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Nuclear Power Newsletter

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Contents

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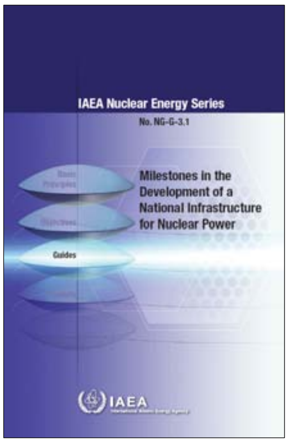
New Nuclear Power – How to Proceed



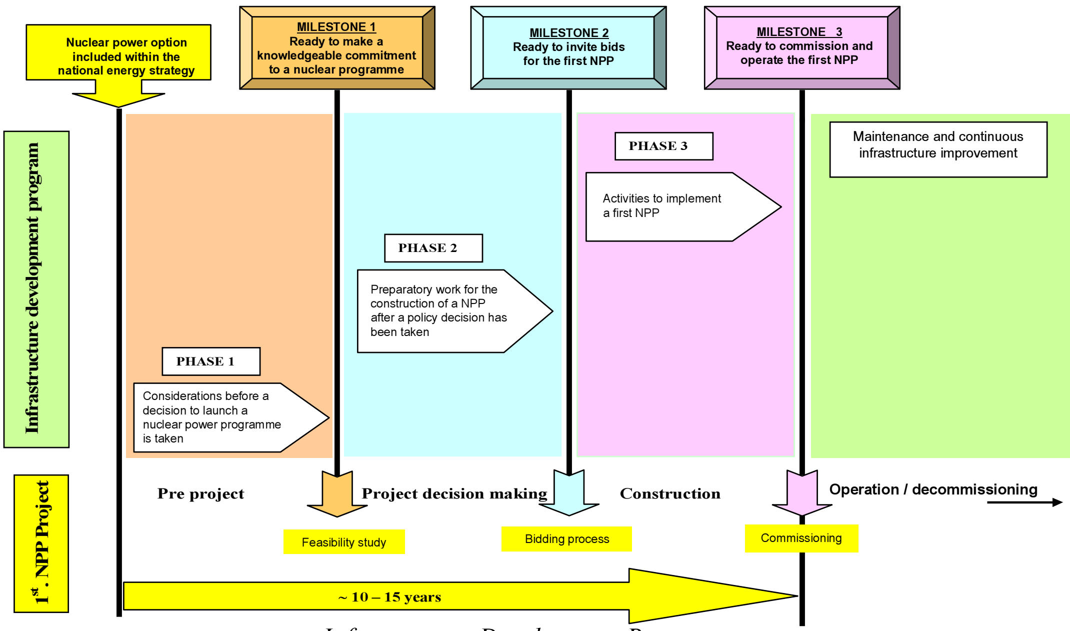
The decision by a Member State to embark on a nuclear programme should be based upon a commitment to use nuclear power for peaceful purposes, in a safe and secure manner. This commitment requires establishing a sustainable national infrastructure that provides governmental, legal, regulatory, managerial, technological, human and industrial support for the nuclear programme throughout its life cycle. Demonstration of the compliance with international legal instruments, internationally accepted nuclear safety standards, security guidelines and safeguards requirements are essential for establishing of a responsible nuclear power programme.

The IAEA has provided guidance activities supporting the development and implementation of nuclear power infrastructure for more than 20 years. The support has also been provided through programmes directed to specific needs of requesting countries under Technical Cooperation (TC) projects delivering training and advice in all infrastructure areas. In particular, extensive practical guidance was developed and made available through the publication of technical documents. The list of publications goes back to 1980, when a guidebook on *Manpower development for nuclear power* was issued. It was followed by another 20 publications produced on infrastructure subjects. These subjects include a broad spectrum of issues related with nuclear power planning, financing, electrical grid, engineering and science education, competitive strategies, bid invitation and evaluation, management and other aspects.

With the increasing interest from Member States in introducing nuclear power programmes it became necessary to consider the available advice to Member Sates and their decision makers. New documentation to clarify the expectations and to provide a time based guidance on how to launch a nuclear power programme has been developed

The new documentation provides advice for policy makers in a brochure *Considerations to launch a nuclear power programme* and also in a new Nuclear Energy (NE) Series document NG-G-3.1 *Milestones in the development of a national infrastructure for nuclear power*. These new documents reflect the conditions that countries would be expected to reach in regard to a wide range of issues, including legal framework, regulatory expectations, human resources and plans for handling nuclear materials under safeguard and security requirements.

The publication IAEA NG-G-3.1 expands the three phases of development outlined in the "Considerations" brochure and provides guidance on the timely preparation for a nuclear power programme through an easy to understand sequential development process. This publication provides a more detailed description for a technical audience of the complete range of infrastructure issues that need to be addressed and the expected level of achievement (or milestones) at the end of each phase. These phases are of unspecified duration, which will depend upon the degree of commitment and resources applied by the Member States. Experience has shown that the time frame from the initial policy decision by the State to the operation of the first NPP may well be at least 10 to 15 years. The completion of the infrastructure conditions of each of these phases is marked by a specific milestone at which the progress and success of the development effort can be assessed and a decision made to move on to the next phase. A schematic representation of the phases as defined in the "Considerations" brochure and milestones at the end of each phase is given in the following figure.



Infrastructure Development Programme

A Technical Meeting/Workshop in Vienna on *Milestones for Nuclear Power Infrastructure Development*, 5 to 9 November 2007, has been organized by the IAEA co sponsored by the Governments of Canada, China, France, India, Japan, Republic of Korea, Russia and United States of America. This is a follow-up of the Technical Meeting/Workshop on *Issues for the Introduction of Nuclear Power* held at the IAEA's Headquarters in December 2006. This Technical Meeting/Workshop is an opportunity for Member States to exchange views on the most important infrastructure issues and:

- To discuss a wide range of relevant nuclear infrastructure issues including those summarized in the IAEA brochure GOV/INF/2007/2, *Considerations to Launch a Nuclear Power Programme*;
- To review issues related to nuclear infrastructure from the perspective of national requirements, as presented in an IAEA publication NG-G-3.1 *Milestones in the Development of a National Infrastructure for Nuclear Power*;
- To enable the IAEA and supplier countries to develop a comprehensive understanding of the concerns and needs of participating Member States;
- To review the effects of infrastructure developments and other related topics on reducing investment risks;
- To discuss possible actions that may improve prospects for financing nuclear power projects.

The proper management of the wide scope of activities to be planned and implemented for the first NPP Project in a country represents a major challenge for the involved governmental, utility, regulatory, supplier and other supportive organizations. A recent publication, IAEA-TECDOC 1555 on *Managing the first Nuclear Power Plant Project*, 2007, selected some relevant elements based on the extensive information contained in previous publications and provided an introductory overall description of the main project management activities to be undertaken when planning the first NPP in a country. The contents include excerpts from existing publications along with new material to reflect the changes that have taken place over the years and references to relevant publications where the user can find more elaborated guidance.

The management of NPP projects with delays of several years with respect to the original scheduled commercial operation date presents particular issues and problem areas beyond the normal management tasks needed for projects implemented within normal schedules. Practical methodologies and successful experience from restarted projects have been reviewed, summarized and included in a guidance document on "Restarting Delayed Nuclear Power Plant Projects" planned to be finalized in 2007. The purpose is to address the specific management issues to be considered for a delayed NPP project in the period after the decision for restarting is adopted. The publication covers those management issues not considered within the normal processes described in other IAEA publications.

Topics relating to the nuclear power infrastructure are addressed by different parts of the IAEA and require close coordination among relevant IAEA activities. An inter-Departmental group (Nuclear Power Support Group), established in the Secretariat to develop a coordinated approach to providing support to interested Member States, has identified several policy issues that need to be considered and proposed means of improving coordination within the IAEA of the required actions.

Trends and Future Activities

In September 2005, in resolution GC(49)/RES/12 Part G, the 49th IAEA General Conference recognized "that the development and implementation of an appropriate infrastructure to support the successful introduction of nuclear power and its safe and efficient use is an issue of central concern, especially for countries that are considering and planning for the introduction of nuclear power".

Since the 49th IAEA General Conference, there has been a significant increase in the number of Member States expressing interest in nuclear power. The IAEA is able to provide advice on what steps need to be taken to be ready to introduce nuclear power.

The nuclear infrastructure of a country is built up on the basis of the requirements imposed by the decision makers, the technology and equipment provided by the technology holders and the international cooperation arrangements. The IAEA can provide effective support for the growing demand in the development and implementation of nuclear infrastructure through the provision of advisory services focused on specific country's needs and the practical guidance made available through the extensive series of technical publications.

In planning the future support activities in the infrastructure area, the IAEA is aiming to address emerging issues such as those mentioned below.

The changing global environment is likely to influence the infrastructure necessary for construction and operation of NPPs. Depending on the Member States' needs, issues such as financing arrangements for capital intensive NPPs, international design approval, harmonization of codes and standards, and assurance of fuel cycle services would need to be addressed.

The issues of investment risk related to nuclear power will be considered, and a review of how the perceived investment risk can be reduced by improvements in international infrastructure and co-operation will be investigated.

Regional and inter regional arrangements to support the infrastructure will require further co-operation between many Departments of the IAEA, particularly in the field of fuel supply and the storage, management and processing of spent fuel.

The development of a national capability through the establishment of the appropriate technical infrastructure to support nuclear power provides a potentially significant benefit to national development. This will be investigated in order to assess the comparative risk and benefits from the application of nuclear energy.

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Message from the Director

Usually our newsletter addresses what's new since the last letter. Due to the relatively low level of activities in summer in the IAEA, our September newsletter has more overview type articles. We begin with the Infrastructure topic, considering rising interest, documents in the pipeline and planned meetings.

The building of new nuclear power plants around the world has been stagnated since the middle of the 1980s.

Today there are thirty to forty (30-40) countries indicating an interest in introducing a nuclear power (NP) programme into the country's power generation portfolio due to growth in energy demand, energy security and environmental issues.

Under this rising expectation of the possible future role of nuclear power, the IAEA and the nuclear community will have to address three priorities: first, to ensure protection, that, wherever nuclear energy is used., it is used safely, securely, and with minimal proliferation risk; second, to ensure continued technological and institutional improvements to meet the highest standards; and third, to ensure that the needs of developing countries are assessed and evaluated in an effective and systematic manner.

From a practical standpoint, infrastructure building is the key to success in those countries planning to introduce a first plant. The IAEA's activities on infrastructure building includes support for informed decision-making through documents, forums, workshops and analytical tools and various "Review Services" such as an infrastructure preparedness review. Because the IAEA's support covers a wide spectrum of areas including legal and regulatory framework, human resources development, site evaluation and others, the IAEA has established an inter-departmental group for coordinated response to its Member States.

Relevant to the IAEA's support for the future introduction of a Nuclear Power Programme are activities such as:

1. Planned near-term workshops in 2007 relating to the introduction of nuclear power:

- Workshop on *Steps for Conducting Assessment of NPP Technology with Water-Cooled Reactors*, 22-27 October, IAEA, Vienna;
- Workshop on *Milestones for Nuclear Power Infrastructure Development*, 5-9 November, IAEA, Vienna;
- Workshop on *Common User Criteria for Development and Deployment of Nuclear Power Plants for Developing Countries*, 27-30 November, IAEA, Vienna.

2. Recently released and planned guidance documents:

- IAEA-TECDOC-1513 *Basic Infrastructure for a Nuclear Power Project*, June 2006;
- IAEA-TECDOC-1522 *Potential for Sharing Nuclear Power Infrastructure between Countries*, October 2006;
- IAEA-TECDOC-1555 *Managing the First Nuclear Power Plant Project*, May 2007;
- NE series guide NG-G-3.1 *Milestones in the Development of a National Infrastructure for Nuclear Power* (expected for release in September 2007);
- IAEA-TECDOC *Improving Prospects for financing Nuclear Power Plant Projects* (in preparation);
- IAEA-TECDOC *Responsibilities and Competences of the Nuclear Power Implementing Organization to Initiate Nuclear Programme* (in preparation).

It is our expectation that countries introducing their first plants will benefit from this information and these workshops and we would like to encourage Member States to consider the following for a successful nuclear power programme:

- Conducting a national self assessment prior to making the decision for launching a nuclear power programme, including the viability of Nuclear Power through energy planning, legal challenges, and regulatory and legislative aspects;
- Determining the extent of availability of the industrial base for the development of human resources, and a study of necessary commitments and obligations, including the financing methods and others basic needs;
- Performing a self-critical review of infrastructure-preparedness using the IAEA "milestone" document. An IAEA review mission is also possible upon request in order to establish a balanced systematic approach for a nuclear power plant and help establish a time table for infrastructure building for the Member State;
- Evaluating a regional or sub-regional approach for efficiency of establishing a well balanced infrastructure. Sharing of information, lessons learned and ideas is a basic fundamental approach in nuclear power production and can be an established programme at the beginning of infrastructure building.

In closing, the staff and I in the Division of Nuclear Power encourage all Member States to utilize all the information and strategies available to ensure that the beginning of their assessment for infrastructure meets the expectations necessary to deliver an effective, efficient and safe use of future nuclear power.

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Nuclear Power Plant Operating Performance and Life Cycle Management

Nuclear Energy Trends

Introduction

Nuclear reactors have provided electricity since 1954. Today the nuclear energy is an important part of a global energy mix. In 2006 nuclear power supplied about 15.2% of the world's electricity. During more than 50 years nuclear power plants have accumulated 12500 reactor-years of operating experience. World energy demand is expected to more than double by 2050, and expansion of nuclear energy is a key to meeting this demand while reducing pollution and greenhouse gases.

Current Status of Nuclear Power

In the middle of 2007 the nuclear industry is represented by 439 operational nuclear power plants (NPP) totaling 371.7 GWe of capacity. In addition there are 5 operational units in long-term shutdown with a total net capacity 2.8 GWe. There are 30 reactor units with a total capacity 23.4 GWe under construction.

Figure 1 shows that nuclear energy is concentrated in Europe, North America and the Far East (FE). Asia and Eastern Europe are expanding their installed capacity by constructing new NPPs whereas North America and Western Europe are, in recent years, benefiting instead from power uprates of existing units.

Current expansion in Asia can be illustrated by the facts that 17 of the 30 reactors under construction are in Asia and, during the last 7 years, 23 of the last 31 grid connections were in Asia.

