Nuclear Power

Objective

To enhance the capability of interested Member States, in a rapidly changing market environment, to improve nuclear power plant operating performance, life cycle management including decommissioning, human performance, quality assurance and technical infrastructure, through good practices and innovative approaches consistent with global objectives on non-proliferation, nuclear safety and security; to enhance the capacity of Member States for the development of evolutionary and innovative nuclear system technology for electricity generation, actinide utilization and transmutation and for non-electric applications, consistent with sustainability goals; and to facilitate the improvement of public understanding of nuclear power.

Engineering Support for Operation, Maintenance and Plant Life Management

Rising expectations for nuclear power include not only growing interest in building new nuclear power plants, as discussed in the following section, but also increased interest in extending the operating lives of existing plants. The Agency supports the safe long term operation (LTO) of nuclear power plants through comprehensive plant life management (PLiM) (i.e. planning and managing for LTO throughout the life of a plant) by compiling and disseminating information on technological advances, best practices and lessons learned from past experience. In 2008, nine reports were published (see Table A23 on the attached CD-ROM).

Two CRPs were completed in 2008. The first was on the 'Master Curve Approach to Monitor the Fracture Toughness of Reactor Pressure Vessels' (RPVs), while the second was entitled 'Benchmark of Calculation Methods for Structural Integrity Assessment of Pressure Vessels during Pressurized Thermal Shock (PTS)'. These were completed in cooperation with the OECD/NEA and the Joint Research Centre of the European Commission. The first developed alternative ways to handle certain technical issues associated with using the master curve approach to quantify fracture toughness when testing surveillance specimens. Improved understanding of elastic–plastic fracture mechanics allowed the fracture toughness of RPV steels to be determined using fewer and smaller specimens. The second performed benchmark deterministic calculations for a typical PTS regime to compare the effects of different parameters on assessed integrity. Final reports for both CRPs will be published in 2009.

Also important to extending the life and improving the performance of operating nuclear power plants are the modernization and improved use of instrumentation and control (I&C) systems. In 2008, the Agency published *On-line Monitoring for Improving Performance of Nuclear Power Plants: Parts 1 and 2* (IAEA Nuclear Energy Series Nos NP-T-1.1 and NP-T-1.2). In addition, a report on *The Role of Instrumentation and Control Systems in Power Uprating Projects for Nuclear Power Plants* (IAEA Nuclear Energy Series No. NP-T-1.3) was issued.

Launching Nuclear Power Programmes

More than 50 Member States have indicated to the Agency that they are considering or planning to introduce nuclear power. In 2008, the technical cooperation programme for 2009–2011 was approved and included a tripling of the projects supporting countries considering the introduction of nuclear power. The Agency published *Nuclear Energy Basic Principles*, which describes the rationale and vision for the peaceful uses of nuclear energy and identifies the basic principles on which nuclear energy systems should be based to fulfil their potential to meet growing global energy demand (Fig. 1). It also published *Evaluation of the Status of National Nuclear Infrastructure Development* (IAEA Nuclear Energy Series No. NG-T-3.2), which provides guidance for evaluating a country's infrastructure status based on *Milestones in the Development of a National Infrastructure for Nuclear Power* (IAEA Nuclear Energy Series No. NG-G-3.1). The Agency held a workshop in December 2008 to introduce the evaluation method described in this publication.

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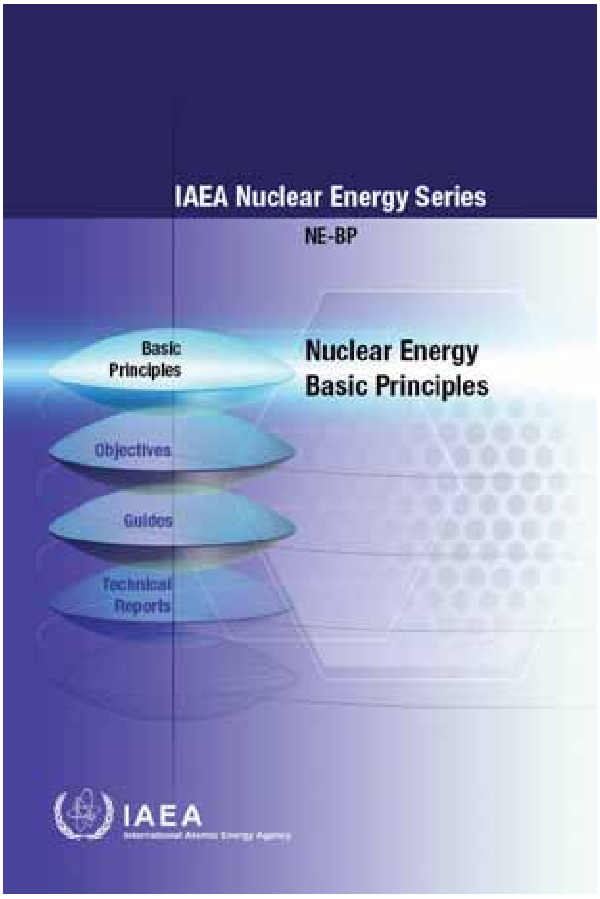

