Topical Issues in Nuclear Installation Safety

Continuous Improvement of Nuclear Safety in a Changing World

Proceedings of an International Conference
Beijing, 18–22 October 2004

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TOPICAL ISSUES IN NUCLEAR INSTALLATION SAFETY:
CONTINUOUS IMPROVEMENT OF NUCLEAR SAFETY
IN A CHANGING WORLD

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

PROCEEDINGS SERIES

TOPICAL ISSUES IN NUCLEAR INSTALLATION SAFETY: CONTINUOUS IMPROVEMENT OF NUCLEAR SAFETY IN A CHANGING WORLD

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FOREWORD

In 1991, the IAEA organized an International Conference on the Safety of Nuclear Power: Strategy for the Future. Recommendations from that conference prompted actions in subsequent years that advanced the safety of nuclear installations worldwide, and included the establishment of the Convention on Nuclear Safety, which entered into force in October 1996.

In 1998, the IAEA sponsored an International Conference on Topical Issues in Nuclear, Radiation and Radioactive Waste Safety. In response to the concerns identified and the recommendations provided by the conference, actions were taken to improve the monitoring of safety by developing performance indicators; furthering the use of probabilistic safety insights to complement and help optimize the prescriptive nature of regulations; and addressing actions needed to ensure the future availability of competent professionals.

In 2001, the IAEA sponsored an International Conference on Topical Issues in Nuclear Safety. The findings were again essential in providing Member States, the IAEA and the nuclear industry with insights into where future activities should be focused. Some of these areas included the need to develop international guidance on the use of probabilistic safety insights, the potential negative impacts on safety from external factors, the need for emergency preparedness guidance for fuel cycle facilities, the safety challenges associated with poor utilization programmes at research reactors, and the need to develop simple indicators of safe operating performance.

Although substantial progress has been made in improving the safe operational performance of nuclear installations over the past years, numerous issues continue to be of concern. These include ensuring quality of design and operation of nuclear installations with the growing diversification and globalization of the nuclear community, obtaining, maintaining and managing knowledge, utilizing common internationally accepted safety standards, balancing the needs between safety and security, promoting cooperation and sharing of experience between regulatory authorities and integrating the practices and methodologies of international vendors and contractors into diverse cultures.

Events at nuclear installations continue to be reported whose root causes call into question the effectiveness of safety at those facilities. These events all have common issues that contributed to non-conservative decisions being taken or omissions in the decision process. More importantly, these events have highlighted issues within both the regulatory authorities and the operating organizations. In addition, there are unique challenges that regulatory authorities face in dealing with the changing environment and related to the long term operation of nuclear facilities.

In the light of these developments, it was considered appropriate to convene another conference on the following current topical issues:

- Changing Environments: Coping with Diversity and Globalization;
- Operating Experience: Managing Changes Effectively;
- Regulatory Management Systems: Adapting to Changes in the Environment;
- Long Term Operations: Maintaining Safety Margins while Extending Plant Lifetimes.

The objective of the conference was to foster the exchange of information of these topical issues in nuclear safety. The conference developed an international consensus on the basic approaches for dealing with these issues in the context of overall safety activities for Member States, the IAEA and the nuclear industry. The conference was successful in identifying future activities for the IAEA and the need for strengthening international cooperation.

The IAEA gratefully acknowledges the support and generous hospitality of the Government of China through its China Atomic Energy Authority and National Nuclear Safety Administration.

EDITORIAL NOTE

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CLOSING SESSION

CONFERENCE SUMMARY

1. BACKGROUND

The objective of this international conference, was to foster the exchange of information on topical issues in nuclear safety. The conference developed an international consensus on the basic approaches for dealing with these issues, and has proposed recommendations concerning:

— The present status of these issues;
— Priorities for future work;
— The need for strengthening international cooperation, including recommendations for future activities for the IAEA, nuclear utilities and regulatory authorities;
— Emerging issues with international implications.

During the week of 18–22 October 2004, 274 participants presented, critiqued and discussed issues related to the challenges before the world nuclear community as it moves into an environment of change and globalization. These participants represented 37 countries, 5 international and private organizations, and all parts of the nuclear power community. In addition, ten observers and ten members of the press were in attendance.

2. MAIN CONCLUSIONS

The conference participants identified a need to harmonize regulatory approaches and to build on existing IAEA safety standards to provide vendors, operators and regulatory authorities with internationally accepted standards for designing, licensing, operating and regulating nuclear installations. There were many opinions on design certification and on how to harmonize the transition point between safety standards and industrial standards. However, the participants recognized the role of the IAEA International Regulatory Review Team (IRRT) to act as a vehicle to promote regulatory consistency with emphasis on the new IRRT process that addresses self-assessment. They also recognized the general call for all Member States with nuclear installations to consider availing themselves of this valuable peer review service.

The participants noted the need to establish the right balance in using, in a complementary manner, both deterministic and probabilistic approaches during design, operation and regulatory activities. They also recognized that globalization and the provision of reactors to Member States with no vendor knowledge (or allowing for the new business concepts where new corporate owners or individual site managers are 'business oriented and experienced' as opposed to being 'operationally experienced') call into question who 'owns' the design (design conscience), who is responsible for providing the necessary focus (decision making and resources) on safety (safety conscience) and security (security conscience).

During the conference, there was much discussion on the concept of operational experience, and the need to foster an environment conducive to becoming 'learning organizations' was identified. The conference participants strongly agreed that maintaining a transparent environment is essential, both with other owner–operators, with the regulatory authorities and with the public. Recurrent events are taking place and the conference realized the need to ensure that the lessons learned in the past are not forgotten during the present and lost in the future. The process for identifying 'low level' and 'near miss' events must be stimulated and serve as a repository of lessons learned for all members of the nuclear community. In addition, the participants recognized the need for breaching artificial barriers in order to share safety related information. This includes addressing proprietary, technical and political factors that stand in the way of information sharing.

The participants agreed that information technology methods, such as self-sustaining networks, must be pursued to ensure that resources are leveraged to the maximum degree possible. Lessons learned are not unique to any specific period in the life cycle of a nuclear installation or any particular type of nuclear installation. Knowledge must be shared during design, construction, operation and decommissioning phases of all facilities (power plants, research reactor and fuel cycle facilities). Similarly, lessons learned are not unique to any particular industry. All sources of lessons relative to material and process safety insights must be pursued.

The conference participants discussed the concept of extended operations and what safety standards are needed, if any, for the transition from 'normal operation' to 'long term operations'. Some countries view long term operation as a continuous process and others as something that is tied to their licensing process. The participants agreed that for the safe long term operation of an installation, the safety analysis must show that the plant will continue to operate within its design envelope. Thus, there was agreement that there is a need for sound knowledge of the current design basis, accurate knowledge of the actual state of the plant and verification that adequate safety margins will be maintained. The participants also concluded that long term operation must consider the concept of ageing management in its broadest context, addressing both material (pumps, valves, etc.) and personnel (knowledge) issues.