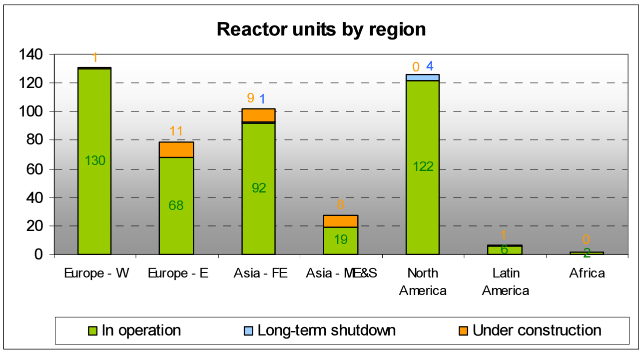

Fig.1 Number of reactors by region

To date in 2007 three new units have been connected to the grid, Kaiga-3 in India, Tianwan-2 in China and Cernavoda-2 in Romania. Browns Ferry-1 was reconnected to the grid in USA after long-term shutdown. Construction of four new units has been started in 2007: Qinshan II-4 in China, Shin Kori-2 in Rep. of Korea and two reactors in Severodvinsk, Russia as the world first floating NPP.

In the current fleet of operational power reactors the Pressurized Water Reactor (PWR) is the dominant reactor type as shown in Figure 2. PWR units represent 60.4% of installed nuclear capacity. The PWR category includes also the Russian PWR design (WWER). Boiling Water Reactors (BWR), including the Advanced Boiling Water Reactors (ABWR), represent 21.4% of installed capacity. Only 18% of installed nuclear capacity belongs to all other reactor types.

Capacity and production in 2006

In spite of permanent shutdown of eight reactors (2236 MWe) and only two new grid connections (1490 MWe) the total installed capacity of the nuclear industry has risen from 368.2 to 369.7 GWe during 2006. Power uprating of operating plants nearly fully compensated shutdown capacity.

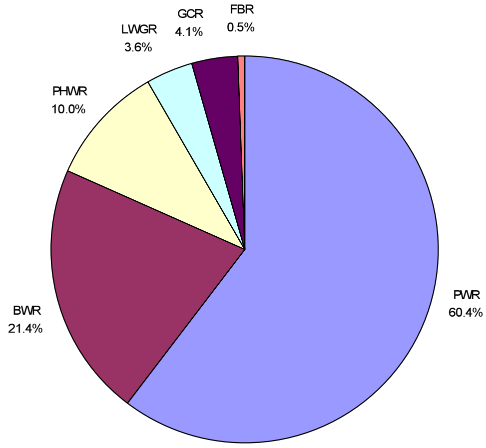

Fig.2 Nuclear capacity by reactor type

In 2006 nuclear electricity production again exceeded the historical maximum reaching 2661 TWh. In Figure 3 the red bars show the growth in global nuclear electricity production since 1990 (measured against the right scale). The yellow bars show the growth in installed capacity measured against the left scale.

Difference between trends of growth of installed capacity and energy production indicates more efficient utilization of nuclear capacity by improved availability of nuclear reactors.

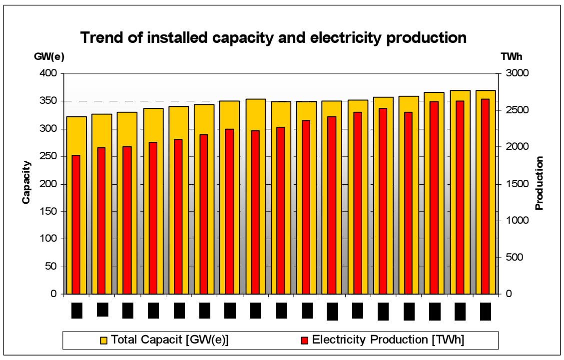

Fig.3 Nuclear energy production

Availability of Nuclear reactors

The Energy Availability Factor (EAF) is the percentage of maximum energy generation that plant is available to supply to the electrical grid.

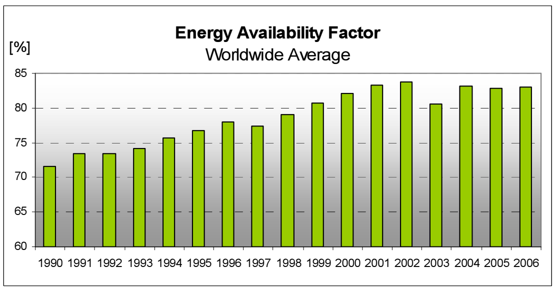

Fig.4 EAF trend

In 2006 the worldwide EAF was 83% in average. Half of nuclear reactors operated with EAF above 86% (world-wide median value). The top quarter of reactors reached EAF above 91%. For comparison the global energy availability factor for NPPs was 72% in 1990.

In 1990s the continuous increase in the EAF averaged around 1% per year. In last 6 years this trend was halted and EAF varies around 83%.

Breaking down EAF by reactor type the high availability of PWR, PHWR and BWR reactors is illustrated on Figure 5. Results for BWRs were affected by the TEPCO case in 2003.

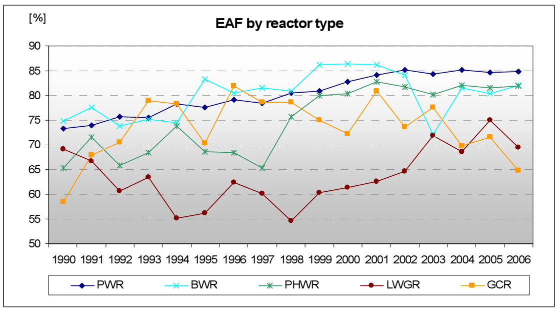

Fig.5 EAF for the most common reactor types

Planned energy losses related to maintenance activities and refuelling are generally the main contributor to plant unavailability. Frequency and organization of planned outages are determined in principle by reactor design but experience shows that for all reactor types there is a space for improvement in planned outage management.

Reactor Unit Lifetime

Most nuclear power plants currently in operation were constructed in the 1970s and the 1980s. Figure 6 shows that 75% of reactors are older than 19 years and 50% are older than 23 years.

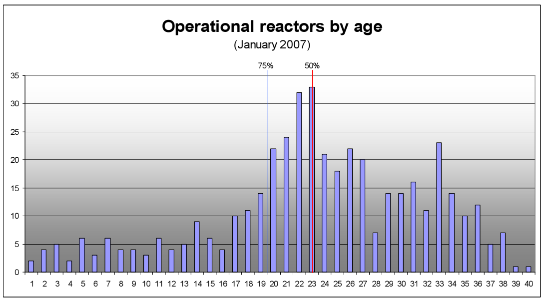

Fig.6 Age of operated reactors

Lifetime management and licence renewals have become significant programs for the nuclear industry.

The distribution of operational reactors in four categories by decades varies in regions (Figure 7). For instance no new reactor was connected to the grid in North America during the last 10 years (just reconnection of long-term shutdown Browns Ferry 1), but in Asia new reactors from the last decade represents more then 20%.

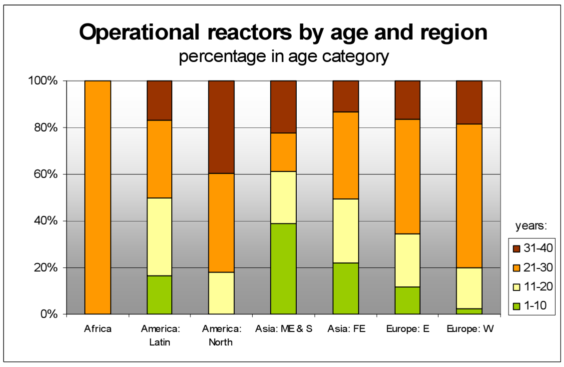

Fig.7 Reactor age categories in regions

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Nuclear Power Plant Instrumentation and Control Technologies

The majority of instrumentation and control (I&C) systems and equipment in nuclear power plants (NPPs) in the world were designed 30 to over 45 years ago with analog components. Much of this equipment is approaching or exceeding its life expectancy, resulting in increasing maintenance efforts to sustain acceptable system performance. Refurbishments and license extensions mean that a plant must be supported longer, which will increase the obsolescence issues. In addition, the older technology limits the possibilities for adding new beneficial capabilities to the plant systems and interfaces. New technology provides the opportunity to improve plant performance, human system interface (HSI) functionality, and reliability; to enhance operator performance and reliability, and to address difficulties in finding young professionals with education and experience with older analog technology. Finally, there may be changes in regulatory requirements that could necessitate modernization activities.

Modernization of I&C systems and components, using digital equipment to address these obsolescence problems, is a current major issue for nuclear power plants throughout the world. The potential benefits of implementing digital technology include more efficient operations and maintenance, leading to improved power plant availability and safety through the avoidance of transients, forced outages, and unnecessary shutdowns. New digital systems provide the opportunity to give personnel information they did not have with conventional systems.

The introduction of digital technologies also brings in new challenges both in licensing and operating digital I&C systems. Examples are hybrid main control rooms, where analog and digital systems are integrated, cyber security, and potential common-cause failures (CCF) in digital I&C systems. The importance of these issues has led the IAEA to organize several Technical Meetings on these subjects.

Preventing Common Cause Failures in Digital I&C

The task of preventing common-cause failures (CCFs) occurring in digital I&C systems is especially important in the instrumentation of NPP safety systems, since the occurrence of common-cause failures could defeat the effectiveness of the protection provided by the use of redundant components and safety instrument channels. The purpose of redundancy and independence is to make the system immune to the consequences of single component failure, that is, no single failure can prevent safety system actuation, if that activation is needed, and no single failure can cause spurious activation of safety systems. However, potential common-cause failures can occur in redundant systems, if the assumption of independence of parallel components is not valid due to a combination of internal design errors and external environmental effects, such as electromagnetic interference, triggering a CCF in redundant trains or systems.

The issue of CCF was extensively discussed at a recent IAEA Technical Meeting titled *Common-Cause Failures in Digital Instrumentation and Control Systems of Nuclear Power Plants*. The meeting was held from 19 to 21 June 2007, in Bethesda, Maryland, USA, and it was co-hosted by the U.S. NRC, EPRI, NEI, and DOE. The purpose of the meeting was to provide and expert forum to discuss the use of redundancies and defense-in-depth-and-diversity (D3) principles to prevent common-cause failures in reactor protection and control systems and to review the draft of a related IAEA technical document.. Practical aspects of the following areas are discussed:

- Achieving functional, physical, and design diversity;
- Defense-in-depth solutions;
- System robustness and fault tolerance;
- Functional and physical separation;
- Parallel systems supporting the same function;
- Testing digital I&C systems for susceptibility of common-cause failures;
- Possible CCFs triggered by maintenance activities and human errors;
- Potential increase in CCF by the use of commercial-of-the shelf components;
- Potential increase in CCF with increasing system complexity;
- CCF-proof system design and requirement specification.

The meeting was attended by 90 participants from 20 IAEA Member States delivering 40 presentations. NRC Commissioner Peter Lyons opened the meeting and emphasized the importance and complexity of implementing and licensing digital I&C systems with the features of defense-in-depth, diversity, and independence in new NPP I&C designs.

Participants of the Technical Meeting, Bethesda, Maryland, USA, 19-21 June 2007

Cyber Security of Nuclear Power Plant Instrumentation, Control and Information Systems

Over the last decades, new computer-based digital I&C systems have been installed in NPPs for functions, which have a varying importance for safety. This development has unfortunately also given rise to new vulnerabilities that may endanger technical and administrative systems for nuclear safety and physical protection at the facilities. The computers that, for example, are used in safety and safety-related I&C systems, where non-availability or malfunction may directly impact nuclear safety, must have very good protection from possible intrusions. Computers used in process controls and in the control of access to sensitive areas are also a concern due to the importance of continuity of power production and avoidance of unauthorized access.

To address these important issues the IAEA has organized a Technical Meeting on *Cyber Security of Nuclear Power Plant Instrumentation, Control and Information Systems* in cooperation with Idaho National Laboratory. The meeting was held from 17 to 20 October 2006 in Idaho Falls, USA. The objective of the meeting was to discuss effective measures to ensure computer security by drawing on the collective experience of the meeting participants. Experts in all fields of physical protection, nuclear safety, digital I&C and computer security were invited to participate in the meeting, which provided a stepping point for developing further guidance on computer security at the nuclear power plants. This guidance document is anticipated to reduce the likelihood of a successful intentional or inadvertent attack, to reduce the consequences of a successful attack and the time and cost to recover, and to potentially make systems fault tolerant and fault recoverable.

Participants of the Technical Meeting, Idaho Falls, ID, USA, 17-20 October 2006

The meeting was attended by 35 participants from 11 countries, delivering 24 presentations. The related IAEA guidance document was further developed in three break-out sessions during the meeting. The meeting's CD-ROM proceedings are available on the IAEA NPES website at http://www.iaea.org/NuclearPower/NPES/.

Joint IAEA-EPRI Workshop on Modernization of I&C Systems in NPPs

Participants of the joint IAEA-EPRI Workshop, Vienna, Austria, 3-6 October 2006

A joint IAEA-EPRI Workshop was held from 3 to 6 October 2006 in Vienna, Austria. 45 participants from 23 countries attended the workshop. The purpose of the workshop was to provide an opportunity for I&C experts representing the various stakeholders in the nuclear power industry to share nuclear power plant modernization experiences and lessons learned..

Design, engineering, implementation, and project management issues were presented and discussed.

`The workshop included eight international experts giving presentations on I&C modernization projects of nuclear power plants. Four lecturers from EPRI and four from the European Region (Areva, VTT, Paks NPP, and IAEA) delivered 25 presentations.

The following topics were discussed in detail: (1) modernizing operating plants and licensing new plants, control room and human-system interface modernization, and the use of visualization technologies, (2) assessment of digital equipment for safety and high-integrity applications, important analog-to-digital differences, assessment of reliability and dependability by equipment type, and the implementation of the "defense-in-depth and diversity" principle, (3) on-line monitoring for instrument calibration and the monitoring of processes and equipment, applications of wireless technology, and fleet-wide monitoring. (4) safety I&C system modernization and digital system applications in VVER-440 plants, (5) the role of I&C systems in power uprating projects, (6) implementing and licensing digital I&C systems and equipment in NPPs, (7) cyber security of NPP instrumentation, control, and information systems, (8) main design steps in I&C modernization projects, (9) experiences gained from various digital I&C projects, and (10) testing the response time and effectiveness of I&C systems used in reactor protection systems.

Twelve presentations from the workshop's audience were also delivered describing I&C modernization projects performed at NPPs.

Increasing Power Output and Performance of NPPs by Improved I&C Systems

Improvements made in I&C systems may lead to higher power output and better performance of NPPs. This issue was addressed at an IAEA Technical Meeting on *Increasing Power Output and Performance of Nuclear Power Plants by Improved Instrumentation and Control Systems* which was held from 29 to 31 May 2007 in Prague, Czech Republic. The meeting was hosted by I&C Energo a.s. The purpose of the meeting was to provide an international forum for presentation and discussion of experience in the field of I&C improvements and modernization projects. Eighty participants from 26 countries attended the meeting, delivering 43 presentations. The meeting's CD-ROM proceedings are available on the IAEA NPES website at http://www.iaea.org/NuclearPower/NPES/.

