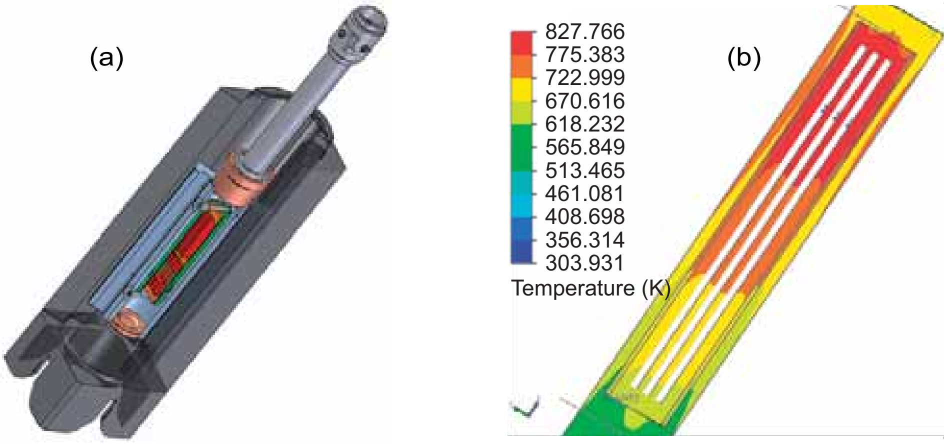

FIG. 1. (a) Design of a new in-pile irradiation rig for structural materials studies of lead–lithium; and (b) modelling of the thermodynamics of the lead–lithium irradiation rig (graphic courtesy of NRI, the Czech Republic).

opportunities and challenges in using them to produce medical isotopes. A follow-up CRP was started in 2008 to study the technical feasibility of using LEU in AHRs, to carry out benchmarking for modelling AHRs and to evaluate the feasibility of producing short lived fission product isotopes such as molybdenum-99. The related topic of molybdenum-99 production from LEU continued to be the focus of an ongoing CRP.

Up to 70% of operating research reactors are over 30 years old. In 2008, the Agency started development of a 'knowledge bank' on research reactor ageing management programmes.

In the area of materials studies for the energy sector, the Agency convened a technical meeting on using research reactors to study materials under high neutron fluence, including initiatives relevant for INPRO and GIF, and including both experimental and modelling studies. Figure 1 illustrates (a) one of the designs and (b) results of modelling the thermodynamics of the lead–lithium irradiation rig. The Agency also published *Neutron Imaging: A Non-Destructive Tool for Materials Testing* (IAEA-TECDOC-1604), which summarizes the use of this technique in industrial applications and research.

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Planning new research reactors

In response to increased requests for assistance in evaluating and planning new research reactors, in 2008 the Agency, together with the East European Research Reactor Initiative (EERRI), organized a training course to develop evaluation and planning skills using a combination of theory and hands-on experience. A complementary project was also launched in 2008 to capture the lessons learned from recent and current research reactor construction projects. The project involves experts with experience in such projects, reactor suppliers and representatives from countries considering new reactor projects.

Research reactor fuel

The Agency continued to support Member States participating in international programmes to return research reactor fuel to its country of origin. At the request of Portugal and the US Foreign Research Reactor Spent Nuclear Fuel Acceptance Program, the Agency contracted for the removal from Portugal and repatriation to the USA of 7 kg of spent HEU fuel. As part of the Russian Research Reactor Fuel Return (RRRFR) programme, the Agency assisted in the repatriation to the Russian Federation of spent HEU fuel from Bulgaria, Hungary and Latvia.

In addition to supporting repatriation shipments, the Agency developed and made available to all potential participants in the RRRFR a report on the *Experience of Shipping Russian-Origin Research Reactor Spent Fuel to the Russian Federation*. This report presents guidelines for institutions repatriating spent fuel to the Russian Federation based on experience gained in this area from Bulgaria, the Czech Republic, Hungary, Latvia and Uzbekistan.