OPENING SESSION

Chairperson

K. BROCKMAN
IAEA

OPENING ADDRESS

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On behalf of the International Atomic Energy Agency, I would like to welcome you to this important International Conference on Topical Issues in Nuclear Installation Safety. In addition, I would like to express our sincere appreciation to the Government of China, especially the Chinese Atomic Energy Authority and the National Nuclear Safety Authority, for the excellent cooperation that they have provided in the preparation and organization of this conference.

It is of great significance that this conference is being hosted by China as it celebrates 20 years of IAEA membership, and I would like to take this opportunity to congratulate them.

As you know, we are in a time of continuous change accelerated by information technology and the globalization process. The nuclear industry has, over the past decade, shown steady improvement in its performance, at least in areas such as capacity factor, automatic shutdowns and safety system actuations. There are some strong signs of emergence and resurgence in the use of nuclear power for generating electricity — this is most obvious here in China and, more broadly, across Asia. Therefore, it is fitting that we are holding this conference in the region of positive and extensive expansion of the peaceful use of nuclear technology for electric power generation, especially since the focus of the conference is on encouraging the continuous improvement of nuclear safety in a changing world.

The overall objective of the conference, which is held every three years, is to foster the exchange of views and experiences on topical issues in nuclear safety. The conference will provide a forum to develop an international consensus on the broad perspective and the basic directions for dealing with these issues. We hope you will propose recommendations concerning priorities for future work in the utilities, by vendors, regulatory authorities and the IAEA. We also expect that as a result of this conference, international cooperation will be strengthened, and a culture of active sharing and learning will be encouraged.

I firmly believe that through this conference we will be able to contribute to the worldwide sharing of recent topical lessons that have been learned from our experiences, and that this sharing will play a critical role in the development of new and effective approaches to safety management. Within a dynamically developing Asia, the Asian Nuclear Safety Network, strongly supported by China, Japan and the Republic of Korea as the hub centres, will be an important pioneering tool in assisting us with this vision.

The effective management of safety continues to be a real issue that challenges us.

This was recognized at the last Review Meeting of the Convention on Nuclear Safety, and has been reinforced by subsequent operational events and noted by numerous meetings of international experts. In facing this challenge, we have identified four topical issues that we consider appropriate for discussion and focus throughout this conference. These topics are:

— The challenge of changing political, economic and social environments and the corresponding changes in the response of business and government administration;
— Effective operating experience feedback, encouraging sharing and learning;
— Future regulatory approaches in adapting to the new environments;
— The trend towards long term operation and ensuring safety margins.

It is important to note that these issues are consistent with those recently identified by the International Nuclear Safety Group (INSAG) of the IAEA as requiring international attention. INSAG, which will be chaired by the President of this Conference, Mr. R.A. Meserve, will be formulating its advice in the future, and the results of this conference will, I am sure, be valuable to their deliberations.

I would like all of us to keep the following points in mind during our deliberations over the rest of this week; and of course I would welcome any other important insights regarding possible lessons that could be learned and shared as a result of this conference.

In the area of changing environments and the need to cope with diversity and globalization, we need to answer questions such as:

— How can we establish a global safety regime that will adequately support the trend towards internationalization of the nuclear industry, regulation and public perception?

— How can the Convention on Nuclear Safety and guidance such as the Code of Conduct on the Safety of Research Reactors be utilized to further enhance nuclear installation safety?

In the area of managing the knowledge from operating experience effectively and taking action to prevent the recurrence of events, we should seek solutions to such questions as:

— How can we prevent the continuing recurrence of similar significant events and what can we do to mitigate their significance and their consequences?
— In order to overcome potential restrictions imposed by commercial interests, how can we engender open and frank sharing of safety relevant information, knowledge and technology through encouraging the utilization of regional and global networks?
— How can the ‘industry’ (e.g. the World Association of Nuclear Operators (WANO)) and ‘independent’ (e.g. the IAEA–OECD/NEA Incident Reporting System) infomation sharing networks be adapted into mutually supportive vehicles for learning?

We will discuss how to adapt regulatory management systems to changes in the environment and should ask ourselves how we can solve such issues as:

— Encouraging regulatory authorities to share their experiences more effectively so that the competence of regulatory bodies can be enhanced worldwide;
— Effectively integrating the different design and construction philosophies and implementing guidance (e.g. ASME, IEEE Codes) associated with worldwide industry into national licensing programmes.

And, finally, on the topic of long term operation, typical areas we may consider are:

— How do we establish the adequate level of safety for long term operation? Does it differ from that required for other operations?
— What are the key challenges for long term operation? Are they technical, organizational, legal, regulatory or perceptual?

Our challenge for the next five days of this conference is to understand more fully these issues and the challenges to our naturally conservative approach to the management of safety. We need to identify the best way forward in dealing with these issues.

In closing, I would like to stress that throughout our discussions we should also consider several broader questions:

(1) What is the role of the international safety standards in providing guidance to help solve these issues, and how best can we ensure the effective application of such standards?
(2) How can we maintain and enhance the regulatory and operational infrastructures at national and regional levels? How do we position industry, government and technical support organizations properly to meet their respective responsibilities for ensuring safety?
(3) How can the IAEA assist Member States and the industry in ensuring safety in this new, ever changing and challenging environment? What new techniques should be pursued to complement the activities of the IAEA that have served us well over the past several decades, such as safety standards, safety reviews, workshops, training courses and the encouragement of self-assessment?
(4) How can we better manage and network the knowledge needed for this? How do we ensure that everyone learns from one another's challenges? In this context, the Asian Nuclear Safety Network can provide an effective mechanism for continuous sharing of experience and mutual learning of lessons.
(5) In these days of increasing external threats from malicious acts, the appreciation that ensuring safety and security creates mutually impacting challenges while also offering mutually synergistic opportunities for solutions cannot be overemphasized. The challenge is to use the safety and security synergy to establish an effective and transparent global safety and security regime, including adequate protection of sensitive information. How can we achieve this?
(6) And finally, I would like to hear your views and insights regarding future topical issue conferences and other follow-up technical meetings, seeking greater global outreach and innovative use of state of the art information and communications technology.

I wish all of you success during the conference and thank you for your important contribution. I would now like to introduce our Conference President, Mr. Meserve, who I am sure you all know from his past distinguished service as the Chairman of the United States Nuclear Regulatory Commission.

OPENING ADDRESS BY CONFERENCE PRESIDENT

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I would like to thank Chairman Zhang and Deputy Director General Taniguchi for their helpful introductory remarks. As the President of this International Conference on Topical Issues in Nuclear Installation Safety, I am also very happy to welcome you all.

I understand that I was asked to serve as the President of this Conference as a result of my role as Chairperson of the IAEA's International Nuclear Safety Group (INSAG) — a group that is intended to provide informed advice to the world community on nuclear safety issues. I join you at this conference largely to learn your perspectives on some of the issues that INSAG must address.