Modernizing Hybrid Main Control Rooms in NPPs

As an integral part of the I&C modernization programs at NPPs, the control room (CRs) and other human-system interfaces (HSIs) are often also changed. To support safe and effective operation, it is critical to specify, design, implement, operate, and maintain, as well as train for, the control room and HSI changes to take advantage of human cognitive processing abilities. As part of modernization, HSIs are becoming more computer-based, incorporating features such as computerized procedures, touch-screen interfaces, and large-screen overview displays. As computer-based technologies are integrated into CRs that were largely based on conventional technology, hybrid control rooms are created.

Participants of the Technical Meeting, Prague, Czech Republic, 29-31 May 2007

The importance of these issues has led the IAEA to organize an international forum for presentations and discussions on the potential benefits and challenges related to the integration of analog and digital instrumentation and control systems in hybrid main control rooms. Technical experts and managers from the field of instrumentation and control, process control, human factors engineering, licensing, and computer applications are invited to the Technical Meeting dealing with all important aspects of control room modernization projects. The IAEA meeting will be held in Toronto, Ontario, Canada, from 29 October to 2 November 2007 hosted by Atomic Energy of Canada Limited (AECL). The scope of the meeting includes the following areas: (1) Control Room Modernization Projects, (2) Enhanced Functionality, Safety Status, and Emergency Response, (3) I&C System Design, Implementation and Validation, (4) Human Factors and Performance, (5) Training Approaches, Challenges, Issues, (6) Licensing and Regulator Issues and Challenges, (7) Economic Analysis and Justification of Control Room Upgrades, (8) Envisioning the Future

For more information on the meeting, please see http://www.iaea.org/NuclearPower/NPES/.

IAEA Technical Working Group on Nuclear Power Plant Control and Instrumentation

The subjects of the above mentioned technical meetings were suggested by the members of the IAEA Technical Working Group on Nuclear Power Plant Control and Instrumentation (TWG- NPPCI) at their biennial meetings in 2003 and 2005. The latest meeting of the TWG-NPPCI was held from 23 to 25 May 2007 in Vienna, Austria. The objectives of the meeting were (1) to discuss current issues of instrumentation and control in NPPs, and to address new trends and emerging technical challenges, (2) to evaluate on-going IAEA I&C activities (2006-2007), (3) to obtain input and support for the 2008-2009 activities (participating / hosting meetings), (4) to present National Reports and to discuss needs of Member States in I&C research, development, and applications, (5) to make recommendations to the IAEA on future IAEA I&C activities in 2010-2011, (6) to establish and improve communication channels among national representatives, and the IAEA, and (7) to discuss the new Terms of Reference of the TWG.

45 participants from 28 Member States and two international organizations attended the meeting and 31 presentations were delivered. The Member States' recommendations encompassed the following I&C areas:

- Design, Qualification, and Applications of Digital I&C Systems;
- Modernisation Projects of I&C Components and Systems including Hybrid Main Control Rooms;
- Life-Cycle Related Issues of Hardware and Software Used in I&C Systems;
- Human Factors and Reliability; Main Control Room Design, Human System Interface;
- I&C Knowledge Management and Transfer; Aging Workforce;
- Utilizing Lessons Learned in Operation and Maintenance of I&C Systems;
- Licensing I&C Systems;
- Emerging I&C Technologies.

Participants at the TWG- NPPCI, Vienna, Austria, 23-25 May 2007

All documents, presentations, and recommendations of the 2007 TWG-NPPCI meeting are posted on the IAEA website: http://www.iaea.org/NuclearPower/IandC/TWG/

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Integrated NPP Life Cycle Management

The IAEA has sponsored a series of Coordinated Research Projects (CRPs) that have led to a focus on reactor pressure vessel (RPV) structural integrity application of measured best irradiation fracture parameters using relatively small test specimens. Two CRPs are processing to develop the technical guidelines;

- Good Practice Handbook for Deterministic Evaluation of the Integrity of a Reactor Pressure Vessel during a Pressurised Thermal Shock in NPPs
- Master Curve Approach to Monitor Fracture Toughness of RPVs in NPPs.

The CRP on Master Curve Approach to Monitor Fracture Toughness of RPVs in NPP on resolving technical issues associated with application of the Master Curve (MC) approach to RPV integrity assessment. Overall objectives include: 1) better quantification of fracture toughness issues relative to testing surveillance specimens for application to RPV integrity assessment, and 2) development of approaches for addressing MC technical issues in integrity evaluation of operating RPVs. A total of 15 research organizations from Belgium, the Czech Republic, Finland, Germany, Hungary, Japan, Rep. of Korea, Mexico, Spain, the Russian Federation, USA, and JRC- IE participated in the CRP.

The CRP on Review and benchmark of calculation methods for structural integrity assessment of RPVs during PTS is to review the results of benchmark deterministic calculations of a typical PTS regime and to prepare technical report series. A total of ten experts from China, the Czech Republic, Finland, France, Germany, Hungary, the Republic of Korea, Slovakia and JRC- IE participated in the CRP. Based on commitment at the first

Benchmark calculation results for basic case and national reference code

Organization	National reference code	WWER			PWR		
		Basic case	Nat. ref. doc A)	Nat. ref codes B)	Basic case	Nat. ref codes A)	Nat. ref codes B)
SNERDI, China	ASME Sec. XI				+		+
NRI, Czech Republic	VERLIFE	+	+	+	+		-
FNS, Finland	VERLIFE with modification	+	+	+			
EdF, France	French RSEM code				+		+
AREVA NP, Germany	KTA	+			+	+	+
KFKI, Hungary	VERLIFE	+	+	+	+		
KINS, Republic of Korea	ASME Sect. XI				+	+	+
OKB GP, Russian Federation	MRKR SKhR-2004	+		+	+		
VUJE, Slovakia	VERLIFE	+	+	+			

* National reference code A : national code approach are used, but postulated crack is the same as the basic case,
** National reference code B : national code approach are used with national requirements on crack definition

research coordinated meeting (RCM) held on November 2005 at the IAEA, each organization submitted and presented the calculation results as shown in Table 1. These main results and experiences from benchmark calculations will be generalized to find the best practices for technical guidelines together with the support of existing data from other projects and the literature. This will substantially contribute to better technical support of NPP operation safety and life management.

Utilities are looking for ways to optimize plant lifetime, and must therefore prevent stress corrosion in primary components, while combating other phenomena, such as thermal fatigue or certain metallurgical weaknesses. Since the early 2000's, the driving factors for main component replacements are more complex and interconnected. In respect of the regulatory safety issues, Operators have developed economic models that help them make their decision on main components replacements and fix the optimum dates.

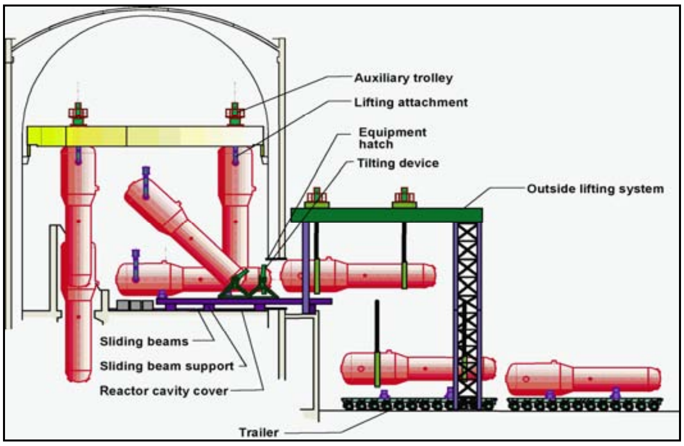
Component replacement is often the most feasible solution to solve the problems associated with primary water stress corrosion cracking (PWSCC) of Alloy 600. Even if mitigation and /or repair were a local solution, replacement offers many advantages when addressing the assortment of potential susceptible parts contained in a major component. The replacement of heavy components is the result of widespread stress corrosion of Alloy 600 (and alloys 82/182) in the primary system. Following the corrosion of steam generator tubes, which led to the first steam generator replacement (SGR) projects, work has begun on reactor vessel head replacements (RVHR) and pressurizer replacements.

The IAEA is developing an IAEA-TECDOC on *Methods of the Replacement of Main Components* (Steam Generator, Reactor Vessel Head and Reactor Vessel Internal).

The IAEA-TECDOC is dedicated on Heavy Components Replacement considered strategic for plants life management and not included in current maintenance replacement carried out by utilities. The major and heavy components to be considered are:

- Steam Generators for PWR and WWER plants;
- Reactor Vessel Head for PWR plants;
- Reactor Internal Components for BWR plants;
- Reactor Vessel Internals for PWR plants;
- Pressurizer for PWR plants;
- Reactor coolant piping/ recirculation piping PWR and BWR plants.

The IAEA-TECDOC will be issues on the end of this year.



Replacement of Steam Generator

The process of increasing the licensed power level of a NPPs is called a “power uprate”. Power uprates are generally categorized based on the magnitude of the power increase and the methods used to achieve the increase. Currently a significant number of NPPs have plans for power uprate by larger or smaller amounts. In most cases this is an economic way of producing more electricity in a NPP, and which has attracted interest due to increased electricity prices; a situation that is expected to remain. The increase in the electricity produced in a NPP can be achieved in two ways:

- One way is to increase the thermal power in the reactor, and
- The other way is to improve the thermal conversion efficiency in the power plant by refurbishing or replacing the high-pressure or low-pressure turbine units - or a combination of these actions.

Participants in the TM on Power Uprate and Side Effects in NPPs

The technical meeting (TM) on *Power Uprate and Side* Effects in Nuclear Power Plants was held at Oskarshamn in Sweden on 12-15 February 2007. A total of 76 participants from 18 countries participated in the meeting and 28 papers were presented. The purpose of the TM is to provide an international forum to share recent technical knowledge and experience relating to the good practices for the management of power uprate and to share lessons learned related to side effects on power uprate issues in nuclear power plants. The TM consists of four technical sessions besides opening and closing sessions. Those are:

- Session 1: Overview & guidance for power uprate;
- Session 2: Technical issues;
- Session 3: Management issues;
- Session 4: Regulatory aspects.

The meeting of Technical Working Group on Life Management of NPPs (TWG-LMNPP) on Plant Life Management for Long Term Operation (PLiM–LTO) was held at Vienna on 21-23 February to share the information on PLiM–LTO activities since last 2005 meeting and prepare the recommendations for the PLiM–LTO activities and directions to be implemented in 2010- 2011. A total of 25 delegates from 18 countries and 2 international organizations were participated in TWG meeting and each delegate reported his national report on PLiM for LTO. The scientific secretary, K.S. Kang reported the achievements since 2005 and planning activities for 2007-2009. A lot of recommendations were raised during meeting. Finally all recommendations were categories into 4 groups and an international symposium as below and prioritized to fill the gaps and update current technical documents:

Participants of the TWG Meeting

- Programme level;
- Technological aspects (engineering part and Research part);
- Human resource management aspects;
- Regulatory aspects;
- 3rd Int. Sym on PLiM in 2011.

The IAEA regional workshop on *Optimization of Service Life of Operating Nuclear Power Plants* was held in Angra, Brazil, on 14-17 May 2007, followed by a technical visit to the Angra NPP. The agenda of the workshop included presentations on IAEA Activities in PLiM, PLiM programmes in France and Spain, Aging management and degradation mode with life cycle management, Management aspects of service life on NPPs, Light water reactor vessel and internals, periodic inspections and monitoring application on established programs to enhance monitoring and diagnosis, PLiM code, standards and guides. Three invited experts and 40 participants from Argentina, Brazil and Mexico attended the workshop.

Participants in the workshop, Angra Brazil, 16-18 May 2007

A preparatory meeting for the IAEA international symposium on plant life management (PLiM 2007) was held at Shanghai on 24-25 May in China. The objective of the meeting is to finalize a symposium technical programme and arrange the detailed administrative issues.

The technical meeting was participated by four IAEA staff members and nine international experts from Canada, Czech Republic, Hungary, Germany, Japan, Republic of Korea, Russian Federation and Switzerland and five from Chinese host organizations.

This is the update information before 2007 PLiM symposium in Shanghai on October 15. Metrics as of July 31st are shown as below:

Submitted papers and exhibitions	Number
Abstracts Submitted	180
Keynote presentation	9
Oral Session presentation	85
Post session presentation	80
Exhibitors as of August 31	7

15th October 2007	*16th October 2007*	*17th October 2007*	*18th October 2007*

• Opening:
• Two key note speeches from China and Finland
• Session 1: Ap-proaches to PLiM
	• Three key note speeches from France, Canada, Germany
	• Session 2:
	  ○ General AM (1-3)
	  ○ AM for BWR,
	  ○ ISI,
	  ○ Prob. approach to AM,
	  ○ AM for PHWR
	• Session 3:
	  ○ SCC, EAC, Non-metallic AM,
	  ○ FAC, Fatigue, RPV and core internals integrity
		• Three key note speeches from Russia Federation, USA and EC JRC
		• Session 4:
		  ○ I&C refurbishment
		• Session 5:
		  ○ Economics of PLiM)
		• Poster session
			• One key note speech from Japan
			• Session 6 :Regulatory aspects of PLiM
			• Recommendations and Closing:

Note : AM : Ageing Management, SCC : Stress Corrosion Crack, EAC: Environmental Assisted Cracking , ISI : In-Service Inspection, RPV : Reactor Pressure Vessel

The symposium technical programme is established as in the table above.

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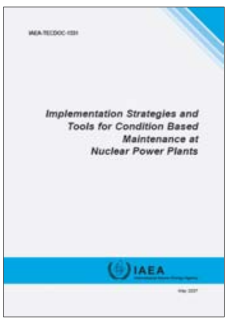
Nuclear Power Plant Maintenance

The objective of the Project on Optimization of Nuclear Power Plant Overall Performance within the IAEA's sub-program of 'Nuclear Power Planning, Implementation and Performance' of the Division of Nuclear Power is to systematically improve the overall performance and competitiveness of nuclear power plants with due regard to safety through the application of technological and engineering best practices, including quality assurance/quality management, and the utilization of relevant databases.



IAEA-TECDOC 1551 *Implementation strategies and tools for condition base maintenance at NPP* was developed in the above-mentioned framework with the objective to collect and analyze proven maintenance optimization methods and techniques (engineering and organizational) in Member States. Appendices to this IAEA-TECDOC consists of selected papers on maintenance optimization presented during the preparation of this document. A systematic evaluation approach to establishing what maintenance tasks are to be performed on which SSCs and at what periodicity, can lead to optimize the use of resources (maintenance costs, personnel doses, equipment and tools, competent personnel, etc.) allocated for maintenance and availability of plant. This approach can be used in establishing a preventive maintenance program and for the optimization of the ongoing maintenance program. The process seeks to make the best use of condition-based maintenance where unnecessarily costly maintenance actions and associated maintenance error induced failures can be avoided. If a probabilistic risk assessment has been performed, its result can be used to help define the important systems and components. This optimization process can lead to the achievement of nearly all maintenance targets concerning safety, reliability and cost.

