# Nuclear Science

## Objective

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

## Atomic and Nuclear Data

Agency products in the area of atomic and nuclear data are increasingly used by Member States for the design of nuclear reactor and fuel handling facilities, theoretical nuclear physics calculations, and the preparation of national databases for nuclear applications.

A CRP that ended in 2006 addressed the issue of tritium buildup in fusion machines, with a major emphasis on the International Thermonuclear Experimental Reactor (ITER). A review article summarizing important results was submitted to the journal *Nuclear Fusion*; more complete results are being submitted as separate articles to the journal *Atomic and Plasma-Material Interaction Data for Fusion*. The numerical data collected in the CRP are being reviewed for inclusion in the atomic and molecular database. This work will be extended to characterize the formation of fine dust within the fusion plasma region. This dust represents a significant safety hazard and might also jeopardize the operation of fusion devices by acting as an important carrier of any resulting tritium.

New data standards for neutron cross-sections were prepared by the Agency and finalized in 2006. They are now being adopted around the world. Extensively revised thermal scattering data were produced in 2006 through an Agency data development project in conjunction with the University of Stuttgart. These new evaluations have been adopted in recent reconstructions of a number of important nuclear applications libraries maintained by the OECD/NEA and the USA.

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The Agency's Reference Input Parameter Library (RIPL-2) has been used extensively, providing comprehensive reference input parameter data for theoretical nuclear reaction calculations. In 2006, these data facilitated the measurement of important nuclear reaction data and in predicting cross-sections. Further improvements to the database are being developed through the new RIPL-3 initiative.

Based on a modelling code for reactor physics calculations called WIMS-D that was originally developed in the United Kingdom, applications databases were assembled by the Agency in 2006. These databases contain fission product yields, decay data, and cross-sections for actinides, fission products, and structural and other major reactor materials (including hydrogen bound in water, oxygen, aluminium, U-235 and U-238).

Nuclear cross-section data for studying the thorium–uranium nuclear fuel cycle were produced in 2006 through a CRP entitled 'Evaluated Nuclear Data for Thorium–Uranium Fuel Cycle'. The data are already being applied in a number of fuel cycle analyses.

## Research Reactors

The characterization of materials is very important for fabricating efficient, reliable machine components. In this regard, the Agency published *Neutron Reflectometry: A Probe for Materials Studies* in 2006. This monograph summarizes work on characterizing surfaces, and reviews the application of neutron reflectometry in fields from biological sciences to engineering. Other work in this area included the completion of a CRP and the initiation of another one. The completed CRP produced detection systems for fast neutron radiography, software to correct radiographs, and a microtron based neutron source. The new CRP concerns the measurement of residual stresses that develop in materials during synthesis. It will focus on residual stress measurements, the standardization of instruments, and intercomparison studies.

The Agency intensified its support for Member States participating in international programmes to return research reactor fuel to the country of origin. For example, to assist countries participating in the Russian Research Reactor Fuel Return (RRRFR)

programme, it conducted meetings on technical and administrative preparations for shipping the fuel, and on transit requirements and arrangements for shipping irradiated fuel (Fig. 1). In addition, the Agency procured ten spent fuel casks — under a €4 million contract — to directly assist the RRRFR programme.

Under a technical cooperation project aimed at safely removing irradiated Russian research reactor spent fuel from the Vinča Institute in Serbia, the Agency concluded a $9.75 million contract with a consortium of Russian companies to repackage the spent fuel and ship it to the Russian Federation. On-site operations began in November.

A regional technical cooperation project assessed alternatives for managing spent fuel from research reactors in Latin America. The project identified options for operational and interim storage, spent fuel conditioning and final disposal. Follow-up projects will study alternatives for interim storage, develop engineering and preliminary safety documents, and complete the engineering work for a dual purpose, research reactor spent fuel storage and transport cask. The Agency also provided assistance to countries shipping eligible irradiated research reactor fuel to the USA, in particular through a technical meeting where national experience was reviewed and recommendations made to facilitate future shipments.