I will try this morning to set out the context for our discussions over the course of the next week. There are approximately 440 nuclear power plants around the globe, contributing roughly 16% of the world's total supply of electric power. Because of the importance of electricity as a foundation for societal activities and for economic growth, nuclear energy provides an important contribution to the well-being of the world's peoples. Indeed, the electric energy from nuclear power plants is all the more important when it is recognized that nuclear power does not present many of the environmental problems associated with other major sources of energy. In particular, it provides the means to meet growing energy needs throughout the globe without the generation of greenhouse gases and the resulting disruptive effects of climate change. Moreover, nuclear technology and materials offer diverse and significant benefits in many health and industrial applications.

Nuclear technology has particular significance here in China. The Chinese economy is expanding at a faster rate than that of any other major country, with attendant huge demands for electricity generating capacity. I understand that China plans to build 30 new nuclear power plants by 2020 and internal Chinese studies estimate that, by 2050, China will need as much as 300 GW of additional nuclear power — not much less than the current world total capacity of 350 GW of nuclear power. If this dream is realized, China will lead the world in its reliance on this clean source of electricity supply.

The world's reliance on nuclear power presents special challenges and special obligations. Nuclear technology can present significant risks without care being taken in design, construction and operation. Although accidents are more common in the handling and use of nuclear materials than in electric power generation, the public has a particular concern about an accident at a nuclear power plant. And because an accident at a nuclear power plant could have transnational effects, there is strong international interest in ensuring that such plants are designed, constructed and operated with close attention to safety. Indeed, it is a commonplace but nonetheless valid observation that a nuclear accident anywhere will have consequences around the globe, if only through indirect impacts on public opinion. There is, therefore, both a local and an international interest in ensuring nuclear safety.

As a general matter, the safety performance of nuclear power plants continues to show steady gains. Safety indicators — that is, measures of such things as actuations of reactor safety equipment, availability of safety related equipment and unplanned shutdowns — have shown steady improvement over a period of decades. These improvements are no doubt the result of heightened management attention to safety, improved maintenance, better training, more sophisticated diagnostic and other technology, safety upgrades and increased international exchange of operating experience by way of the IAEA, the OECD/NEA, the World Association of Nuclear Operators and conferences like this one. This improved performance is impressive and, as a general matter, should be reassuring.

Indeed, there is an interesting and important correlation between improved safety performance and improved economic performance. At the same time that safety, in the aggregate, has improved, the average capacity factors for nuclear power plants have also improved. The fact that safety and superior economic performance are linked to each other is not surprising, since each is dependent on reliable equipment, careful maintenance and training, and attention to detail. The important lesson is that it is good business to strive for the highest levels of safety even when measured solely by the contribution to the bottom line.

Nonetheless, despite the favourable trends with the indicators, we cannot rest comfortably on the assumption that our safety obligations are fully satisfied. In fact, there are significant safety challenges with which the world's nuclear enterprises must grapple now and in the years ahead. In the past few years, there were several noteworthy events that warrant careful examination to ensure that the appropriate lessons are learned. Some of these events occurred in plants that had an otherwise impressive operational and safety record and that were operated by organizations with extensive experience. And some of these events were in countries with strong and capable regulators. These facts are both troubling and humbling. The events show that no one can assume that the task of ensuring nuclear safety has been successfully accomplished. We have much hard work ahead of us. The events underscore the reality that constant vigilance is required by all who are engaged in the nuclear enterprise.

Indeed, the events reinforce that the general trends of favourable safety indicators, while desirable, should not be allowed to provide false comfort. We face many challenges. Let me mention just a few.

Firstly, there is the challenge presented by ageing nuclear power plants. Plant and equipment can deteriorate as a result of continuing use and the ravages of time. Some plants were built without the safety features or characteristics that are integral to more modern designs. There also are fewer suppliers of nuclear equipment and services, and the acquisition of spare parts and components of appropriate quality can sometimes be difficult. Nonetheless, there is the necessity of ensuring that all operating plants have and maintain an adequate safety margin over the whole life cycle of the facility. This is a continuing challenge, particularly as a result of the complacency that can arise from uneventful past operations and the costs associated with extensive repairs or construction of replacement facilities.

Secondly, in many parts of the world, the nuclear infrastructure, including in particular the human resources involved in the nuclear enterprise, is deteriorating. While older workers can provide experience and informed judgement, there is a need to ensure that their specialized skills are replicated in a younger generation. Indeed, the sustainability of the nuclear enterprise requires a continuing influx of new recruits and the current flow is simply too small to meet the need. In this context, we observe that, in comparison with 20–30 years ago, there is a smaller cadre of highly qualified experts, fewer graduates in nuclear engineering from the world's universities, and less global financing for safety research. Focused effort to rebuild the nuclear infrastructure, including important human resources, is necessary if nuclear safety is to be maintained and enhanced.

Finally, and perhaps most importantly, every operator and every regulator must fight to overcome the complacency that can arise from uneventful past operations. Nuclear technology is not forgiving and even nations with the most advanced nuclear programmes have found that there must be constant attention to safety. It is often appropriately observed that backsliding in safety performance is inevitable unless there is a continuing effort for safety improvement. Hence, the focus of this conference is on the very issue of ensuring continuous improvement of nuclear safety in a changing world.

The nuclear industry has learned that the effort must include not only careful maintenance and thorough training, but also the establishment of an appropriate ‘safety culture’ in design, construction and operation. Safety must be the highest priority and there must be in place a management structure and set of incentives that serve to ensure that everyone associated with a nuclear facility understands and seeks to pursue safety.

In this context, operators must resist any economic pressures to cut back attention to safety matters. The harsh reality is that every nuclear plant requires continuing investments in staff, systems and equipment. Perhaps equally importantly, there must be special efforts to ensure that expert knowledge is continually being applied both by operating organizations and by regulators. Knowledge relating to safety is increasing as we learn from operating experience, from safety research and from revised safety analyses using improved tools. But that new knowledge is of little value unless it is applied in a process of ongoing safety improvement.

The need to apply new safety insights is the reason why we are gathered here today. We have a common interest in ensuring that the safety of all nuclear plants is enhanced. No one country has exclusive control of the information from which we can and should learn. This conference is intended to provide a forum in which insights from around the world can be discussed and analysed so that we all can benefit.

We will hear in a moment from some experienced and knowledgeable observers of the world safety scene. They will set the stage for our discussions. As Mr. Taniguchi has indicated, we will then have four topical sessions to illuminate various aspects of the challenge that is before us. Our final session will attempt to pull together these disparate threads and to chart a course of action for the future.

I look forward to an exciting week and I welcome the opportunity to learn from all of you in the days ahead.

KEYNOTE ADDRESS

PROSPECTS FOR NUCLEAR POWER: THE ROLE OF SAFETY

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It is an honour for me to represent the World Association of Nuclear Operators (WANO) before this distinguished audience.

Over the past several years, the worldwide nuclear industry has achieved an impressive record of performance. Many things have contributed to this improvement, but I believe it is due — in a very significant way — to unprecedented cooperation and information exchange. IAEA international conferences help further this dialogue and cooperation, and I appreciate Mr. Ken Brockman's invitation to speak to you today during the opening session.