FIG. 1. The apex publication in the IAEA Nuclear Energy Series deals with the basic principles for nuclear energy systems.

The Agency established a new service in 2008 known as Integrated Nuclear Infrastructure Review (INIR). INIR missions are external peer reviews conducted by the Agency at the request of a country, and each is intended to build on a self-evaluation — using the references mentioned previously — already carried out by the country. INIR missions cover all 19 infrastructure issues in the 'milestones' publication, including legal, safety, social, financial, engineering, security and safeguards issues. The first INIR missions are planned for 2009 through the technical cooperation programme.

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There is also increased interest in resuming work on nuclear power plants where construction started but has since been delayed. The Agency published *Restarting Delayed Nuclear Power Plant Projects* (IAEA Nuclear Energy Series No. NP-T-3.4), which presents lessons learned from delayed projects that were successfully restarted, completed and brought to commercial operation.

Human Resources

An important challenge for the nuclear power industry, government authorities, research and development organizations, and educational institutions is ensuring that there is a sufficient and skilled workforce for all stages of the nuclear fuel cycle. For countries considering starting nuclear power, human resources are one of the 19 issues for which the Agency has suggested milestones. In 2008, two new reports were published: *Commissioning of Nuclear Power Plants: Training and Human Resource Considerations* (IAEA Nuclear Energy Series No. NG-T-2.2); and *Decommissioning of Nuclear Facilities: Training and Human Resource Considerations* (IAEA Nuclear Energy Series No. NG-T-2.3).

Nuclear Reactor Technology Development

The Agency seeks to stimulate innovation in nuclear power through activities in four areas:

- Technological progress along the main reactor lines: light water, heavy water, fast and gas cooled reactors;
- INPRO;
- Small and medium sized reactors;
- Non-electric applications such as hydrogen generation and desalination using nuclear power.

In the area of water cooled reactors, the Agency published *Advanced Applications of Water Cooled Nuclear Power Plants* (IAEA-TECDOC-1584) and completed a CRP on Natural Circulation Phenomena, Modelling and Reliability of Passive Systems. The CRP brought together 16 institutes from 13 IAEA Member States. They examined the use of natural circulation and passive systems in 20 reference advanced water cooled reactor designs. Twelve phenomena influencing natural circulation were characterized, including liquid behaviour in large pools, the effect of non-condensable gasses on condensation heat transfer, condensation on containment structures, and steam–liquid interactions.