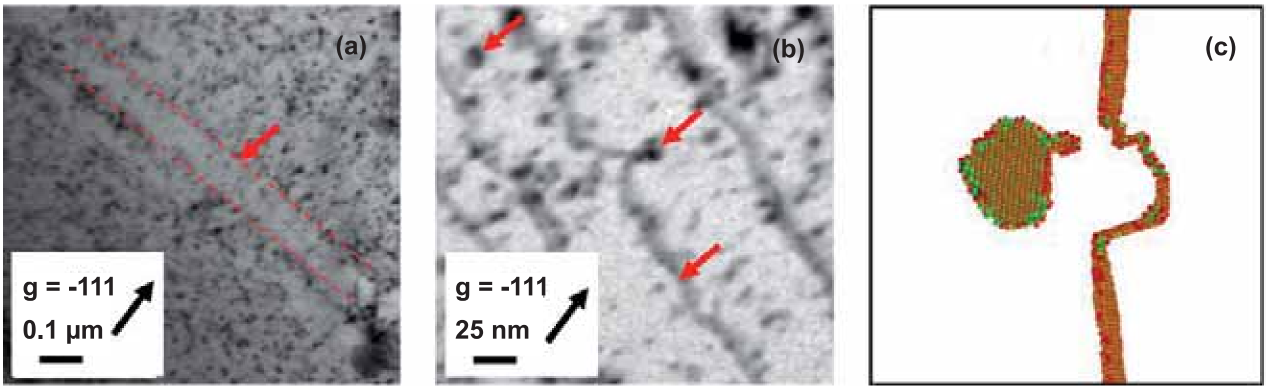

FIG. 2. Accelerator based ion irradiation induced degradation of stainless steel 316L at (a) the micrometre level (strain localization into clear bands) and (b) the nanometre level (interstitial loops dislocation/interactions). Photograph (c) shows the simulation of the molecular dynamics of edge dislocation behaviour under stress at 150 MPa (courtesy of CEA, France)

The Agency also published *Return of Research Reactor Spent Fuel to the Country of Origin: Requirements for Technical and Administrative Preparations and National Experiences* (IAEA-TECDOC-1593), which describes the preparations required for repatriating spent fuel to the USA and summarizes the experience of countries that have already repatriated spent fuel to the USA and the Russian Federation.

A technical cooperation project to repatriate spent fuel from the RA research reactor at the Vinča Institute in Serbia, the largest technical cooperation project in the Agency's history, continued on schedule. Manufacturing began on custom designed equipment to clean and prepare the water in the spent fuel pond for fuel repackaging. All fuel will be transported to the Russian Federation as a single shipment in 2010.

Accelerators for Materials Science and Analytical Applications

In 2008, the Agency initiated new activities on materials research focused on structural materials for advanced fission and fusion reactors. With the Kharkov Institute of Physics and Technology of the National Science Centre of Ukraine, the Agency co-hosted a technical meeting on 'Accelerator Simulation and Theoretical Modelling of Radiation Effects' in June. New technologies for studying materials under high radiation doses as recommended by the meeting encouraged a new CRP aimed at gaining a better understanding of the mechanisms by which radiation causes material damage in order to develop or identify structural materials for new nuclear power plants. The CRP includes both theoretical modelling of radiation induced degradation mechanisms, especially on microstructural and mechanical properties of materials under high irradiation (Fig. 2), and round robin exercises to help develop and test radiation resistant materials.

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Nuclear Instrumentation and Spectrometry

Agency activities on nuclear instrumentation focused on strengthening Member State capabilities through training and assistance with quality control. Three regional and three national training courses and two group fellowship training courses were organized at the Agency's Laboratories, Seibersdorf, and Member State laboratories through technical cooperation projects on nuclear electronics and nuclear instrumentation. To support these activities, the Agency published *Quality Control Procedures Applied to Nuclear Instruments* (IAEA-TECDOC-1599), *A Training Module for Quality Management in Calibration, Maintenance and Repair of Nuclear Instrumentation* (IAEA-TCS-33/CD), and guidelines on the role and utilization of regional resource centres in nuclear instrumentation.

The capabilities of the Agency's Laboratories, Seibersdorf, were enhanced with the transfer of a scanning electron microscope from the Safeguards Analytical Laboratory. The microscope will be used to characterize individual particles in support of work on environmental chemistry and to study biological materials for agricultural research.

Support for X ray based techniques included the organization of a worldwide proficiency test for X ray spectrometry laboratories to improve the quality of analytical results in 20 Member States. Through the technical cooperation programme, human resources development was enhanced in one national and four regional training courses on the application of nuclear analytical techniques to environmental pollution monitoring and the conservation of cultural heritage objects. Two technical reports were also prepared on the adaptation of nuclear spectrometry applications for in situ characterization of materials and microanalytical techniques using low energy particle accelerators and synchrotron radiation sources.

Nuclear Fusion

The 22nd IAEA Fusion Energy Conference (FEC 2008) was convened in October, commemorating 50 years of international fusion research. It was held in the Palais des Nations, in Geneva, the site of the second United Nations Conference on the Peaceful Uses of Atomic Energy in 1958 where international cooperation on fusion began.

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Also in October, the Agency and the ITER International Fusion Energy Organization (ITER Organization) signed a cooperation agreement to facilitate interactions with Member States and to foster fusion energy development through information exchange, training, publications, the organization of scientific conferences, research on plasma physics and modelling, and fusion safety and security. In February, the ITER Organization formally applied for a construction permit to build ITER in Cadarache, France. Massive ground development work is already under way to construct facilities that will house the sophisticated equipment for ITER.

A CRP on joint research using small tokamaks was completed in 2008. It confirmed the importance of small and medium size tokamaks in fusion research, particularly for: developing and testing novel diagnostics; benchmarking new numerical codes, materials and technologies (which cannot be done in large machines without preliminary studies); and broadening education and training. The CRP stimulated cooperation on fusion research in Thailand and led to new research using small tokamaks for joint experiments in developing Member States.