In July, I succeeded Mr. Hajimu Maeda as WANO Chairman. Mr. Maeda provided strong leadership to WANO as chairman for two years, and our industry owes him a debt of gratitude for his service. He continues to serve our industry as a member of the Atomic Energy Commission of Japan.

I have worked in the commercial nuclear power industry for more than 30 years — both on the operational side and the executive side. And my involvement with WANO goes back to its beginnings, including serving for many years as a member of the WANO Governing Board and participating in seven of the eight Biennial General Meetings that have been held. A hurricane kept me away from the one I missed.

This long experience has reinforced my belief in the great value, and even greater potential, of both nuclear energy and WANO.

Nuclear energy makes a unique contribution to meeting the world's energy needs — a role that grows in importance as we face environmental issues and economic realities. But, as we will discuss throughout this conference, fulfilling the potential of nuclear energy will not happen easily. It is a changing world as our theme suggests, and public trust and a competitive edge have to be earned daily.

With the echoes of the Mihama steam leak event still reverberating throughout our industry, we meet here today to talk about the prospects for nuclear power. Given WANO's mission, I will share some thoughts on the vital role of safety and how it is fundamental to any discussion about the prospects for nuclear power in the future.

Mihama is just the most recent event that brings us face to face once again with the fact that our technology requires constant vigilance, sensitivity to operations, and conservative decision making.

As WANO marks its 15th anniversary this year, it's clear to me that WANO is as important today as it was when it was founded as a response to the Chernobyl accident.

I vividly recall that when WANO was just an idea, the thought of getting more than 30 countries in all corners of the globe to really cooperate in a non-governmental safety organization was considered a formidable — if not impossible — task.

I also recall the day that Mr. Lin signed the WANO charter on behalf of the Guangdong Nuclear Power Joint Venture Company. It was at the WANO Biennial General Meeting in April 1991 in Atlanta. He signed the charter, shook hands with WANO's first President, Bill Lee, and then he proudly held the charter above his head. With that began the positive association between WANO and the operators of the nuclear power reactors in the People's Republic of China.

I had the opportunity to meet recently with several former leaders of WANO and I was particularly struck by a comment made by Rémy Carle, WANO's second Chairman and a former senior executive at EDF. Many of you know Rémy, I'm sure.

Of WANO's 15th anniversary, he said:

> "I think good work has been done, but the risk is to say that, 'Well, now we have 15 years of good work, it's enough.' No, it's not enough because you have to increase safety culture everywhere and forever. WANO has to remain a tool for creating and exchanging safety culture."

He went on to say that WANO was formed to help bring all the members up to the same high level of performance. As long as WANO has not done that, he said, WANO has not succeeded.

So our work is not done.

In our time together today, I have been asked to highlight issues of future concern. So I plan to discuss the complexities of operating in a competitive environment, the need for greater sharing of operating experience, and why

WANO peer reviews figure prominently in the prospects for nuclear power in the future.

First, the competitive environment. Let me state clearly my strong belief that high levels of safety and a competitive environment can coexist. I know this is true because I have seen it in many places throughout the world. I have also seen examples in which the rigors of a competitive marketplace have tempted operators to reduce plant resources to a level that will not sustain safety and reliability.

An additional concern is that commercial competition has the potential to erode nuclear cooperation. I challenge you instead to use increased competition as a catalyst to increase sharing among nuclear organizations.

Each nuclear operator must recognize and respond to the simple but profound fact that it is in their economic self-interest to ensure that every other nuclear plant succeeds. In Cameroon, they have a saying that rain does not fall on one rooftop alone. So it is with the immediate and global effect of a nuclear accident. In an age of instantaneous news coverage and limited public support for nuclear energy, an accident at one plant affects us all.

However, this fundamental truth may not be self-evident to the many new senior executives in our industry who have little or no nuclear background. Many new CEOs didn't grow up in this industry. They come from a different business environment — a very challenging, competitive one — and now they're operating nuclear plants. While financially astute, they don't share the 'emotional operating experience' of the founders of WANO.

The market is focused on short term results. The nuclear industry must be managed for the long term. Therein lies the conflict.

But when viewed from a purely financial perspective, there is no better insurance policy than participating fully in WANO programmes — given the huge economic investment that our members have in their nuclear facilities. As Rémy Carle said to me recently:

> "It will take a new vocabulary to communicate with people who think profit and sales — they must be taught to think safety first."

It is vital for the CEOs of the world's nuclear companies to be involved with WANO — for two reasons. First, CEOs play a key role in establishing the safety culture of their organizations. One of the most powerful tools for ensuring safe operation is a CEO's clear communication of his or her personal expectations about nuclear safety. A CEO who is visibly committed to WANO sends a clear, unambiguous message about the importance of nuclear safety.

The second reason that CEO involvement in WANO is essential is that WANO needs resources to be effective. This not only includes funding but it also includes the CEO's support to send personnel to participate in peer reviews and other WANO activities.

The 18 years since the Chernobyl accident serve to further distance us from the galvanizing reasons we came together to form WANO. Quite simply, the passage of time since Chernobyl works against us. The stark realization that we are only as strong as our weakest link has faded.

This leads me to the second challenge: the need for more emphasis on sharing operating experience.

Before WANO was formed, many operators had essentially no contact with plants in other regions of the world, and often little meaningful exchange with plants in their own region. The cost of that isolation was high. Windscale. Three Mile Island. Chernobyl. But if those events sound like ancient history, let me bring to your mind more recent events: Tokaimura, Phillipsburg, Paks and Davis-Besse. Only by internalizing each other's experiences can we prevent similar events from occurring. I am reminded of a line from a book by Douglas Adams that goes like this:

> "Human beings, who are almost unique in having the ability to learn from the experience of others, are also remarkable for their apparent disinclination to do so."

Worldwide there are seldom any really 'new' events, and even fewer new *causes* of events. In addition, the methods available for sharing and for using operating experience are better today than ever before.

As an industry we have more potential for using operating experience today than at any other time. That's good, because never before have we been so challenged. For example, the industry needs to better understand material vulnerabilities — particularly as ageing occurs on the nuclear and secondary side of the plants. But to benefit from operating experience, we need to first know about it. The level and timeliness of event reporting to WANO improved significantly last year, but we have just scratched the surface.

In addition, learning lessons from the experience of others has to be given visibility and high priority. And that message must come from the top of the organization. This will become increasingly important as we prepare for the retirement of a significant percentage of our workforce. Just as our plants are ageing, our workforce is as well. It is essential that the lessons learned over the past 50 years are systematically retained and shared with those entering the industry.

The plans to build new nuclear plants in several countries will also provide an important opportunity to share experience. Last October, nearly 400 nuclear utility executives from around the world participated in the WANO

Biennial General Meeting in Berlin, where we heard presentations about the significant construction programmes under way in Asia. Nowhere is the need for safe, reliable nuclear generation more obvious than in *this* country where a large population and a rapidly expanding economy are combining to fuel an unprecedented demand for energy. China's nuclear capacity is anticipated to grow fourfold by 2020. This new construction provides us an opportunity to learn, as well as an opportunity to provide assistance. Sharing information is critical for the success of these units and for the future of nuclear power.