In countries operating WWER-440/1000 NPPs, there are big differences in the eddy current inspection strategy and practice as well as in the approach to steam generator heat exchanger tube structural integrity assessment (plugging criteria for defective tubes vary from 40 to 90 % wall thickness degradation). To address such an issue, 13 organizations being involved in In-Service Inspection of steam generators in WWER operating countries and in industrialized countries completed an IAEA CRP in 2001-05, whose overall objective is to improve structural integrity assessment of steam generators of WWER-440/1000 NPPs. The specific research activities that have been done are:

- Non-destructive (eddy current) testing results were compared with destructive (mechanical, micro-structural and micro-analytical) testing results on the same steam generator tube samples with special attention to operational history data;
- Strength and fracture mechanics calculations applying real data of non-destructive and destructive tests were carried out;

- Methodology for establishing reasonable plugging criteria was elaborated.

This approach can provide assurance that the steam generators will continue to satisfy the appropriate performance criteria. The technical documents on "Verification of WWER Steam Generator Tube Integrity" will be issued before the end of 2007.

The guideline on water Chemistry for WWER NPPs is developing to support WWER NPPs. At first, the different technical opinions about some important issues are defined for the document development.

This document is expected to be published in the first half of 2008. The IAEA Technical Meeting on *water chemistry* is to be held on 1-3 Oct. 2007 in Moscow to disseminate the best practices of water chemistry control.

From 2005 to 2006, there was a TC regional project RER/4/027: *Strengthening Capabilities for Nuclear Power Plant Performance and Service Life Including Engineering Aspects* for Europe in order to improve NPP reliability and competitiveness; to optimize NPP service life including ageing management and license renewal; to improve management of interfaces with regulator, other organizations and the public. It was successfully implemented. On 1-3 November 2006, the representatives of Europe convened a planning meeting on 2007-08 regional TC programme at the IAEA. This project was commended and given an extension of two years. This project will continue to assist the regional NPPs in 2007-08.

As many as 15 technical workshops, technical meetings and training courses were organized in various facilities around Europe in 2006, thanks to the great regional interests and enthusiasms of the region and good co-operation between the Department of Technical Cooperation and NENP. Many of these meetings provided the timely information to the regional NPPs on structural integrity, ageing and plant life management; risk-informed in-service inspection; and I&C modernization and power uprate. These technical topics are exactly in accordance with what the regional NPPs are undertaking, that is, ageing management programme, plant life extension and power uprate, risk informed decision making to optimiser operation and maintenance.

In addition, a pilot study on *Risk Informed In-Service Inspection for WWER NPPs* was carried out in co-operation with Nuclear Research Institute of Czech republic. The EPRI methodology on RI-ISI was tested on primary piping and pressurizer surge line of WWER-440 Dukovany NPP. 119 welds were assigned to risk category IV and 5 welds to risk category II among a total number of 124 welds per WWER-440 unit. Based on RI-ISI optimization procedure, 12 welds of Category IV and 2 welds of Category II were selected for inspection, while the current inspection programme covers 66 welds. This means a one fourth to one fifth reduction of inspection scope (14 vs. 66 welds), while the safety level is still maintained.

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Improving Organizational Performance

IAEA Safety Standards on Management Systems

Introduction

The IAEA published a new set of safety standards on application of the management system concept. These standards are *GS-R-3 The Management Systems for Facilities and Activities* and *GS-G-3.1 Application of Management System for Facilities and Activities*.

The new set of Safety Standards directed to establish requirements and provide guidance for implementing Management Systems that integrate safety, health, environmental, security, quality, and economic objectives. The IAEA Code 50-C-Q (1996) and developments within the International Organization for Standardization (ISO) ISO 9001:2000 and ISO14001: 1996 publications are considered in developing this comprehensive, integrated set of Management System requirements. Member States experience in developing, implementing and improving Management Systems is also taken into account.

The aim of the new set of Safety Standards is to provide requirements and guidance for implementing an effective Management System that:

- Integrates all aspects of managing nuclear installations and activities including the safety, health, environmental, security, quality and economic requirements in a coherent manner,
- Describes the planned and systematic actions necessary to provide adequate confidence that all these requirements can be satisfied, and
- Supports the enhancement and improvement of organizational and safety culture.

This integration aims to ensure that economic, environmental, health, security and quality matters are not considered separately to safety matters, to avoid any potential negative impact on safety.

IAEA GS-R-3 establishes management system requirements at the interface between the operator and interested parties, who may be regulators, suppliers, customers, or other interested parties. IAEA GS-R-3 requirements apply to both regulators and operators. IAEA GS-R-3, together with its supporting Safety Guides supersedes IAEA Safety Series No. 50-C/SG-Q, Quality Assurance for Safety in Nuclear Power Plants and other Nuclear Installations, which was used, directly or indirectly, to establish quality assurance nuclear safety requirements at the nuclear installation owner/operator–regulator interface. IAEA GS-R-3 requirements correspond to, and supersede, the requirements in the Code in 50-C/SG-Q, the part of the safety standard and guide to which hereinafter we refer to as 50-C-Q.

What is new in the safety standards on management systems?

The detailed comparison of GS-R-3 and 50-C-Q showed that there are clear commonalities and also differences between the two standards.

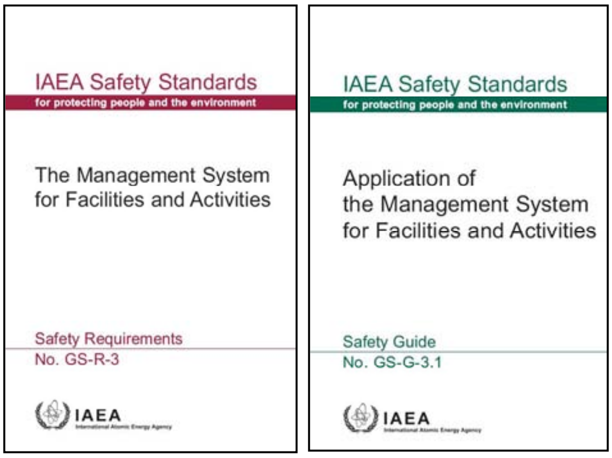
It is important to mention that both safety standards seek to ensure that safety is enhanced and not compromised. IAEA GS-R-3 defines requirements to help an organization establish, implement, assess and continually improve a management system that integrates safety, health, environmental, security, quality and economic elements, to foster a strong safety culture and improve safety performance, in all the activities of the organization. 50-C-Q defines requirements to help an organization establish and implement a quality assurance programme to enhance nuclear safety by continuously improving the methods employed to achieve quality.

Both IAEA GS-R-3 and 50-C-Q are used by regulatory bodies to set requirements that the management systems of operators of nuclear facilities or organizations conducting nuclear activities must fulfill to provide assurance of adequate safety, to regulatory bodies. IAEA GS-R-3 also is based on the principle of the integrated management system, which includes all factors affecting the activities and safety performance of an organization. It specifies requirements designed to achieve and enhance safety, while enhancing the satisfaction of interested parties.

Safety culture and human performance are important management principles in IAEA GS-R-3; they are part of the focus of the standard. Risk management is another important management principle included in IAEA GS-R-3.

IAEA GS-R-3 requires an integrated process approach that involves proactive strategic thinking and planning, integrating all goals, strategies and objectives, while the emphasis of 50-C-Q is on performance and the operational level of product 'quality assurance.'

50-C-Q has no requirement to integrate safety, health, environmental, security, quality and economic elements



Management system document cover pages

of the management system to ensure that safety is properly taken into account in all activities of the organization. Also, although 50-C-Q recognizes and uses the process approach, the involvement of people, and continual improvement, it neither develops nor requires the implementation of these principles to the extent that IAEA GS-R-3 does. The other principles do not figure prominently at all in 50-C-Q.

IAEA GS-R-3 is applicable to the establishment, implementation, assessment and continual improvement of management systems for:

- Nuclear facilities;
- Activities using sources of ionizing radiation;
- Radioactive waste management;
- The transport of radioactive material;
- Radiation protection activities;
- Any other practices or circumstances in which people may be exposed to radiation from naturally occurring or artificial sources;
- The regulation of such facilities and activities.

GS-R-3 is applicable throughout the lifetime, from siting to decommissioning, of these facilities and for the entire duration of these activities.

50-C-Q is intended for use in the establishment and implementation of quality assurance programmes for the stages of siting, design, construction, commissioning, operation, and decommissioning of nuclear power plants. Appropriate modification is required to apply the basic quality assurance requirements specified in 50-C-Q to nuclear installations other than nuclear power plants.

The promotion of and support for a strong safety culture is an integral part of the integrated management system described in IAEA GS-R-3; safety culture is not a requirement of 50-C-Q.

IAEA GS-R-3 has a broader view of leadership and management responsibility than 50-C-Q. In IAEA GS-R-3, senior management has a number of responsibilities not specified in 50-C-Q; they include:

- developing individual values, institutional values and behavioral expectations for the organization to support the implementation of the management system and acting as role models in the promulgation of these values and expectations;
- communicating to individuals the need to adopt these values and expectations;
- fostering the involvement of all individuals in the implementation and continual improvement of the management system;
- developing organizational policies;
- establishing goals, strategies, plans and objectives that are consistent with the policies of the organization; and
- developing the goals, strategies, plans and objectives of the organization in an integrated manner so that their collective impact on safety is understood.

IAEA GS-R-3 has more detailed and specific requirements on senior management to determine and provide the resources necessary to carry out the activities of the organization and to establish, implement, assess and continually improve its management system. 50-C-Q merely requires the quality assurance programme to address resource considerations and to demonstrate the principle of management providing resources.

Both standards treat work as a process but IAEA GS-R-3 adopts the process approach more explicitly, with detailed requirements for process development and management, without equivalent ones in 50-C-Q.

Integration of the IAEA resources in the area of management systems

In order to enhance the effectiveness and efficiency of the IAEA work programmes, the department of Nuclear safety and department of Nuclear Energy merged budgets and programmes in the areas of Management Systems, Management for Safety and Safety Culture. The purpose of this joint programme is to enhance Member States' capabilities to maintain and improve the safety and overall performance of nuclear facilities through the establishment and implementation of integrated management systems; it integrates safety as the paramount objective in all processes and fosters the development of a strong safety culture. NS has been appointed to lead and coordinate the joint programme.

In order to achieve this goal, five main objectives have been identified in the areas of Management Systems, Management for Safety and Safety Culture:

- To finalize the ongoing safety standards and establish supportive documents (Safety Reports Series, Guidelines, NE Series documents, Technical Report Series, IAEA-TECDOC, etc.) related to management systems and safety culture;
- To promote the current and future standards;
- To provide safety review services to Member States;
- To provide assistance and support to nuclear organizations in the enhancement of management systems and safety culture;
- To foster information exchange with Member states as well as with other international organisations.

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Developments to Help Achieve New Nuclear Energy Application

The changing global environment of increasing energy consumption and need for energy security is influencing the type of and means for obtaining the resources (material, human and financial) necessary for nuclear power projects. The effects of issues such as financing arrangements for capital intensive plants, international design approval/evaluation, harmonization of codes and standards, and assurance of fuel cycle services need to be considered.

The development of a Nuclear Energy Series Report on Issues Improving Prospects for Financing Nuclear Power Projects has been initiated. The Report will provide a review and practical approaches on the effects of infrastructure developments and other related topics upon reducing investment risks, and the actions possible that may improve prospects for financing nuclear power projects.

The introduction of nuclear power opens new challenges to Member States starting nuclear programmes for the first time, and these challenges are connected to the need to support the expansion in the areas such as infrastructure, human, financial and industrial resources.

The IAEA addressed this concern in recent publications such as "Considerations to launch a NP programme", the Guide on "Milestones in the development of a national infrastructure for nuclear power" and other documents. All of them reflect the needed change in the focus of the IAEA's support and concern. In the current period the support needed by Member States is directed to building up the capabilities of organisations that will be responsible for implementation of nuclear programs.

The development of a Nuclear Energy Series Guide on responsibilities and competences of the nuclear implementing organizations to initiate nuclear program has been started. This document will provide practical guidance on the responsibilities, competences and interfaces by the designated implementing organisation (possible future owner/operator) in a country initiating a nuclear power programme and on the attributes that will enable the future owner operator to achieve these.

New web based NEPIS database

Nuclear Economic Performance Information System (NEPIS) includes detailed NPP annual operation, maintenance with and without outage costs. Users can do analysis and benchmarking with it. This database is sharing between IAEA and Electric Utility Cost Group, USA based on the agreement. It is open for participation to all NPP operators and utilities in the world, which are committed to provide data relevant to the database. Recently, the NEPIS database was updated to a web based application, which will be more effective and convenient to use. A TM is planning to hold in Dec. 2007 to discuss the implementation of the new web based database and the development of the two new models: NPP capital costs and staffing cost due to the requests from MS.

The Evolution of Improvements in Training and Performance of NPP Personnel

As the end of the current programme and budget cycle is now in sight, by December we are expecting approval for publication of the following documents:

- A Guidance-level Nuclear Energy Series document on human resources in the field of nuclear energy (including the approach to systematic building and maintaining the competence of personnel, selection, training and qualification, performance improvement, and relationships with education and knowledge management). This document will provide the framework for the planned updating of IAEA documents in this area; and will serve for both operating and newly established nuclear industries.
- A Report-level NE Series document on human resource management and training issues related to commissioning of NPPs. This document provides a summary of lessons learned from recent NPP commissioning experience in a number of Member States.
- A Report-level NE Series document on increasing training effectiveness and improving organizational performance in nuclear facilities. This document is targeted for nuclear facility managers.
- A Report-level NE Series document on implementing a code of ethics for nuclear industry operating organizations. In this newsletter we are choosing to focus on this topic, as formal business ethics programmes are relatively new.

A code of ethics is a standard that governs and guides ethical behaviour for an organization of: its employees, and also of interactions between the organization and its external stakeholders. Although a handful of companies have had codes of ethics for twenty to thirty years, the majority of business ethics programs are no more than a few years old. In the past 10 years there has been a significant increase in large and multi-national organizations that have codes of ethics and business conduct. In many Member States and particularly for multi-national organizations, having a code/policy on ethics is now considered one of the hallmarks of a well managed organization.