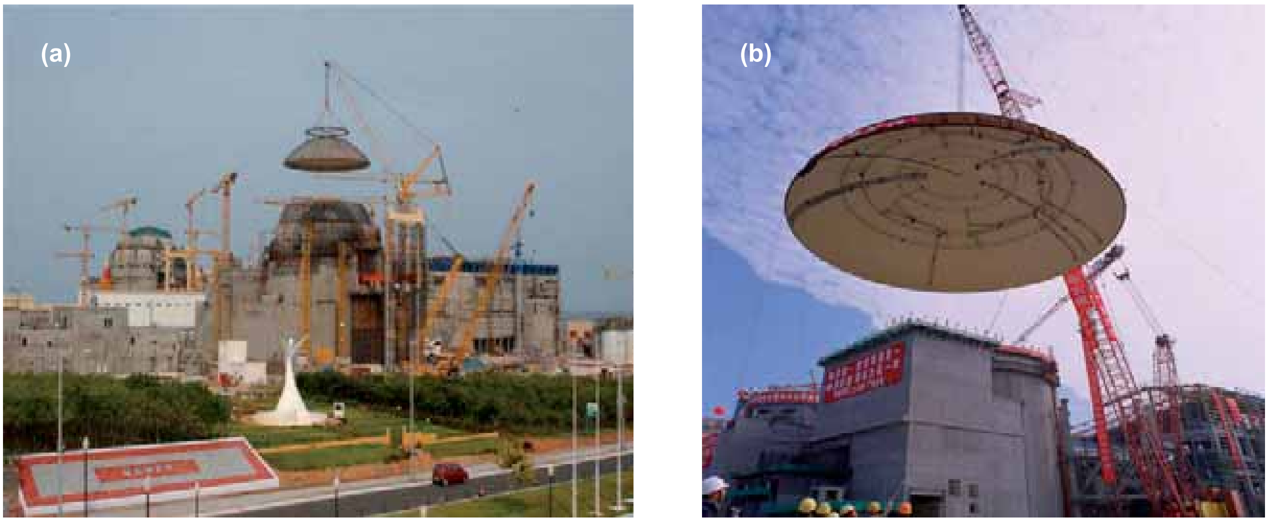

FIG. 2. Lifting the containment dome into position at: (a) the Kudankulam nuclear power plant in India (photograph courtesy of Nuclear Power Corporation of India); and (b) the Lingao-4 plant in China.

Constraints on installing major components inside the reactor and containment building can have a major impact on the construction schedule, and hence cost, of a nuclear power plant. In the past, the walls of the reactor and containment building were constructed with temporary openings to allow the entry of large equipment. A recent technique that has shortened construction time is open top installation (Fig. 2), where the reactor/containment building is built with a temporary roof with an opening through which major pieces of equipment, such as the reactor vessel and steam generators, are lowered into position using very heavy lift cranes.

"INPRO provides a forum in which technology holders and users jointly consider innovation."

The Agency convened workshops on 'Steps for Conducting Nuclear Power Plant Technology Assessments' and 'Best Practices on Heavy Water Reactor Operation', and organized two courses on natural circulation, one in cooperation with the ICTP. The Agency also maintained and updated THERPRO, the Thermophysical Properties of Nuclear Materials Database, available to all Member States.

In the area of fast reactors, the Agency launched two CRPs in 2008 linked to experimental programmes at Japan's MONJU reactor and France's PHÉNIX reactor within the framework of the former reactor's restart and the latter's end of life studies. These CRPs will address natural convection in the coolant in the upper plenum of the reactor vessel of a sodium cooled fast reactor, temperature and power distributions in off-balance situations, and sodium natural circulation phenomena in fast reactor cores. And as part of its activities to coordinate efforts to preserve knowledge about fast reactors, the Agency published *Fast Reactor Knowledge Preservation System: Taxonomy and Basic Requirements* (IAEA Nuclear Energy Series No. NG-T-6.3).

INPRO provides a forum in which technology holders and users jointly consider innovation. As of December 2008, INPRO had 28 members. Since 2001, 34 cost free experts from 17 Member States have contributed to INPRO's work. In 2008, six countries (Argentina, Armenia, Brazil, India, the Republic of Korea and Ukraine) finished assessments of innovative nuclear systems using the method developed by the Agency through INPRO. A progress report on INPRO was published in 2008. Another progress report focused on a joint study of the closed fuel cycle using fast reactors by Canada, China, France, India, Japan, the Republic of Korea, the Russian Federation and Ukraine. A multivolume INPRO manual was also published: *Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems: INPRO Manual — Overview of the Methodology* (IAEA-TECDOC-1575). In 2008, a two year effort to develop common user considerations was completed. The effort identified commonalities in the expectations held by developing countries considering the introduction of nuclear power. Publication of the results is planned for 2009.

Phase 2 of INPRO, which began in 2006, includes work in three areas: (1) continuous improvement of the INPRO methodology; (2) institutional and infrastructure activities; and (3) specific collaborative projects among INPRO Members. Of 12 collaborative projects proposed by INPRO members, ten were operational in 2008.

The Agency's cooperation with GIF[1] included organization of a workshop in October to apply software developed by GIF in evaluations of the economics of high temperature gas cooled reactors. The workshop identified improvements needed in the software to better analyse multi-unit, modular and co-generation designs.

In the area of non-electric applications, the Agency released an update of the Desalination Economic Evaluation Program (DEEP), a computer code developed to assess the economic aspects of desalination projects using nuclear energy. The Agency also released the first 'pre-alpha' version of the Hydrogen Economic Evaluation Program (HEEP), a comparable computer code to evaluate the economic aspects of hydrogen production using nuclear energy.

[1] GIF was established to lead the collaborative efforts of the world's leading nuclear technology nations to develop next generation nuclear energy systems to meet future energy needs. The current members of GIF are Argentina, Brazil, Canada, China, France, Japan, the Republic of Korea, the Russian Federation, South Africa, Switzerland, the United Kingdom, the USA and Euratom.