WANO will be working closely with companies that are building new reactors to conduct pre-operational peer reviews. We completed two such visits in April in Ukraine at Khmelnitski 2 and Rovno 4. These reviews are based on standard peer review methodology, but they incorporate important aspects of a nuclear power plant nearing the beginning of operation.

This leads me to my final topic: peer reviews.

At the 1991 WANO Biennial General Meeting, Josef Ponya stood up and volunteered Paks to be the site of the very first WANO peer review. That was a huge leap of faith for our industry. By the end of this year, WANO will have completed some 250 peer reviews since the programme began. Several stations have completed multiple peer reviews over the years, which is a testament to their value. I am pleased to report that WANO will meet its goal to complete a peer review at every nuclear station in the world by 2005 — with the exception of a few plants in Europe that are hosting IAEA Operational Safety Assessment Team (OSART) missions.

We have worked closely with the IAEA over the years to coordinate the timing of peer reviews and OSART missions. The relationship between WANO and the IAEA is very important as we both seek to improve operational safety through different but complementary methods.

Completing a peer review at every nuclear station in the world was an extremely ambitious goal set forth by WANO President Al Kupcis at the WANO Biennial General Meeting in 1999, and I know he would be pleased with this result.

WANO will conduct about 35 peer reviews this year and that number has been increasing. I'm also pleased to report that members in all four WANO regional centres are working towards each nuclear station hosting an outside review of its performance at least every three years and a WANO peer review at least every six years.

I can tell you the value of peer reviews from personal experience. While I was at Progress Energy, we hosted several WANO peer reviews. They are truly an opportunity to look at yourself through someone else's eyes. And the diverse backgrounds of the peer review team members provide valuable insights.

Peer reviews are really the heart of WANO. When the peer review process is working best, the plant is sharing its strengths and weaknesses with the team in an atmosphere of professional pride. The plant is being managed with the goal of being a top performer and it uses the WANO peer review as a resource to achieve that goal.

Let me close my remarks today with a story from Armen Abagyan, the Director General of the Russian nuclear research institute VNIIAES, and Vice President of Rosenergoatom. Armen was a founder of WANO who began his nuclear career nearly 50 years ago. After graduating from the Moscow Engineering Physics Institute, he reported to work at the world's first nuclear reactor at Obninsk in 1956. Hear Armen's words:

> "When we were young, nuclear energy was new and viewed very favourably by society. It was a high-level priority. This made me want to go into the nuclear field. We felt like we were the first people in the world. We were like heroes."

So what about the prospects for nuclear energy? I think they are as bright today as they were when Armen Abagyan was a young engineer. Working together — through WANO, the IAEA and other organizations — we can rekindle that sense of purpose, that sense of passion felt by the pioneers of our industry. We can ensure the safe and reliable operation of this important energy source. At times, society may not make us feel like this is the work of heroes, but it is.

KEYNOTE ADDRESS

CRITICAL THINKING ABOUT THE PAST, PRESENT AND FUTURE OF NUCLEAR POWER

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It is my great pleasure and privilege to speak with you today on a subject that I believe needs to receive much more attention: how nuclear regulators have, and will continue, to make vital contributions in ensuring nuclear safety, security and preparedness. Nuclear regulators need to be recognized and supported in order that they can continue to enable the safety and security of nuclear power as a significant component of the world's energy supply. Regulators use a variety of frameworks to implement their activities, but all share common objectives.

Eight years ago, almost to the day, the Convention on Nuclear Safety (CNS), a key framework for regulators, was approved and entered into force for the signatory nations with civilian nuclear power programmes which recognized the importance of ensuring that the safe use of nuclear energy needs to be well regulated and environmentally sound. The key objectives of the CNS are:

"(i) to achieve and maintain a high level of nuclear safety worldwide…;
(ii) to establish and maintain effective defences in nuclear installations against potential radiological hazards…;
(iii) to prevent accidents with radiological consequences and to mitigate such consequences should they occur."

The framers of the CNS were interested in promoting a high level of nuclear safety and an effective nuclear safety culture globally. The Convention entailed a commitment to the application of fundamental safety principles for nuclear installations rather than to detailed safety standards.

However, this original intent to give regulators and operators helpful directions on how to be more safety conscious has entered into the world of the

21st century. As such, the CNS is now even more important to the commonwealth of nations that have committed to it. We need to recognize that there are threats we did not foresee ten years ago, that there are not just the possibilities of operator error, but of malevolent actions being taken against nuclear facilities that could cause significant consequences. Therefore, the concept of 'safety' has undergone a significant revision in that we now recognize that safety also includes security and preparedness.

During the G-8 Nuclear Regulators Conference in Moscow in June of this year (2004), a Statement on Guidelines for Nuclear Safety and Security Regulatory Authorities was developed. The objective is to complement the CNS in supplementing the regulator's responsibilities. It is the G-8's intent that these Guidelines are available to all countries with civilian nuclear programmes so that they may consider them as they enhance their regulatory framework, both for nuclear power plants and other nuclear installations. This is especially necessary in countries that are undergoing changes in their political infrastructure and when the legal and practical authority of the regulators needs to be clearly defined. The G-8 Guidelines stated that, in order to accomplish the mission of being strong, effective, credible, transparent and independent protectors of the public health and safety, security and the environment, the nuclear regulator needs the necessary infrastructure and expertise, including the power to:

- Regulate nuclear facilities and types of activities associated with the use of nuclear energy and utilization of radioactive materials;
- Develop and, after approval, to issue rules, regulations or other requirements to ensure safety and the protection of the environment;
- Conduct a licensing process and to perform independent safety evaluations, as necessary;
- Enforce the regulations;
- Perform analysis to support the development of such rules and regulations and other requirements;
- Require operators using nuclear energy and radioactive materials for civilian purposes to provide information and reports about their activities;
- Inspect the activities dealing with nuclear energy and radioactive materials;
- Require compliance with licence conditions and fulfilment of regulatory decisions, as well as to require remedial action for violation of regulatory requirements and to impose penalties, including suspension of operation;
- Secure resources to conduct its activities effectively, and to attract and maintain a highly competent and respected technical staff;

— Require that the operator fulfil its primary responsibility and maintain competence for ensuring safety;
— Require appropriate emergency preparedness and response capabilities.

These are not new, yet together they form a simple yet compelling set of the authority and responsibility needed to exercise the mandate to protect the public and the environment from the regulated uses of nuclear materials.

The Nuclear Regulatory Commission (NRC) is addressing these safety, security and preparedness needs both in our day-to-day activities and in our revised Strategic Plan, which states that the NRC's mission is to:

> "License and regulate the nation's civilian use of byproduct, source, and special nuclear materials to ensure adequate protection of public health and safety, promote the common defense and security, and protect the environment."

This is further captured in the Strategic Goals that we use to establish quantitatively how we are achieving our mission:

"I. Safety: Ensure Protection of public health and safety and the environment.
II. Security: Ensure the secure use and management of radioactive materials.
III. Openness: Ensure openness in our regulatory process.
IV. Effectiveness: Ensure that NRC actions are effective, efficient, realistic, and timely.
V. Management: Ensure excellence in agency management to carry out the NRC's strategic objective."