The environmentally benign aspects of nuclear power, compared to alternative energy sources are important to our society for sustainability. Nuclear power can contribute to the responsible use of natural resources and the abatement of climate change. However, nuclear industry operating organizations are also aware of the serious hazards associated with nuclear facilities and the importance of not violating the trust that society has placed in them. Thus, the only one way to do business as a nuclear industry operating organization; is with high ethical standards in all respects. The lifetime of nuclear facilities can be 60 years or more. Taking into account the management of spent fuel and radioactive waste, the period to consider is even longer. This makes the long term sustainability of nuclear industry operating organizations particularly important for society.

The graphic below illustrates that a nuclear industry operating organization's culture and ethics provide the basic foundation for its management systems processes. The culture of the world's nuclear industry is that the operating organization is always responsible for the safety and security of its facilities, even if the implementation of some activities is delegated to others.

Thus, the health and safety of its employees, subcontractors, and the public, as well as protection of the environment needs to be a fundamental basis for a nuclear industry operating organization. This graphic also illustrates the strong linkages between the leadership of the organization, its culture and ethics, and its management system. Top managers and leaders influence the culture and ethics of the organization in what they say, but even more importantly in what they do, and what they monitor regarding the organization's performance.

The following are examples of the behaviours that are particularly important for nuclear facility operating organizations:

- Adopt a conservative, risk-based approach to decision making;
- Always place safety before commercial gain;
- Accept personal responsibility for own and others' safety;
- Integrate safety and environmental considerations into business practices;
- Ensure that there are effective mechanisms for communication between the Board and operational level managers in order that Board-level decision making is done with appropriate consideration of safety and environmental risks;
- Communicate openly and honesty with regulators, employees and all other stakeholders;
- Maintain a "blame-free" reporting culture that encourages full reporting of unsafe or unethical practices, incidents and near misses, and that uses this information to continually improve the organization;
- Openly share operating experience information with other industry operating organizations, including benchmarking, and make effective use of the experiences of others, while respecting commercial confidentiality;
- Participate objectively and honestly in local, national and global discussions and policy making processes regarding energy supply decisions
- Bribery and corruption are not tolerated at any level, or in any area of the organization;
- Materials, technology, and information regarding nuclear activities are not illegally sold or distributed, or otherwise misused;
- Being a good neighbour to, and supporter of, the local community, including advising them of measures taken to protect their health and safety, and the local environment.

All of these behaviours need to be based upon the values and ethics of the organization.

This document is intended to:

- explain the benefits for nuclear industry operating organizations of having a well functioning code of ethics;
- propose areas that should be considered for inclusion in a nuclear industry operating organization's code of ethics, and
- explain how to develop, implement and sustain such a Code.

This document is addressed primarily to senior managers of nuclear industry operating organizations, as experience has shown that, in order to succeed, such initiatives need to come from and be continually supported by the highest levels of the organization. An organization's code of ethics should apply to behaviours at all levels of the organization; from the Board Room to the working level.

For further information regarding the above, please contact T.Mazour@iaea.org or A.Kazennov@iaea.org.

Coordination of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)

INPRO - Six years of development

The 21st century promises the most competitive, globalized markets in human history, the most rapid pace of technological change ever, and the greatest expansion of energy use, particularly in developing countries. As the IAEA Director General said, technological and institutional innovation is a key factor in ensuring the benefit from the use of nuclear energy for sustainability. (50th General Conference, September 2006).

INPRO provides an open international forum for studying the nuclear energy option, its associated requirements and its potential application deployment in IAEA Member States. INPRO helps to make available adequate competence to the development and deployment of Innovative Nuclear Energy Systems (INSs) and to assist Member States in the coordination of related Collaborative Projects.

Since its onset, its members grew to the current number of 28 (as at end of July 2007).

INPRO's initial activity (phase 1: 2001-2006) focused on the development of assessment methodology which can be applied for screening an Innovative Nuclear Energy System (INS), comparing different INS to find a preferred one consistent with the sustainable development of a given state, and identifying RD&D needs.

INPRO takes a holistic approach to assess INS in seven areas (Economics, Safety, Waste Management, Environment, Proliferation Resistance, Physical Protection and Infrastructure Issues (See Annex) so that INPRO may facilitate decision making and the implementation process for satisfying future energy needs in a sustainable manner through development and deployment of INS. Currently 9 assessments using this methodology are being carried out.

Mr. Y. Sokolov, INPRO Project Manager, is responsible for the overall implementation of the project, defines the key strategic and policy issues relevant for INPRO and makes a final decision on the scope, contents and methods of work within the project. He is supported by a Policy Coordinator (Mr. A. Omoto) and two Technical Coordinators (Messrs A. Rao and Ch. Ganguly). They are also supported by INPRO Area Coordinators, that provide effective assistance and coordination, both in-house and external, and by the International Coordinating Group (ICG) for the planning, implementation and documentation of INPRO activities within their responsible Areas of Economy, Safety, Waste Management, Environment, Proliferation Resistance, Infrastructure and Physical Protection.

INPRO team

The INPRO Steering Committee, consisting of representatives nominated by the INPRO Members is a decision-making organ on key issues of the project, such as future direction and action plan. In its 11th meeting held in July 2007, INPRO Members endorsed 14 Collaborative Projects to be developed in phase 2 and the most relevant aspects of the INPRO Action Plan 2008-2009.

INPRO activities in Phase 2 include the following tasks:

a) Support to Members on the application of methodology

The IAEA facilitates and assists Member States in the use of INPRO "Methodology" for assessing and selecting INS according to sustainable development and in the corresponding training of national staff.

Currently there are 9 ongoing assessment studies:

- Joint assessment based on a closed fuel cycle with sodium fast reactors (Russian Federation, Canada, China, France, India, Japan , Republic of Korea and Ukraine);
- Assessment of hydrogen generating INS in national energy mix (India);
- Assessment on the transition from the current NPP fleet towards Generation IV fast neutron systems (France);
- Assessment of additional nuclear generation capacity in the country for the period 2010-2025 for the evaluation of NFC strategies (Argentina);
- Assessment of INS for countries with a small electricity grid (Armenia);
- Assessments of different reactor concepts (Brazil);
- Assessment of advanced HTGR (China);
- Assessment of national INS (Ukraine); and
- Comparison assessment between fast reactors cooled by sodium and by lead/lead-bismuth (European Commission).

A set of manuals are scheduled to be published soon in order to enable a user to perform an assessment of an Innovative Nuclear Energy System using the INPRO Methodology.

b) Development of a vision on scenarios for nuclear energy development

The INPRO vision activity will develop a holistic perspective on the contribution of INS to a sustainable development and will identify opportunities and challenges on a global and regional scale in the long run. INPRO members can translate the vision into their national nuclear policies to assure that the nuclear energy is a viable and a sustainable option in their countries.

c) The IAEA is providing Support to Member States' capacity building and decision making

IAEA provides qualified analytical tools necessary to evaluate the opportunities and challenges facing INS. This will include consideration of how global energy resources may influence the national decisions on future nuclear energy systems. The IAEA provides training support to INPRO methodology users through workshops.

d) Infrastructure and institutional areas

INPRO will monitor and propose, upon necessity, arrangements on nuclear infrastructure that would facilitate the development and deployment of INS, integrating the potential synergies with other international initiatives. These arrangements may address issues such as regional approach to smooth deployment of INS, licensing and financing for developing countries.

e) Collaborative Projects

The IAEA will coordinate and support INPRO Collaborative Projects identified by INPRO Members to a commonly study enabling technologies and approaches to topics of major interest.

f) Common User Criteria/Requirements

The IAEA will identify common user requirements and criteria from developing countries with respect to the reactor systems necessary in the 21st century, focussing on small and medium sized reactors, and potentially establishing joint actions by technology holders and users for development and deployment of such reactor systems.

Fourteen Collaborative Projects, as Joint Initiatives (JI), were currently proposed by INPRO members and they were endorsed in the 11th Steering Committee meeting of INPRO (July 2007). They can be categorized in the following groups:

Scenarios of Nuclear Energy development

- Global architecture of INS operating in closed fuel cycle and using both thermal and fast reactors (GAINS);
- Scenarios in the period of raw materials insufficiency during the 21st century.

Safety issues

- Performance assessment of passive gaseous provisions (PGAP);
- Safety issues for advanced high temperature reactors and their combined operation with hydrogen producing plants;
- Safe operation in a power system having limited capacity.

Proliferation Resistance

- Acquisition/diversion pathway analysis for the assessment of proliferation resistance.

Technical challenges in Reactor technologies

- Technological challenges of liquid metals and molten salts used as coolants of advanced high temperature reactors, accelerator driven systems (ADS) and fast reactors (FR);
- Advanced water cooled reactors;
- Integrated approach for the design of the decay heat removal system of Liquid Metal Reactors.

Environment & Nuclear Fuel Cycle &Infrastructure

- Methodologies for ranking radionuclides from nuclear reactors, based on their environmental impact on humans;
- Options for management of spent nuclear fuel and radioactive waste in a small country;
- Legal, institutional and technical issues of introduction of movable NPPs with small and medium sized reactors in the developing countries;
- Further investigations of the 233U/Th fuel cycles;
- Joint assessment on advanced and innovative nuclear fuel cycles used in the INSs based on closed fuel cycle.

INPRO Web page: http://www.iaea.org//INPRO.

Technology Development for Advanced Reactors

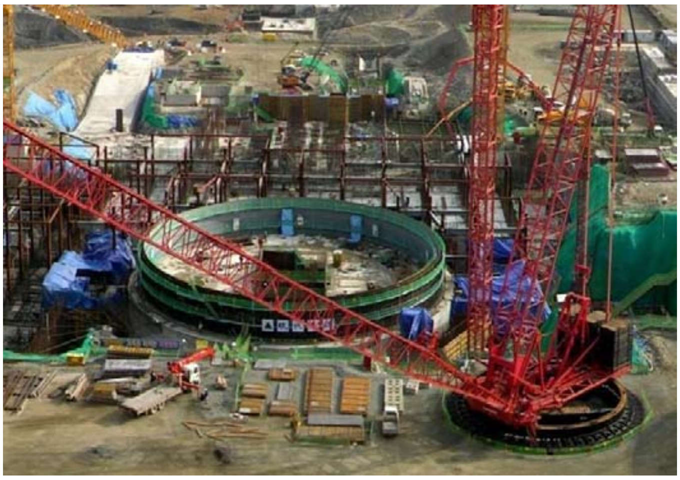
Advanced Technologies for Water-Cooled Reactors

IAEA's Project in Advanced Technologies for Water-Cooled Reactors has evolved from an initiative in 1987 by then Director General Hans Blix. At that time, just after the Chernobyl accident, Dr. Blix formed the International Working Group on Advanced Technologies for Water Cooled Reactors, stressing that this initiative would provide a forum for Member States to exchange information on technological developments incorporating enhanced safety features and on advanced technologies and new concepts for water cooled reactors. Considerable collaboration was carried out within the frame of this International Working Group, and in 1995, at the suggestion of then Chairman of the IAEA Board of Governors, and Chairman of the Atomic Energy Commission of India, Dr. Chidambaram, it was realized that the intense collaboration desired by the Member States warranted the establishment of two Groups, addressing respectively Advanced Technologies for LWRs and Advanced Technologies for HWRs, which would collaborate in areas of common technologies of interest to both Groups.

Construction of Olkiluoto-3 (2007) [credit: Teollisuuden Voima Oy (TVO)]

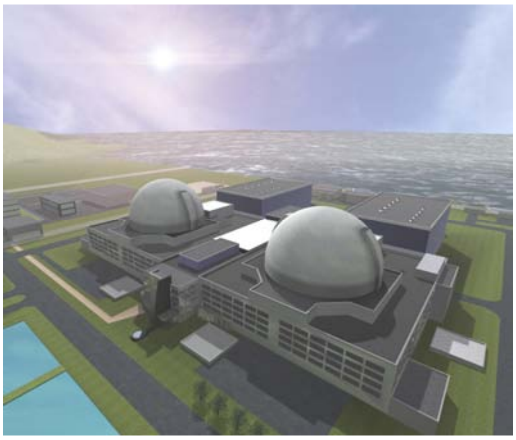
Presently, the two Groups, now called the Technical Working Groups on Advanced Technologies for LWRs and HWRs (the TWG-LWR and the TWG-HWR) focus on technology development for improving the economics of water-cooled reactors, while meeting stringent safety objectives. The most recent meetings, convened with some joint sessions to address common technological issues, were the 13th meeting of the TWG-LWR and the 9th meeting of the TWG-HWR, convened in June, 2007.

Construction Site at Kudankulam, India of two evolutionary WWER-1000 Units [credit: Nuclear Power Corporation of India (NPCIL)]



Construction of OPR-1000 at Shin-Kori, Rep. of Korea [credit: Korea Hydro & Nuclear Power (KHNP)]

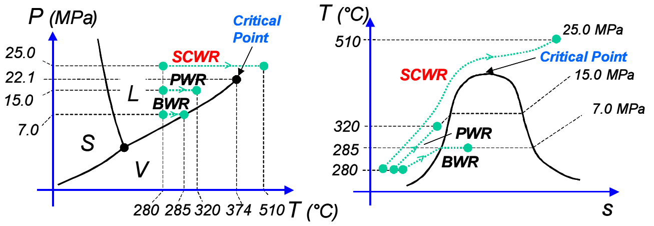
On the advice, and with the support of the IAEA Department of Nuclear Energy's TWG-LWR and the TWG-HWR, the IAEA conducts activities on international information exchange, co-operative research and collaborative assessments of advanced water-cooled reactor technology. Also, to provide balanced and objective information on technology status and development trends to all Member States, the IAEA periodically publishes Status Reports on advanced LWR and HWR designs. The IAEA recently published a Status Report on Advanced LWR Designs (IAEA-TECDOC-1391), a Report on the Status and Projected Development of HWRs (TRS-407), and a report on recent Construction and Commissioning Experiences with Evolutionary Water-Cooled NPPs (IAEA-TECDOC-1390). Further, a Collaborative Assessment has reviewed proven means and new approaches for reducing capital cost of new plants while meeting stringent safety requirements (IAEA-TECDOC-1290).



Artist's concept of Advanced CANDU Reactor - ACR-1000 (credit: AECL)

A new approach to improve economics through plant simplification involves development of passive safety systems based on natural circulation. To facilitate cooperation on this approach, the IAEA is conducting a Coordinated Research Programme (CRP) on natural circulation phenomena, modelling and reliability of passive systems, and has published a document on the present state of knowledge of natural circulation (IAEA-TECDOC-1474).

Another approach involves development of systems with higher thermal efficiency. In a collaborative effort to support development of Super-Critical Water Cooled Reactors (SCWRs), the IAEA is organizing a new CRP on heat transfer and thermo-hydraulics code testing for SCWRs.