The Agency initiated a new CRP in 2006 to assist States in the conversion of their Miniature Neutron Source Reactors (MNSRs) with HEU cores to LEU fuel. The conversion is to be carried out with minimal reduction of the utilization capacity of the reactors, in concert with international non-proliferation initiatives to reduce and eventually eliminate the use of HEU in civil commerce. Preliminary work in the CRP included preparations for the conversion of MNSRs operating in China and five other countries operating MNSRs supplied by China.

A report on *Understanding and Managing Ageing of Material in Spent Fuel Storage Facilities* (Technical Reports Series No. 443) was published based on the results of a completed CRP. This CRP drew from strategies developed for ageing management in nuclear power plants and recommended adaptation of these methods to smaller fuel storage facilities at research and test reactors. The CRP provided a valuable insight into age related phenomena at storage facilities in the countries participating in the CRP and led to the formulation of a set of suggested strategies for ageing management that have been applied in a number of facilities in those countries. In addition, a CRP on the corrosion of research reactor aluminium clad spent fuel in water (phase II) was concluded in 2006. This CRP demonstrated that water quality affects crevice and galvanic corrosion and that sediments produce degradation independent of water quality. It also clarified the influence of sediments and orientation of the aluminium specimens used to study corrosion mechanisms.

*"The CRP provided a valuable insight into age related phenomena at storage facilities ... and led to the formulation of strategies for ageing management."*

The Agency began international collaborative work on the use of LEU in accelerator driven subcritical assemblies. The main objective of the undertaking is to demonstrate the technical feasibility of using LEU in assembly systems currently operating with HEU, and in future projects involving these assemblies.

In a CRP on the use of LEU targets for the small scale production of molybdenum-99, a workshop in Serpong, Indonesia, trained the participants in a technique developed by Argonne National Laboratory to recover molybdenum-99 from irradiated LEU targets. A second workshop was held in cooperation with the major international commercial producers of molybdenum-99 to review operational aspects of the production of this isotope.

*FIG. 1. Handling a transport cask with fresh HEU prior to shipment back to the Russian Federation under the RRRFR programme.*

## Utilization of Accelerators and Nuclear Spectrometry

### *Accelerators*

Charged particle accelerators provide powerful analytical techniques in fields such as materials science, environmental science, cultural heritage and the biosciences. In 2006, the Agency, through its technical cooperation programme, provided training for fellows at the Agency's Laboratories, Seibersdorf on the application of X ray fluorescence (XRF) techniques to the study of objects of historical or archaeological importance. The Agency also cooperated in three international conferences and a workshop on microprobe techniques and applications of accelerator generated neutrons, and facilitated the participation of young scientists from developing Member States in these events to help build human resource capabilities. A further initiative to build human resource capabilities was the convening of a 'school' on ion beam analysis and accelerator applications conducted in cooperation with the Abdus Salam ICTP.

Neutron research and the pursuit of new developments in neutron science in many Member States are supported by making optimum use of more intense and better adapted neutron beams at new spallation sources and existing research reactors. In this connection, a new CRP was initiated on improved production and utilization of short pulsed, cold neutrons at low–medium energy spallation neutron sources.

### *Nuclear Instrumentation and Spectrometry*

Through its technical cooperation programme, the Agency conducted training programmes both at the Agency's Laboratories, Seibersdorf, and in the field on the effective use of modern nuclear instruments; on the development and use of training materials based on information and communication technology (ICT); on the methods and applications of XRF techniques; and on the application of nuclear analytical techniques in support of air pollution monitoring. To support practical experiments, approximately 450 ICT based training kits were prepared for trainees.

The Agency completed tests with laboratories in Brazil, the United Republic of Tanzania and Zambia on innovative methods in maintaining and repairing nuclear instruments. The tests involved equipment and communication software for remote diagnosis and technical advice through the Internet. First results showed the advantage of prompt and accurate interaction to avoid costly mistakes in the use of nuclear electronic equipment.

A quality manual for nuclear instrumentation services was prepared and is now being used at the Agency's Laboratories, Seibersdorf. After testing of the procedures is complete, the manual will be made available to Member States. In addition, specialized software for automation was implemented to improve the quality of measurements. The Agency also carried out proficiency tests for laboratories in Europe and Latin America applying nuclear analytical techniques in support of air pollution studies.