The CNS has affirmed that the responsibility for nuclear safety rests with the State having jurisdiction over a nuclear installation, in the form of a properly constructed and authorized regulator. I agree and believe that the primary responsibility for nuclear safety resides with both the operator and the regulator. As I acknowledged during the international conference on Global Threat Reduction Initiative (GTRI) Partners in Vienna last month, the various national nuclear regulators may approach and resolve safety issues in different ways, but we understand that these differences do not equate to different goals or results. All of us are focused on ensuring adequate safety and security for nuclear power plants and radioactive materials of concern. However, I believe that we should, to the extent practicable, share information, expertise and operating experience lessons learned to better allow all of us to achieve our mutual goals of safety, security and preparedness.

Regulators historically have the expertise and have been capable of conducting the activities needed to address safety, security and preparedness concerns in this post-11 September 2001 era. Independent regulators can be centres of disciplined change, but only if they have, as the CNS states, adequate financial resources to support the safety of each nuclear installation and sufficient numbers of qualified staff with appropriate education and training. An independent and credible regulator with sufficient resources is a tremendous asset to both their nation and the international community, an asset that needs to be recognized and appropriately utilized by their nation.

As nuclear regulators, our primary responsibility is to provide, consistently and unmistakably, adequate protection from radiological hazards, including those resulting from terrorist acts, while preserving the benefits that the nation accrues from the use of nuclear materials and radioactive materials. We are also part of a well established international network centred on the civilian uses of radiation, with well known communications links, that is continuously addressing matters of importance to our nations and to the international community. These elements make nuclear regulators natural partners, and these are also the reasons that regulators need to be recognized and appreciated for the necessary work they do, day in and day out.

We need to be prepared, with the right tools, to face the challenges of a more technologically advanced and a more energy demanding world. By giving regulators the necessary legal authority and the appropriate resources, and by encouraging that they work closely with their international counterparts to share knowledge, expertise, and to develop internationally acceptable standards and regulations, we will be better able to ensure the safety and security of this essential component of the 21st century energy mix.

The NRC is ensuring that we have in place appropriate and realistic regulations and processes that will enable this next generation of reactors to be safely and securely built and operated. As such, we have developed a design certification process that provides a stable and predictable licensing process for new nuclear power plant designs. This process resolves safety and environmental issues before authorizing construction, thus reducing licensees' financial risk while allowing for timely and meaningful public participation. However, we have retained the capability to effect changes to insert technological advances via a disciplined licence amendment process. Further, by placing the approved designs under a restrictive change process, that applies to both the regulator and the applicant for design certification, we have reduced licensing uncertainty. The NRC ensures that licence applicants who reference a certified design that the safety issues already resolved will not be needlessly reconsidered during the plant licensing process. The NRC has issued rules certifying three standard designs: the Advanced Boiling Water Reactor (ABWR), System 80+, and the AP-600 — and the AP-1000 design, which has received a safety evaluation report and final design approval is now in the rulemaking phase of the certification process.

Earlier this year, I proposed to the Generation IV International Forum (GIF) meeting in Paris, that the development and international adoption of a regulatory framework that can establish the appropriate safety requirements, compatible with the ongoing evolutionary nature of today's nuclear technologies, is the logical next step. This internationally acceptable framework could put into place a consistent set of regulatory requirements that any nuclear vendor and utility could utilize in designing and building new power plants. Specifically, I offered the NRC's design certification process as a starting point for the world's nuclear regulators to use in starting to build an internationally acceptable regulatory framework.

The IAEA has a tremendous job to do in supporting and advocating safety and reliability, and that includes advocating regulators' capabilities and expertise and, in doing so, they will be championing nuclear safety, security and preparedness worldwide. It is time to move forward from "a nuclear accident anywhere is a nuclear accident everywhere" to "a nuclear safety improvement anywhere is a nuclear safety improvement everywhere", and that is everyone's job.

KEYNOTE ADDRESS

OVERVIEW OF ACTIVITIES OF THE NUCLEAR SAFETY COMMISSION OF JAPAN: KEY SAFETY ISSUES FOR RESPONDING TO NUCLEAR POWER PLANT AGEING

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1. INTRODUCTION

The Nuclear Safety Commission (NSC) of Japan agreed on basic political measures to be taken in January 2002, just after the critical accident at the uranium reprocessing plant of JCO. The NSC, based on this decision, has been implementing various measures concerned and taking prompt measures to cope with the related problems, so that it will henceforth improve safety assurance activities in Japan .

It can be said that almost all the planned measures have already been carried out, including emergency preparedness for nuclear disasters. In consideration of the recent safety assurance situation in Japan, the NSC decided to settle the basic political measures to be taken for coming years.

In the course of discussion of the new basic political measures, a regrettable accident has happened at Mihama Unit 3 of the Kansai Electric Company. After investigation and consideration of the Mihama Unit 3 accident, the NSC has decided on the basic political measures to be taken from 13 September 2004 onwards.

As part of the new basic political measures, the NSC emphasizes the following priority issues involving nuclear safety activities in Japan:

(1) Establishment of safety goals;
(2) Introduction of risk informed nuclear safety regulation;
(3) Investigation of the root cause of accidents;
(4) Review of the effectiveness of regulation;

(5) Fostering a safety culture in the organization of nuclear facilities;
(6) Enhancement of regulatory transparency and openness in the NSC's activities.

Looking at the present situation of nuclear power plants in Japan, one of the most urgent and common issues deals with the measures in place to respond to ageing problems, in connection with the investigation of the root causes of accidents. Here, key issues for responding to ageing are discussed through the observation of recent cases of accidents.

2. PRESENT SITUATION OF NUCLEAR POWER PLANTS IN JAPAN

At the present time, 52 commercial nuclear power reactors are in operation. All of them are LWRs. There are 29 BWRs and 23 PWRs. In addition to these, one BWR has completed the construction stage and is now undergoing commissioning tests. In 1966, the first commercial nuclear power reactor in Japan started operation. It was only one gas cooled reactor, and was closed in 1998 for economic reasons after 32 years of service. In 1970, both the first BWR and PWR in Japan started operation. They have been operating for more than 30 years. Twenty reactors out of 52 started operations in the 1970s, and another 11 reactors have followed them before 1985. That means about 60% of all commercial reactors have been operating for at least 20 years, and Japan will have quite a number of aged reactors in the near future.

Several countermeasures have already been taken to cope with ageing situations. All reactors are required to perform precise examinations for assessing the age situation of important components every ten years. Some practical measures have worked out. For example, core shrouds of some BWRs or steam generators of some PWRs have been renewed. A lot of maintenance work has been done to various piping systems. Generally speaking, the average performance of nuclear power activity in Japan is stable except in some particular cases.

Looking at those particular cases in recent years, it was found that various ageing effects have formed basic and common reasons for those incidents from the viewpoint of mechanical degradation, a failure to share past technical experiences and knowledge, and a lack of appropriate evolution of management and inspection systems.