Thermodynamic cycle of Super-Critical Water-Cooled Reactors, compared to current day Pressurized Water Reactors and Boiling Water Reactors

Other activities include cooperation on validation of thermo-hydraulics codes (IAEA-TECDOC-1395); establishment of a thermo-physical properties database for LWR and HWR materials (www.iaea.org/THERPRO; and IAEA-TECDOC-1496); and inter-comparison of inspection and diagnostic techniques for pressure tubes of HWRs (IAEA-TECDOC-1499).

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Helping Member States to Improve Capability in Technology Assessment

An increasing number of Member States have turned to IAEA for information and assistance regarding possible establishment or expansion of their nuclear power programme. As part of the IAEA's response to these requests, the Nuclear Power Technology Development Section is organizing a Technical Cooperation workshop on the process of conducting Nuclear Power Plant (NPP) Technology Assessment.

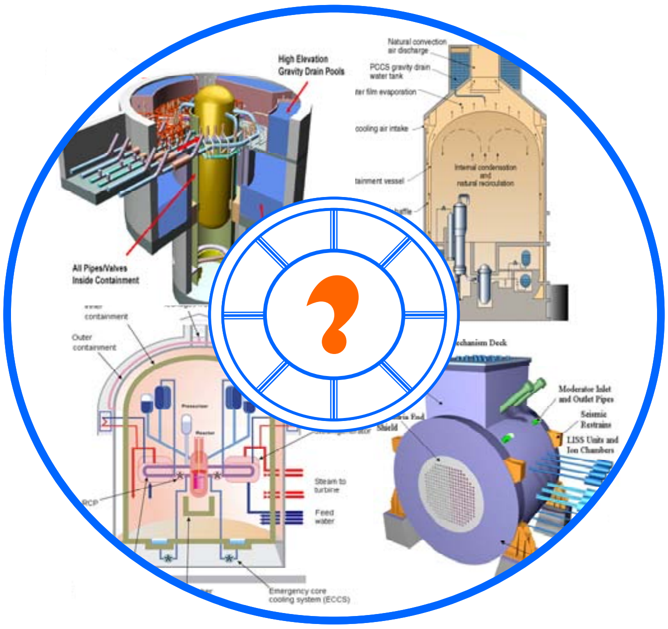
Technology Assessment is an exercise conducted by a country to determine, in general, which NPP technologies and plant concepts are suitable for the country so that they should be retained for further evaluation for introduction to the country. Technology Assessment also provides the technical basis for several elements of infrastructure development, including assessment of national capabilities, defining the degree of national technical and industrial participation in the NPP programme; identification of appropriate sites for the NPP; and establishment of a fuel cycle policy. The Technology Assessment thus becomes the technical basis for preparation of bid documents in a subsequent stage.

The workshop will be conducted in Vienna on October 22-25, 2007. Relevant experts from within and outside IAEA and potential users of NPP technologies will come together to exchange information and discuss the approach and process of planning and conducting Technology Assessments. The following will be parts of the discussions:

- Development of National Criteria and specifications for NPP;
- Assessment of NPP designs and plant concepts against the National Criteria and specifications, and identification of factors contributing to the success of NPP programme;
- General concerns and needs of Member States in planning to conduct Technology Assessments

The workshop will not be concerned with which designs are "best candidates" for any country – rather the workshop will examine the steps and approaches for successfully conducting Technology Assessment.

Additional applications with endorsement from national authorities are welcome. For further information please contact Workshop Director Mr. Ray Sollychin (R.Sollychin@iaea.org) or Technical Cooperation Project Officer Mr. Alain Cardoso (A.Cardoso@iaea.org).



How to make assessment of NPP Technology

Technology Advances in Fast Reactors and Accelerator Driven Systems

IAEA's project on "Technology Advances in Fast Reactors and Accelerator Driven Systems" has evolved from an initiative in 1967 by then Director General Sigvard Eklund. Eklund's initiative in response to a growing interest expressed by Member States was to establish the "permanent International Working Group on Fast Reactors (IWG-FR) under IAEA auspices" to provide a framework for international information exchange in this area.

An important extension of the IWG-FR's work scope occurred in 1994 upon an initiative of then Director General Hans Blix, resulting in the inclusion of fast neutron sub-critical systems driven by external sources [e.g. Accelerator Driven Systems (ADS)] for energy production and transmutation into the work scope of the IWG-FR, which, in 2001, was renamed Technical Working Group on Fast Reactors (TWG-FR).

Today and in the years to come, the TWG-FR will assist in formulating an international vision applicable, on the one hand side, to current and innovative fast reactors, and, on the other, to sub-critical hybrid systems for energy production and utilization/transmutation of long-lived radioactive nuclides. The defining elements of this vision are threefold: improved economics – fundamental to all successful technology advances; sustainable development – in which resource utilization and waste management strategies lead to advanced fuel cycles, including those based on the utilization of thorium; and enhanced safety – maintaining current high levels with increased simplification, and passive systems.

Consistent with the vision, the TWG-FR assists in defining and carrying out IAEA's activities in the field of nuclear power technology development for fast reactors and sub-critical hybrid systems, in accordance with its Statute. It promotes the exchange of information on national and multi-national programs and new developments and experience, with the goal of identifying and reviewing problems of importance and stimulating and facilitating cooperation, development and practical application of fast reactors and sub-critical hybrid systems. Finally, the TWG-FR provides Member States with information about the current status and development trends of advanced technologies for fast reactors and sub-critical hybrid systems.

The scope of the TWG-FR includes:

- Design and technologies for current, evolutionary and innovative fast reactors (experimental, prototype or demonstration, and commercial size fast reactors) and sub-critical hybrid systems, including non-sodium cooled fast reactors and sub-critical hybrid systems;
- Economics, performance and safety of fast reactors and sub-critical hybrid systems;
- Advanced fuel cycles and fuel options for the utilization and transmutation of actinides and long-lived fission products, including the utilization of thorium.

The scope of the TWG-FR is broad, covering all technical aspects of fast reactors and sub-critical hybrid systems research and development, design, deployment, and operation. This coverage will generally be in an integrative sense to satisfy the fast reactor and hybrid systems communities that all key technology areas are covered. Many specific technologies are addressed in detail by other projects within the IAEA and in other international organizations. The TWG-FR keeps abreast of such work, avoids unproductive overlap and engages in cooperative activities with other projects where appropriate. The TWG-FR is coordinating its activities with other IAEA projects, e.g. INPRO, those of the Technical Working Group on Nuclear Fuel Cycle Options (TWG-NFCO), and the Department of Nuclear Safety, in interfacing areas, as well as with related activities of other international organizations (e.g. OECD/NEA, EC-JRC, ISTC, JINR).

The fast reactor, which can generate electricity and breed additional fissile material for future fuel stocks, is a resource that will be needed when economic uranium supplies for the advanced light water reactors or other thermal-spectrum options diminish. Further, the fast-fission fuel cycle in which material is recycled offers the flexibility needed to contribute decisively towards solving the problem of growing ”spent” fuel inventories by greatly reducing the volume of high-level waste that must be disposed of in long-term repositories. This is a long-term waste management option that demands particular attention. In recognition of the fast reactor’s importance for the sustainability of the nuclear option, there is renewed interest worldwide in fast reactor technology development, as indicated by various national and international projects and by increasing funding levels. Accordingly, the IAEA is responding, through its project on “Technology Advances in Fast Reactors and Accelerator Driven Systems”, to expressed Member States needs in the area of fast neutron systems research and technology development through international information exchange and collaborative R&D activities initiated within the framework of the TWG-FR.

Major ongoing and planned (over the next 4 – 6 years) activities include various Coordinated Research Projects (CRPs).

Noteworthy is an ongoing CRP having the objective of studying the calculational uncertainties of fast reactor reactivity coefficients and the possibility to improve the capabilities of the codes in view of the reduction of these uncertainties.

Another CRP is focusing on the preservation of the feedback from commissioning, operation, and decommissioning experience of experimental and power sodium cooled fast reactors. This CRP will produce lessons-learned/synthesis reports from the commissioning, operation, and decommissioning of experimental and power sodium cooled fast reactors.

In another CRP (titled “Studies of Advanced Reactor Technology Options for Effective Incineration of Radioactive Waste”), the participants are studying the transient behavior of various transmutation systems. The comparative investigations cover burner reactors and transmuters both containing fertile and fertile-free, so-called “dedicated” fuels.

Recently, a CRP on “Analytical and Experimental Benchmark Analyses of Accelerator Driven System” was launched. The specific objective of this CRP is to improve the present understanding of the coupling of an external neutron source (e.g. a spallation source in the case of the ADS) with a multiplicative sub-critical core. The participants in the CRP are performing computational and experimental benchmark analyses using integrated calculation schemes.

The scope of two other CRPs will include experimental research at two prototype fast reactors, viz. MONJU in Japan and PHENIX in France. The former CRP, titled “Benchmark Analyses of Sodium Natural Convection in the Upper Plenum of the MONJU Reactor Vessel” addresses the natural convection behavior of the coolant in the reactor vessel of a sodium cooled fast reactor. The CRP participants will perform benchmark exercises focusing, in a first stage, on the numerical simulation of the sodium stratification measurements performed in the MONJU reactor vessel during the original start-up experiments. The latter CRP will be centered on experiments planned before the final shutdown of PHENIX foreseen for 2008 – 2009. At this occasion, the French Commissariat à l'Énergie Atomique (CEA) is planning to implement a PHENIX end-of-life tests program, which includes the systematic and comprehensive collection of the expertise gained in the field of material science and technology from 35 years of PHENIX operation. CEA, recognizing the unique opportunity offered by the PHENIX end-of-life tests program, is ready to open it for international collaboration within the framework, inter alia, of this CRP. The CRP will contribute towards enhancing participating Member States’ analytical tools in the fields of neutronics, thermal hydraulics and mechanics. Moreover, it will provide valuable material behavior data (e.g. material properties, irradiation damage mechanisms, etc), and it will advance the demonstration of technology (validation of materials and components) for, and safety (inherent safety features, verification of design limits, etc) of fast reactors.

280 MWe Fast Reactor MONJU, Tsuruga, Japan (courtesy of JAEA)

233 MWe Fast Reactor PHENIX, Marcoule, France (courtesy of CEA)

Last but not least, it is worthwhile noting that the IAEA project on "Technology Advances in Fast Reactors and Accelerator Driven Systems" will continue fostering the exchange of technical information (by providing up-to-date status reports on fast reactor and transmutation systems technology developments and convening Topical Technical Meetings, Workshops, Symposia and Conferences), and maintaining scientific and technical databases relevant to fast neutron systems technology, viz. the "Fast Reactor Database" and the "Accelerator Driven Systems Database".

For more information see http://www.iaea.org/inisnkm/nkm/aws/fnss/index.html.

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Common Technologies and Issues for Small and Medium Sized Reactors

There is continuing interest in Member States in the development and application of small and medium sized reactors (SMRs). "Small" reactors are defined as those with an equivalent electric power less than 300 MW(e). "Medium sized" reactors are those with an equivalent electric power between 300 and 700 MW(e). In the near term, most new nuclear power plants (NPPs) are likely to be evolutionary water cooled reactor designs building on proven systems while incorporating technological advances and often taking advantage of economics of scale. Currently such designs range up to 1600 MW(e). For the longer term, there is interest in innovative designs that promise improvements in safety, security, proliferation resistance, waste management, resource utilization, economics, product variety (e.g. desalinated seawater, process heat, district heat and hydrogen) and flexibility in siting and fuel cycles. Many innovative reactor designs have been proposed in the small-to-medium sized range. In most cases, they are intended for markets different from those in which large nuclear power plants currently operate, i.e. markets that value more distributed electrical supplies, a better match between supply increments and demand growth, more flexible siting or greater product variety.

For about a dozen innovative SMR designs, current progress in developing the technology and finalizing the design suggests possible deployment within the next decade. Construction began in June 2006 in the Russian Federation on a pilot floating cogeneration plant of 400 MW(th)/70 MW(e) with two water cooled KLT-40S reactors. Deployment is scheduled for 2010. In July 2006, the Russian Federation and Kazakhstan created a joint venture to complete design development for a 350 MW(e) VBER-350 reactor (basically a scaled-up version of the KLT-40S) for use in either floating or land-based co-generation plants. They also agreed to promote nuclear power plants using such reactors in both domestic markets and on the global market. Three integral PWR designs are in advanced design stages and commercialization could start around 2015: the 335 MW(e) IRIS design developed by International consortium led by Westinghouse of USA (currently co-owned by Toshiba Corp. of Japan); the SMART design developed in the Republic of Korea; and the prototype 27 MW(e) CAREM developed in Argentina, for which construction in scheduled to be complete by 2011. The 165 MW(e) PBMR, developed in South Africa, is scheduled for demonstration at full size by 2012. Additional designs from France, India, Japan and the Russian Federation may also be demonstrated and proven on similar timescales, thus providing several potential choices to interested countries in the intermediate term.

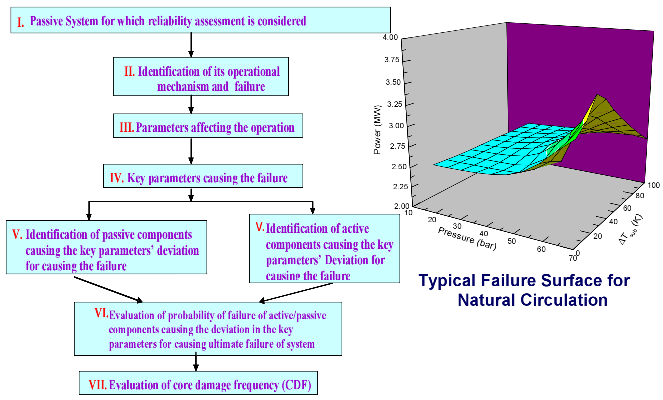
Some small reactor designs incorporate an option of operation without on-site refuelling, which may help reduce the obligations of a user for spent fuel and waste management. Two of such designs might be ready for deployment within the next ten years. The concept that has reached the detailed design stage is the Russian 101.5 MW(e) lead-bismuth cooled SVBR-75/100 with a refuelling interval of 6̃9 years. This design benefits from 80 reactor-years of operating experience with reactors of this type in the Russian submarine fleet and is relatively flexible in terms of both applications and fuel cycle options. Russia's utility Rosenergoatom is supporting further development of this design with prototype deployment being targeted for 2017. In Japan, the Toshiba Corporation, in cooperation with the Central Research Institute of Electric Power Industry (CRIEPI) and several other organizations, is developing the 4S sodium cooled reactor. It has a design power of 10-50 MW(e), a refuelling interval of 10-30 years, and a design that allows the power to be controlled by adjusting the feedwater flow rate in the steam-turbine circuit. The conceptual design and major parts of the system design have been completed. A pre-application review by the US NRC is targeted for the near future. Construction of a demonstration reactor and safety tests are planned for early next decade.