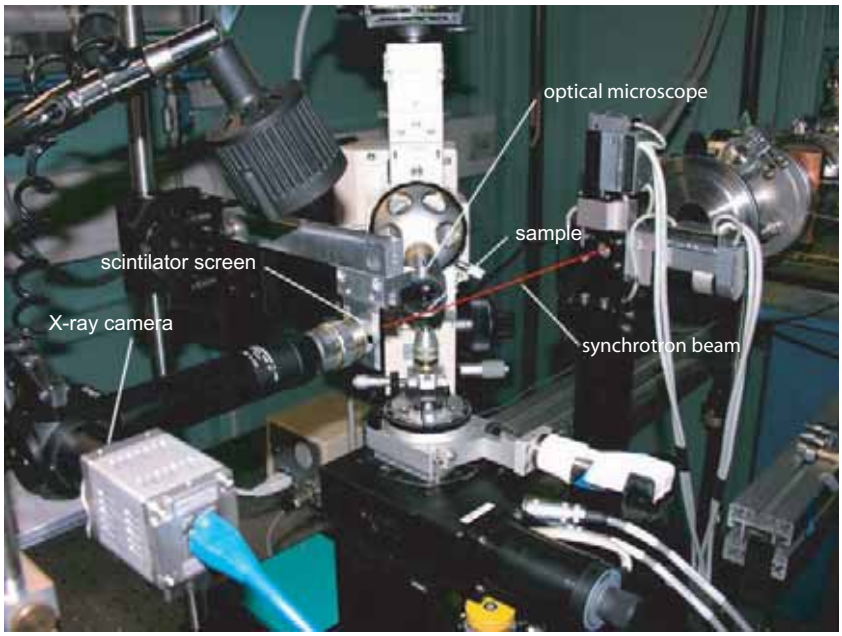


*FIG. 2. X ray phase contrast imaging set-up.*

A new X ray phase contrast micro-tomography technique, based on synchrotron radiation, was developed by the Agency (Fig. 2) in support of the sterile insect technique. It was applied in the study of morphology and 3D imaging of malaria mosquitoes.

To better characterize materials, a new CRP was initiated on unifying nuclear spectrometries. The goal is to develop integrated instruments and analytical methods for use in both small laboratories and state of the art synchrotron sources.

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### *Nuclear Fusion*

The Agency fosters international cooperation in fusion and plasma physics research under the guidance of the International Fusion Research Council (IFRC). On 21 November 2006, ministers representing the seven Parties to ITER signed an Agreement setting up the ITER International Fusion Energy Organization (Fig. 3), an Agreement on Privileges and Immunities and an Arrangement on Provisional Application of the agreements to allow immediate cooperation pending the official entry into force of the agreements. The Director General of the Agency serves as the Depositary for both agreements.

Agency activities in 2006 included meetings to outline general guidance and recommendations regarding safety requirements for first generation fusion power plants. The Agency also contributed to two joint experiments in a series of such experiments intended to disseminate knowledge in fusion research. These joint experiments involve cooperation between a host laboratory and the Abdus Salam ICTP. The Agency also collaborated with the Kurchatov Institute, in Moscow, on a joint experiment on tokamaks, and with the University of Cairo in a joint experiment on plasma physics. These experiments presented an opportunity for young experts from a range of Member States to work together on a variety of fusion topics.

A new CRP, entitled 'Pathways to Energy from Inertial Fusion — An Integrated Approach', was initiated in 2006. The aim is the further development of inertial fusion energy to enhance awareness in Member States of beam–plasma–matter interactions, which are important in experiments and applications using intense laser or particle beams.

The 21st IAEA Fusion Energy Conference (FEC) was hosted by China in the city of Chengdu. More than 700 scientists and senior policy makers from 39 countries and 3 international organizations attended the meeting, the first FEC following the decision to build ITER. It was noted that material development programmes should be developed as part of a broad international approach in order to combine resources with the aim of delivering faster and cheaper fusion data and results. ■

*FIG. 3. The signatories of the ITER Agreement, together with French President Jacques Chirac (centre).*