3. OBSERVED AGEING EFFECTS IN RECENT CASES

3.1. Hamaoka NPP-1 (BWR) case (2001)

Part of a residual heat exchanger pipe was broken due to detonation of hydrogen gas that had accumulated in a part of the pipe. A fair amount of hydrogen gas is generated in the reactor core due to the radiochemical reaction of water. At an early stage of development of BWRs, a hydrogen explosion in the discharging pipeline was a serious technical problem. Countermeasures to treat hydrogen gas have since been well developed and the problem had been thought of as being resolved. Over a long period of time, the possibility of accumulating hydrogen gas in pipelines had been overlooked by both system designers and operators. Experience and knowledge of hydrogen explosion have faded and the importance of the problem has not been shared. According to lessons learned from the Hamaoka case, all BWRs which have similar piping systems have been rearranged for those residual heat exchanger pipeline systems.

3.2. TEPCO (2002–2003)

It was disclosed by a whistleblower that some self-inspection data on stress corrosion cracking (SCC) in some components was inappropriately treated. Very thorough and detailed investigations were carried out by the relevant authorities and no BWR or TEPCO was allowed to operate for almost one year. Part of the regulatory laws were amended and related inspection rules have been made more clear. Also, measurement and evaluation methods for SCC of components have been improved. This TEPCO episode did not cause any practical safety problems but raised a big societal issue about nuclear power utilization. The root causes of this case were connected to such problems as increased complacency in reactor operation with continuous good performance, and the sense of compliance had gradually decreased. Also, technical requirements as per regulations had been neither clear nor practical for a long time.

3.3. Mihama NPP-3 (PWR) case (2004)

A part of a feedwater pipe in a turbine system was broken and a significant amount of high energy steam spouted from the pipe. The accident resulted in the deaths of five workers and injury to six workers who were working in the vicinity of the broken part. The reactor was shut down according to the protection scheme without any anomaly. A work situation in which many workers were in the turbine building made the accident very tragic. At present, a very intensive investigation is being carried out by relevant authorities. It is noted that the breakage of the pipe was caused by erosion and the corrosion reaction of high energy water over a long period of operation, and a decrease of pipe thickness that had not been checked for 28 years. This is one of the worst examples of the ageing effect. The licensee had recognized the precedent of another PWR, but had continuously failed to check the pipe. The details of this case are under investigation.

4. KEY SAFETY ISSUES FOR RESPONDING TO AGEING

In recent years, NSC has been trying to establish a quantitative safety goal based on probabilistic safety analysis for making the basis of safety assurance more clear, and to introduce a risk informed regulation system for making regulatory activity more effective and efficient. At the same time, however, these recent cases will apply pressure to respond to ageing problems. The above mentioned cases will suggest the following issues as the most urgent ones for responding to ageing effects from the viewpoint of technical and management phases:

(1) Risk assessment concerning a nuclear facility has to include not only the risk to damages of facilities but also risk of workers' accidental hazards.
(2) Technical standards and guides should be improved and established to be able to recognize and evaluate more clearly a level of age degradation of a facility, and to assess the risk. In order to realize this, both licensees and regulators should make intensive efforts.
(3) An effective and efficient system should be established and continuously maintained to share the experiences and knowledge that are necessary and indispensable to ensure the safe operation of aged facilities.
(4) Continuity and responsibility in work sharing should be secured completely both on the technical and the management sides. The final responsibility for safety assurance should be kept by the licensee. Any degradation of safety due to economic reasons should be prevented.
(5) Safety culture should continuously be enhanced and examined. Changes due to ageing are very slow but indispensable. Degradations of facilities are continuing with the passage of time. It is essential that management maintain this recognition.

5. CONCLUDING REMARKS

Considering the present situation of nuclear safety assurance, the NSC agreed on new basic political measures in September of this year. The safety performance of nuclear power plants in Japan is generally considered to be acceptable, except in some particular cases. Among these particular cases, the issue of ageing is common and important, especially since Japan is entering into an era of nuclear activities with many aged nuclear power plants. One of the most important and effective measures responding to the ageing issue is to share experience and knowledge on ageing problems with generations, organizations and countries. International engagement on the issue should be most encouraged.

KEYNOTE ADDRESS

CURRENT STATUS AND STRATEGY OF SAFETY REGULATION OF NUCLEAR POWER PLANTS IN CHINA

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The National Nuclear Safety Administration (NNSA) of China, which insists on the policy of 'safety first, quality first', regulates nuclear power plants by means of a licensing system according to international standards and experiences, and performs nuclear safety reviews and inspections strictly since its foundation 20 years ago. The nuclear safety regulation in China, starting from zero and developing gradually, has established its elementary system and has greatly contributed to ensure the safety of nuclear power plants. Nuclear power will be developed on a larger scale in the future in China, so there would be more challenges in the field of safety administration. NNSA will take positive measures to face the challenges in order to ensure nuclear safety.

1. BASIC OPERATION AND CONSTRUCTION INFORMATION OF NUCLEAR POWER PLANTS IN CHINA

At present, there are six nuclear power plants (11 units) under construction, commissioning and in operation in China, of which nine units are in commercial operation. In the past few years, the operation of nuclear power plants in China was safe and no incident that may influence the staff and environment happened. The quality of the nuclear power plants under construction is effectively controlled.

In 2003, no incident beyond class 2 happened in all the nuclear power plants in operation in China, and the integrity of all three safety barriers met the requirements of the technical specifications, and no incidents over discharge took place; the waste discharge was also below national standards. The environmental radiation level around nuclear power plants in operation recorded no change compared with the background radiation levels prior to their operation.

The Qinshan nuclear power plant's safety status remained good in 2003, and it had an output of 2.41 billion kW·h of electricity with a capacity factor of 88.74%. Through the sixth and seventh outage, Qinshan nuclear power plant accomplished many critical technique modifications, and the condition of the unit's equipment improved markedly, which enhanced the safety and the equipment's reliability. Unit 1 of Qinshan Phase NPP entered into commercial operation on 15 April 2002, 47 days ahead of schedule, which is a breakthrough in China's local nuclear power equipment manufacture. Its rate of manufacture localization reached 55%, 47 items of all the 55 main equipments are manufactured in China. By the end of 2003, unit 1 had generated 4.6 billion kW·h of electricity with a capacity factor of 81%. After fixing the nozzle safety-end welding defect of the unit 2 pressure vessel, the potential risk on the important safety equipment was eliminated, unit 2 was permitted first fuel loading by NNSA on 28 January 2004 and then successfully entered into commercial operation on 3 May 2004.

Unit 1 of the Third Qinshan nuclear power plant entered into commercial operation on 31 December 2002, 43 days ahead of schedule with some technical breakthroughs, and reached international level in project management. Unit 1 generated 5.593 billion kW·h of electricity with a capacity factor of 90.21%. Unit 2 was firstly and successfully incorporated into the electricity network on 11 June 2003, and entered into commercial operation on 24 July 2003, 112 days ahead of schedule. Unit 2 generated 2.291 billion kW·h of electricity with a capacity factor of 90.42%.