Reflecting on the developments in Member States, the IAEA carries out a dedicated project "Common Technologies and Issues for SMRs"; it has an objective to ensure progress in the development of key enabling technologies and in the resolution of enabling infrastructure issues common to SMRs of various types. Within this project, the IAEA periodically produces and updates Status Reports and other publications on design and technology development for such reactors (e.g., IAEA-TECDOCs-1485, 1487, and 1536 published in 2006-2007). The activities also include coordinated research projects (CRP) on important topics of design and technology development and assessment of various SMR options. A CRP "Small Reactors without On-site Refuelling" is ongoing with 17 participating institutions from 9 member states, and the research topics include source term calculations to justify reduced off-site emergency planning for SMRs, benchmarking for whole core depletion models of lead-bismuth cooled reactors, benchmarking for cells and fuel assemblies of light water reactors with coated particle based fuel, data and information exchange regarding fuel and coolant properties and progress in design development for the concepts addressed, and inter-regional and intra-regional scenario studies for energy systems with small reactors without on-site refuelling. Upon an arrangement with the NEA OECD, several participants of this CRP from non-OECD countries will participate in a benchmarking exercise for natural circulation of lead-bismuth coolant based on the tests performed in the HELIOS loop at the Seoul National University (the Republic of Korea), to be carried out in 2007-2008. A Web page of the CRP is at: http://www.iaea.org/NuclearPower/SMR/CRP1/.

A new Nuclear Energy Series report on "Review of Passive Safety Design Options for SMRs" is under preparation, which is, inter alia, to assist potential users of innovative SMRs in their evaluation of the overall technical potential of SMRs in various subject areas, such as safety, economics, siting, and operation. Structured descriptions of safety concepts/features for 10 advanced SMR concepts, following IAEA safety standards and representing 5 reactor lines, have been collected from 8 Member States, edited and reviewed; and the main chapters drafted and discussed at two dedicated technical meetings. The report, prepared in cooperation with the IAEA's Department of Nuclear Safety and Security, is to be submitted for publication by the end of 2007.

Specifically, the above mentioned report identifies the need to develop a common technology-neutral methodology for substantiation of passive system performance in advanced reactors. Reflecting on this, for 2008-2011, the IAEA has planned a CRP on "Development of Advanced Methodologies for Substantiation of Passive System Performance in Advanced Reactors", which would be conducted in cooperation with the Technical Working Groups for Advanced Light Water Reactors and Fast Reactors of the Department of Nuclear Energy and the Safety Assessment Section of the IAEA's Department of Nuclear Safety and Security. The objective of this CRP is to identify a consistent approach to substantiation of passive system performance, which would merge both the deterministic and the probabilistic aspects relevant to the topic in a time saving and cost-effective way, see Fig. 1. A detailed CRP proposal has been elaborated and submitted for clearance; seven research organizations from 6 Member States have confirmed their intention to participate.

A series of case studies to address competitiveness considerations for SMRs in different applications is ongoing with the development of a country-independent model to examine and quantify the need for SMRs; development and application of models to assist decision making of public and private investors regarding SMRs; and a generic study with an approach taking into account all economic factors affecting present value capital costs of SMRs. The collection of materials for a new Nuclear Energy Series Report "Approaches to Assess SMR Competitiveness" is near completion; the report is to be submitted for publication in 2008. To shape-up the conclusions and recommendations to this report, an IAEA technical meeting on "Options to Break the Economy of Scale for SMRs" will be convened in Vienna 15-18 October 2007.



A generic scheme of the APSRA advanced passive system reliability assessment methodology being developed at the Bhabha Atomic Research Centre (India)

Advances in Gas Cooled Reactor Technology

Gas-cooled reactor design concepts have been evolving since the 1940s and in recent years there have been a surge of global interest in their modular variants due to their promising features of enhanced safety and improved economics. Modular HTGR designs are currently considered one of the leading reactor concepts being considered for future nuclear power plant deployment. In addition to their high efficiency in electricity generation, HTGR designs are also well placed for co-generation of process heat, promising high thermal efficiency. Potential process heat applications include high-temperature applications such as hydrogen production and low-temperature applications, such as seawater desalination and district heating.

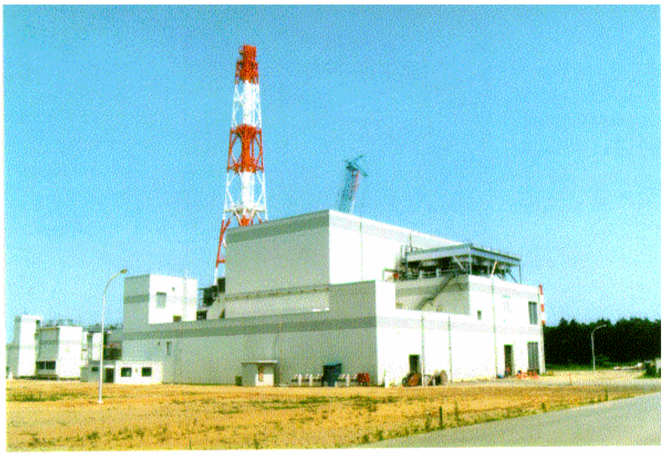
Since the 1970s, major IAEA HTGR activities have been conducted with advice and support from the Technical Working Group on Gas Cooled Reactors (TWG-GCR) and are directed towards the exchange of scientific and technical information between Member States to minimize design uncertainties and optimise inherent safety features. Current activities include three CRPs. CRP-5 on HTGR performance evaluation, which focuses on core physics and thermal-hydraulics benchmarking, CRP-6, which focuses on advances in HTGR fuel technology and a new CRP-7, which addresses the potential of HTGRs for process heat applications, including hydrogen production and seawater desalination. In addition, conferences, topical meetings, and training workshops are organized periodically to facilitate information exchange.

Members of the TWG-GCR, established in 1978 are China, Republic of Korea, France, Netherlands, Germany, Russian Federation, Indonesia, South Africa, Japan, Turkey, USA, United Kingdom.

On the international level, HTGR-related R&D projects are under way in several Member States, including South Africa, China, Japan, Russia, the US, countries of the European Union and the Republic of Korea.

In South Africa, PBMR (Pty) Ltd is accelerating its efforts on licensing work on a 165 MW(e) Pebble Bed Modular Reactor, which is expected to be commissioned around 2010. The South African government has already allocated initial funding for the project and orders for some lead components have already been made.

In China, work continues on safety tests and design improvements for the 10 MW(th) High Temperature Gas-cooled Reactor (HTR-10) and there are plans to design and construct a power reactor prototype (HTR-PM).



JAEA's High Temperature Engineering Test Reactor

In Japan, a 30 MW(th) High Temperature Engineering Test Reactor began operation in 1998 and work continues on safety testing and coupling to a hydrogen production unit. A 300 MW power reactor prototype is also under consideration.

Russia, in cooperation with the US, continues its research and development work on a 284 MW(e) Gas Turbine Modular Helium Reactor (GT MHR) for Plutonium burning.

France has an active R&D programme on both thermal as well as fast gas reactor concepts and in the US, efforts by the Department of Energy (DOE) continue on the qualification of advanced gas reactor fuel, with work being performed at major organizations such as the Idaho National Laboratory and Oak Ridge National Laboratory.

The IAEA is following progress of these activities, coordinating research and facilitating information exchange among Member States.

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Web site: http://www.iaea.org/htgr.

Support for Non-Electric Applications of Nuclear Power

Support for Demonstration of Nuclear Seawater Desalination

Worldwide, concern to alleviate water shortages has become high. Recent statistics show that more than 2.5 billion people live in water-stressed areas and among them 1.7 billion live in water-scarce areas, where the water availability per person is less than 1000 m3/year. The situation is even expected to worsen further. In 2025, the number of people suffering from water stress or scarcity is expected to be around 3.5 billion. It is for this reason that the Millennium Declaration by UN General Assembly in 2000 set up a target to halve, by the year 2015, the world population, which is unable to reach, or to afford, safe drinking water.

Seawater desalination has also been growing very rapidly. By the end of 2006, the total contracted capacity of all desalination technologies was about 38 million m3/day, of which 60% was for desalting seawater. Nuclear desalination of seawater has been considered as one of the suitable solution to meet the global water demand.

The desalination of seawater using nuclear energy was given attention ever since the awakening of nuclear power almost 6 decades ago. In fact, starting with the IAEA convened first symposium at Madrid in the late sixties, nuclear desalination has been recognized as a feasible option to meet the growing demand for potable water. Now, nearly 200 reactor-years of operating experience on nuclear desalination have been accumulated worldwide. All nuclear reactor types can provide the energy required by the various desalination processes.

First nuclear desalination plant, Aktau, Kazakhstan

New developments in nuclear desalination are numerous as many Member States have consistently progressed almost simultaneously in three technical fields: the development of improved or new generation nuclear reactors, the improvements in desalination technologies and the adoption of many cost reduction strategies. These developments have been discussed in detail in the recent IAEA publication on the “Status of Nuclear Desalination in Member States” [IAEA-TECDOC-1524].

Currently operating nuclear desalination plant: Ohi, Japan

An interesting feature of this development is that many Member States, normally not considered as exporting countries, have begun to develop their own nuclear reactors. This is, for example, the case for Argentina, which is developing the CAREM reactor. CAREM is a small sized integral PWR, for which the construction of a prototype is planned. China is pursuing the development of the dedicated heat only reactor NHR-200 providing relatively low-temperature heat for an MED process, with some electricity production to meet the local electricity needs. India is going along with a consistent evolutionary approach to develop its advanced PHWRs. The Republic of Korea continues with its programme to develop the System-integrated Modular Advanced Reactor (SMART), which is a small sized (330 MWth) integral type PWR, containing all major primary components in a single pressurized vessel. It is foreseen for a nuclear desalination project designed to produce 40 000 m3/day of potable water at one of the Korean sites.

Russia has acquired considerable experience in designing of cogeneration plants and nuclear desalination complexes based on floating power units (FPU) with advanced marine light water reactors. Analogues of such reactors are successfully operating on Russian nuclear ships and are serviced by a specially established infrastructure. Presently, construction of a nuclear power plant based on FPU with KLT-40S reactors has been started in Severodvinsk, Arkhangelskaya Region, Russia, development of the reactor design for new icebreaker is continued.

Floating nuclear power and desalination complex, Severodvinsk, Russia

With technical co-ordination or support of the IAEA, several demonstration programs of nuclear desalination are also in progress in several Member States to confirm its technical and economical viability under country-specific conditions. Through numerous IAEA activities, the DEEP software may become an international and consistent approach for desalination cost evaluations of both fossil and nuclear energy based systems. With the help of the DEEP software, several approaches have been proposed and studied in participating countries to reduce the cost of nuclear desalination. The first of these is the use of waste heat from nuclear reactors for desalination. For example, the waste heat rejected by the PWRs to the heat sink through their condensers can be profitably used to preheat the feed-water for Reverse Osmoasis (RO) systems resulting in up to 15% cost reductions as compared to traditional RO systems. Similarly, the waste heat from the pre-cooler and intercooler exchangers of the new generation high temperature reactors such as the GT-MHR and the PBMR, can lead to significant cost reductions in Multi-Effect Distillation systems.

MSF-Desalination unit on barge, Al-Taweelah, UAE

The trend of employing and utilizing nuclear energy for seawater desalination is expected to grow further in the coming 50 years. Many member states have declared their intentions to build nuclear desalination plants in their courtiers among them Algeria, Gulf Cooperation Council (including Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates), Jordan, Indonesia, Libya, and United Arab Emirates. Future developments in the thermal processes can be in areas such as:

- Use of high performance materials, development of high heat transfer alloys for the tubes, increasing use of non-metallic evaporator materials;
- Improvement in corrosion resistance e.g. utilization of anti-scaling organic products;
- Improvements in availability and thermodynamic efficiencies, due to the incorporation of on-line cleaning procedures;
- Modular construction, with improvements in fabrication procedures, reducing construction lead times;
- Development of efficient and more precise process control systems and procedures.

Among other expected advances in the RO systems in particular and other membrane based system are:

- Increase of salt rejection efficiency (from 98 to 99.8 %);
- Increase in permeate flux;
- Enhanced chlorine tolerance;
- Reduction of the costs of cleaning and pre-treatment requirements;
- Development of longer life membranes.

Nuclear Production of Hydrogen

Hydrogen as an energy carrier is seen as one of the major fuels of future. It may replace fossil fuel in general, especially in transportation. Currently, the production of hydrogen relies on typical fossil fuel based methods, hence releases carbon dioxide. However, hydrogen could be produced from nuclear energy and could avoid any concern related to the green house gas emissions. Several technologies using nuclear energy have been persuaded such as electrolysis and thermochemical water splitting cycles.

In general, high temperature reactors are seen as most suitable for the production of nuclear hydrogen using either Sulfer-Iodine thermochemical cycle or high temperature electrolysis. Current light water reactors represent another approach for the production of nuclear hydrogen when their off-peak nuclear-generated electricity is being used with existing water electrolysis production technologies.

The IAEA, within the Gas-cooled Reactor Project, has completed significant efforts related to the nuclear production of hydrogen in the past several years. A coordinated research project assessing heat utilisation system options for the HTTR in Japan evaluated several options for hydrogen production. A parallel effort resulted in an internationally reviewed technical report providing a comprehensive overview of hydrogen production in general, as well as specific considerations for the nuclear production of hydrogen. Industrial production of hydrogen using fossil fuel resources, primarily for the chemical industry, has been conducted for many decades. Recent advances in hydrogen storage and end use applications, particularly in transportation, in combination with substantial environmental benefits from the utilisation of hydrogen as a fuel, support prospects for large future increases in hydrogen consumption.

Since the late seventies, the IAEA launched many activities related either directly or indirectly towards harnessing nuclear energy for hydrogen production. The IAEA has initiated in 1978 the International Working Group on Gas-cooled Reactors , which is now called the Technical Working Group on Gas Cooled Reactors (the TWG-GCR).

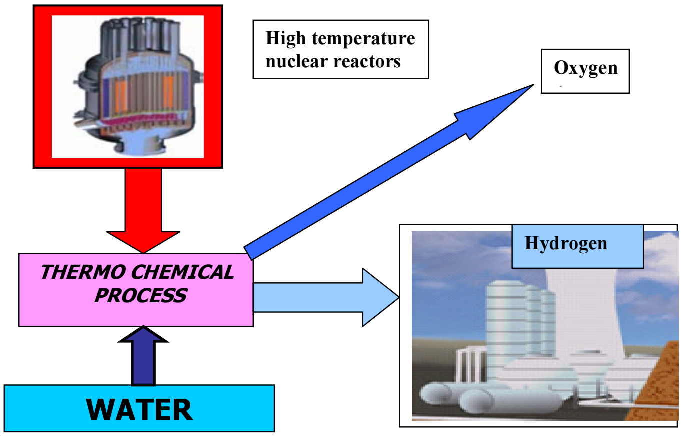
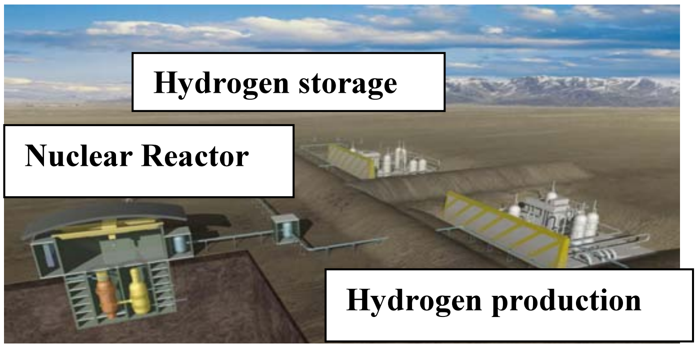
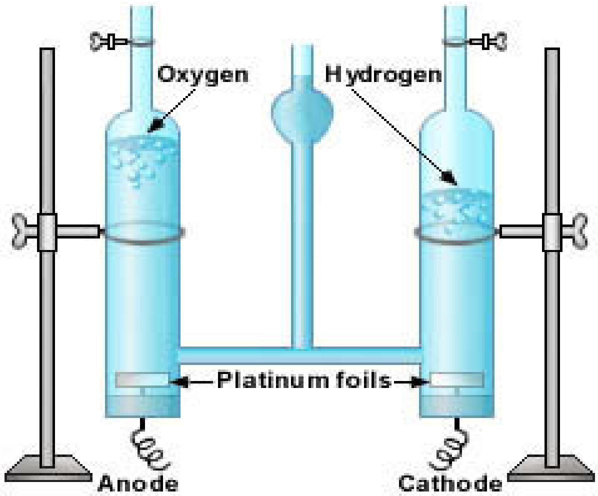


Illustration of nuclear hydrogen production using thermo chemical process

Nuclear generation of hydrogen offers a means of producing hydrogen on a large scale with negligible emissions to the atmosphere. Considerable work has been done regarding technologies for the nuclear production of hydrogen, and technical feasibility is well-established. Significant issues remain with regard to the development of licensed, economically competitive designs, but the enormous energy market associated with transportation alone justifies the investment of funds required to address these issues to enhance the efficiency of hydrogen production in the long term. In the nearer term, production of hydrogen through electrolysis using nuclear-generated electricity can be a viable option, particularly for the distributed production of hydrogen using off-peak power.



Schematic representation of nuclear hydrogen production plant



Schematic representation of electrolysis

Among the results of such activities was the recognition that a clear need for a comprehensive overview of hydrogen as an energy carrier and the options for its production using nuclear power, and the need to provide a global perspective on the potential options and issues for the nuclear production of hydrogen. The subjects of such activities have gained momentum worldwide. New initiatives have been formulated in several Member States such as China, France, Japan, India, Republic of Korea, South Africa, and the United States of America. Therefore, it is expected that in the upcoming 50 years further development and innovations will take place to enhance “the hydrogen economy” using nuclear energy as a prime source. Major focus will be on high temperature applications that would result in the production of hydrogen.

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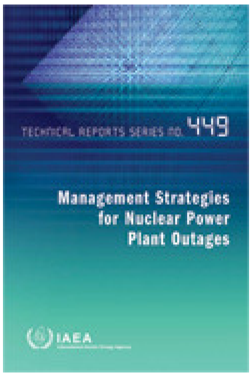
Recent Publications

Management Strategies for Nuclear Power Plant Outages

Technical Reports 449

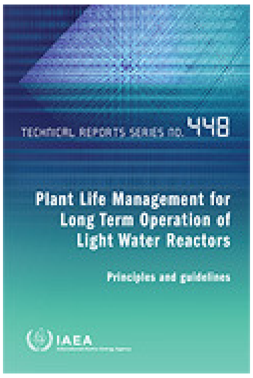


More competitive energy markets have had significant implications for nuclear power plant (NPP) operations, including among others the need for more efficient use of resources and more effective management of plant activities such as on-line maintenance and outages. Outage management is a key factor for safe, reliable and economic NPP performance. It involves many aspects: plant policy, coordination of available resources, nuclear safety, regulatory and technical requirements, and all activities and work hazards, before and during the outage. The IAEA has produced this report on NPP outage management strategies as both a summary and an update to a series of technical publications related to practices regarding outage management and cost effective maintenance. The aim of this report is to identify good practices in outage management: outage planning and preparation, outage execution and post-outage review. This report aims to communicate these practices in a way that can be used by operating organizations and regulatory bodies in Member States.

STI/DOC/010/449, 61 pp.; 9 figures; 2007, ISBN 92-0-101706-5, English. 27.00 Euro. Date of Issue: 1 March 2007. Full Text, (File Size: 2548 KB).

Plant Life Management for Long Term Operation of Light Water Reactors

Technical Reports 448

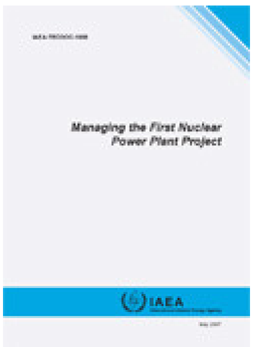


This report explains the general approach to plant life management (PLiM), shows and defines the relationship between nuclear power plant maintenance and PLiM, assembles a list of good practices and formulates guidelines for ageing management of critical structures, systems and components. Additionally, the issues of PLiM for long term operation are discussed in terms of human, technological, economic and regulatory aspects, as well as the importance of the exchange of information regarding lessons learned. PLiM is not only a technical system but is also an attitude of the owners to retain plants in operation as long as possible from a safety and business point of view. Asset management is thus a significant parameter and driving force for PLiM implementation.

STI/DOC/010/448, 123 pp.; 14 figures; 2006, ISBN 92-0-101506-2, English. 35.00 Euro. Date of Issue: 19 February 2007. Full Text, (File Size: 1441 KB).

Managing the First Nuclear Power Plant Project

IAEA TECDOC 1555

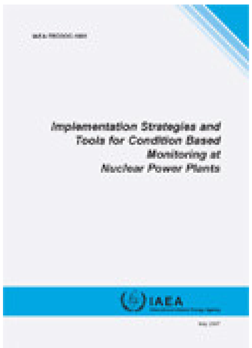


Experience shows that the time between an initial policy decision by a state to consider nuclear power up to the start of its first nuclear power plant is about 10 to 15 years. The proper management of the wide scope of project activities during this period represents a major challenge for the involved governmental, utility, regulatory, supplier and other supportive organizations. The main focus is to ensure that the project is implemented successfully from a commercial point of view while remaining in accordance with the appropriate engineering and quality requirements, safety standards and security guides. This publication provides an introductory overall description of the main project management activities and gives the references to the related detailed guidance. The target audience are decision makers, advisers and senior managers in the govermental organizations, utilities, industrial organizations and regulatory bodies in the countries desiring to launch the first nuclear power plant project..

IAEA-TECDOC-1555, 2007, ISBN 978-92-0-105207-0, English. 15.00 Euro. Date of Issue: 31 July 2007. Full Text, (File Size: 915 KB).

Implementation Strategies and Tools for Condition Based Maintenance at Nuclear Power Plants

IAEA TECDOC 1551



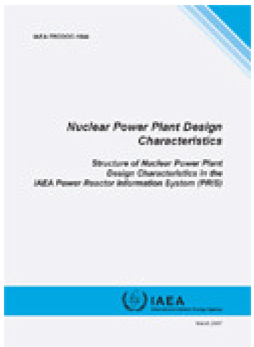
A systematic evaluation approach to establishing what maintenance tasks are to be performed on which systems, structures or components and at what periodicity, can lead to optimize the use of resources (maintenance costs, personnel doses, equipment and tools, competent personnel, etc.) allocated for maintenance and availability of plant. This approach can be used in establishing a preventive maintenance program and for the optimization of the ongoing maintenance program. The process seeks to make the best use of condition-based maintenance where unnecessarily costly maintenance actions and associated maintenance error induced failures can be avoided. If a probabilistic risk assessment has been performed, its result can be used to help define the important systems and components. This optimization process can lead to the achievement of nearly all maintenance targets concerning safety, reliability and cost. The current publication was developed to collect and analyze proven maintenance optimization methods and techniques (engineering and organizational) in Member States. Appendices to this publication consists of selected papers on maintenance optimization presented during the preparation of this document.

IAEA-TECDOC-1551, 2007, ISBN 92-0-103907-7, English. 15.00 Euro. Date of Issue: 31 May 2007. Full Text, (File Size: 2436 KB).

Nuclear Power Plant Design Characteristics

Structure of Nuclear Power Plant Design Characteristics in the IAEA Power Reactor Information System (PRIS)

IAEA TECDOC 1544



The Power Reactor Information System (PRIS) is a comprehensive data source on nuclear power reactors in the world. It includes specification and performance history data of operating reactors as well as of reactors under construction or being decommissioned. The nuclear power plant design characteristics represent a fundamental part of the PRIS database. They provide important information on the main systems and components and can provide a comprehensive picture of unit design, technology and system configuration. The characteristics can also be used as basic criteria to group reactors with similar or identical design features for operational performance analysis. The aim of this publication is to provide guidelines for PRIS data providers and to detail information about PRIS design characteristics for those using PRIS data for performance analysis, benchmarking or just as a reliable source of technical information related to nuclear power plants.

IAEA-TECDOC-1544, 2007, ISBN 92-0-102507-6, English. 15.00 Euro. Date of Issue: 16 May 2007. Full Text, (File Size: 562 KB).

Status of Small Reactor Designs Without On-Site Refuelling

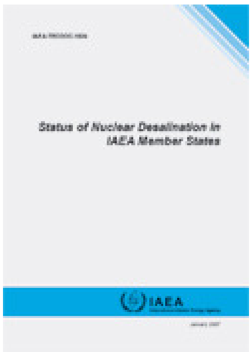
IAEA TECDOC 1536

The objective of this report is to provide Member States, including those considering the initiation of nuclear power programmes and those already having practical experience in nuclear power, with balanced and objective information on important development trends and objectives of small reactors without on-site refuelling, on the achieved state of the art in design and technology development for such reactors, and on their design status and possible applications. The report is intended for many categories of stakeholders, including electricity producers, non-electricity producers, policy makers, designers and regulators. The main chapters of this report survey emerging energy market characteristics, introduce a rationale for such reactors and review their design and technology development status with a consideration of associated fuel cycle and institutional issues. The annexes provide detailed design descriptions of small reactors without on-site refuelling, focusing on their potential to provide solutions in the areas of concern associated with future nuclear energy systems.

IAEA-TECDOC-1536, 2007, ISBN 92-0-115606-5, English. 15.00 Euro. Date of Issue: 14 May 2007. Full Text, (File Size: 20839 KB).

Status of Nuclear Desalination in IAEA Member States

IAEA TECDOC 1524

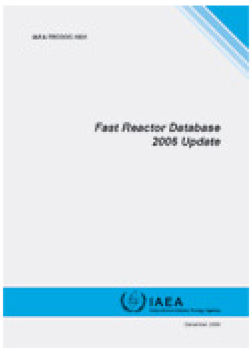


This Status Report briefly describes the recent nuclear seawater desalination related developments in IAEA Member States and relevant IAEA activities. It covers salient aspects of the new generation reactors and some innovative reactors being considered for desalination, recent advances in commonly employed desalination processes and their coupling to nuclear reactors. A summary of the techno-economic feasibility studies carried out in interested Member States is presented. The socioeconomic and environmental benefits of nuclear power driven desalination plants are discussed.

IAEA-TECDOC-1524, 2007, ISBN 92-0-112806-1, English. 15.00 Euro. Date of Issue: 7 March 2007. Full Text, (File Size: 1834 KB).

Fast Reactor Database 2006 Update

IAEA TECDOC 1531

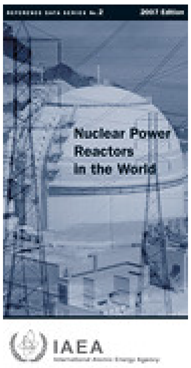


The fast reactor database (FRDB) summarized in this report is very detailed with each liquid metal cooled fast reactor (LMFR) power plant being characterized by about 500 items. It includes operational parameters, physical, hydraulic and thermomechanical characteristics, technological requirements and methods and criteria to ensure safe operation. It also covers design data such as dimensions, materials information and main design features and performance parameters of reactor cores, components and various systems, along with sketches and drawings. The database setup makes it possible not only to easily find the required parameter of a certain reactor, but also to compare it with that of the other reactors. The FRDB includes data on 37 fast reactor plants, their thermal power ranging from 10 to 4000 MW. Thirty-one reactors out of 37 are connected to steam turbine generators of 12 to 1800 MW electric power. It is hoped that this reference book will allow effective design approaches for fast reactor systems and components to be reproduced and the repetition of unsuccessful design approaches to be avoided.

IAEA-TECDOC-1531, 2006, ISBN 92-0-114206-4, English. 15.00 Euro. Date of Issue: 20 February 2007. Full Text, (File Size: 38894 KB).

Nuclear Power Reactors in the World 2007 Edition

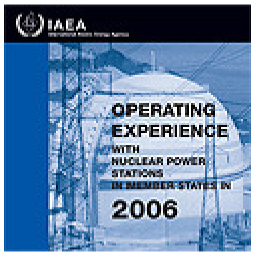
RDS No. 2



This is the twenty-seventh edition of Reference Data Series No. 2, which presents the most recent reactor data available to the IAEA. It contains summarized information as of the end of 2006 on: (1) power reactors operating or under construction, and shut down; and (2) performance data on reactors operating in the IAEA Member States, as reported to the IAEA. The information is collected by the IAEA through designated national correspondents in the Member States. The replies are used to maintain the IAEA's Power Reactor Information System (PRIS).

IAEA-RDS-2/27, 85 pp.; 6 figures; 2007, ISBN 978-92-0-105307-7, English. 12.00 Euro. Date of Issue: 3 August 2007. Full Text, (File Size: 336 KB).

Operating Experience with Nuclear Power Stations in Member States in 2006



This edition is the thirty-eighth report in the IAEA's series of annual reports on operating experience with nuclear power stations in Member States. The first publication was issued in 1970. It is a direct output from the IAEA's Power Reactor Information System (PRIS). It contains information on electricity production and overall performance of individual plants during 2006. In addition to annual information, the report contains a historical summary of performance during the lifetime of individual plants and figures illustrating worldwide performance of the nuclear industry. This CD-ROM provides enhanced features for data search and analysis.

STI/PUB/1303, 6 figures; 2007, ISBN 978-92-0-157307-0, English, CD-ROM. 170.50 Euro. Date of Issue: 16 August 2007. Full Text, (File Size: 3905 KB).

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