In 2003, the Guangdong Daya Bay nuclear power plant operated safely with steady power and sent 14.383 billion kW·h of electricity to the grid. Unit 1 sent 7.4 billion kW·h with a capacity factor of 91.1%, while unit 2 sent 6.983 billion kW·h with a capacity factor of 83.6%. In order to optimize the resources distribution and increase the utility rate and safety operation level of the nuclear power unit, and for management with specialization, standardization and concentration, with the authorization of NNSA, Guangdong Nuclear Power Group set up the Daya Bay nuclear power management Company to arrange four operating units of Guangdong Daya Bay nuclear power plant and LNPP. The operating practice in more than one year shows that the safety operation of the four units was regulated with norm and uniformity, and the advantage of professional management was developed.

Units 1 and 2 of LNPP entered into commercial operation on 28 May 2002 and 8 January 2003, 48 and 66 days ahead of schedule, respectively. Both of them remained in a good operational state. In 2003, the total electricity sent to the grid by LNPP amounted to 13.310 billion kW·h, of which unit 1 accounts for 6.375 billion kW·h with a capacity factor of 76.38%, while for unit 2, 6.935 billion kW·h with a capacity factor of 85.00%. Unit 2 achieved the record of 239 days of continuous safe operation that had no unplanned reactor shutdown in the first fuel cycle after it entered commercial operation. In general, both LNPPs' main technical and economic index exceeded that of the Guangdong Daya Bay nuclear power plant over the same period historically. Independent project management, independent construction and facilities repair, independent production preparation and design, and independent equipment manufacture were achieved, which fulfilled the aim that "LNPP should be better than the Guangdong Daya Bay Nuclear Power Plant".

Moreover, another two units at the Tianwan nuclear power plant under construction in Jiangsu Province are entering the stage of installation and commissioning. The plant will enter into commercial operation in 2005.

2. DIFFICULTIES AND CHALLENGES IN THE REGULATION AND SURVEILLANCE OF NUCLEAR SAFETY

The construction and operation of nuclear power plants in China have been a great achievement. Nuclear power in China started its first step with technology introduced from more than one country, multitype reactors and standards. Therefore, there are different reactor types, systems, operation and management patterns, which is rarely found in other countries and makes the nuclear surveillance and regulation more difficult. Because we lack experience in the operation and safety management in such a complicated phase, we must keep our attention concentrated and keep alert all the time.

In 2003, the number of incidents at the five nuclear power plants (8 units) in operation totalled 55, of which the number of incidents of class 0 and 1 on the International Nuclear Event Scale (INES) is 47 and 8, respectively. By analysing the cause of the incidents, it can be seen that the number of equipment failures and human error is 31 and 23, making up 54.6% and 41.8%, respectively. The number of other causes is 1, making up 1.8%. It can be inferred that equipment failure and human error are the main reasons for these incidents. It should be noticed that the figures above are the general statistical figures of the nuclear power plants around China. For certain nuclear power plants, it differs. For instance, there are 21 incidents in one nuclear power plants, of which the number of equipment failures is 17, or 81%; there are 11 incidents in another plant, of which the number of human errors is 9, or 82%.

No incidents beyond class 3 occurred in the construction and operation history in China. But in the past few years, a series of significant incidents took place, happened, such as, in the Qinshan nuclear power plants, break of the pressure shell of the control rod driving mechanism, and damage of the barrel lower structure that leads to slight leakage of the primary coolant; in Guangdong Daya Bay nuclear power plants, exceeding the limit of control rod drop time; in SQNPP, the beyond limit welding defects in the safe end of the unit 2 pressure vessel, and the short period losts of all feedwater of unit 1; and in TNPP, the abnormal results in eddy current examination of steam generator heat exchange tubes of unit 1.

In the construction and operation of the nuclear power plants, because of the limited experience and technology of the operator and because of management reasons, there were significant non-conformance items and incidents at times. These facts suggest that the design, equipment manufacture and operation of the nuclear power plants in China are still to be improved, and the surveillance of nuclear safety is becoming very difficult. QNPP will decommission in 2020 and may prolong its service after that time, which will cause new problems for nuclear safety surveillance. Moreover, nuclear energy will develop greatly in the next 20 years according to the national energy plan, in which nuclear power will reach 36 000 MW, making up 4% of the total State power supply, which means 26–28 more 1000 MW(e) units should be built by the year 2020.

For such extensive work, the professionals in this career area are in temporary shortage, the relevant laws and codes are not yet complete, the research and surveillance is not enough, and the capability of responding to nuclear emergency is not enough. Therefore, we are facing more challenges in this field.

3. MEASURES FOR STRENGTHENING REGULATION AND SURVEILLANCE OF NUCLEAR SAFETY

NNSA carries out the State Council's guideline of 'safety first, quality first' in developing nuclear power since its foundation. According to international generic standards and experience, based on the principles of independence, openness, effectiveness, transparence and reliability, NNSA supervised and regulated nuclear power plants strictly by law to ensure nuclear safety.

Independence means NNSA supervises nuclear power plants uniformly and exercises surveillance rights independently. Open surveillance enables the public to know the process and result, and facilitates other parties supervising the activities of NNSA. Effective surveillance means scientifically checking and supervising the entire process for a nuclear power plant, which includes site selection, design, manufacture, construction, commissioning, operation and decommissioning to ensure nuclear power plant safety. Transparency means any deed concerning surveillance should be logical, scientific and consistent with regulations. Reliability means that all behaviour relevant to surveillance should be predictable, transparent and traceable, and have sufficient evidence and support on which reliable conclusions can be made.

In order to satisfy the principles above and to ensure nuclear safety, surveillance and regulation, the focus should be on the following six aspects:

(1) Establish where the risk is highest;
(2) Strengthen surveillance in nuclear power plant with problems;
(3) Objective evaluation of the behaviour of the nuclear power plant;
(4) Predict and respond to activities against the law and regulations in advance;
(5) Establish a set of basic syllabuses for supervision and examination;
(6) Put forward the minimum level of required supervision for all the nuclear power plants.

NNSA has accumulated some experience and played an important role in the past 20 years, working on surveillance and regulation of nuclear safety. Summing up the past work and looking forward to the future, we should consider the present difficulties and challenges, with the aim of carrying out safety supervision work efficiently and ensuring minimum risk nuclear safety. In this regard, the following measures should be taken.

3.1. Further improve the law systems and reinforce execution of the law

Firstly, draw, revise and perfect the administrative and departmental rules against radioactive contamination. Secondly, according to the operating experience feedback from home and abroad, revise the technical rules and standards for nuclear safety, and keep the regulations in China parallel with those at the international level in this field. Moreover, we should further carry out the request ‘administration by law, building up legal government’ advocated by the State Council, by means of the nuclear safety licensing system, the environmental impact evaluation system, the engineering completion acceptance system, and the system of registered nuclear safety engineers with occupational qualifications, supervising nuclear power plants, adhering to the law all the time to promote the sustainable development of nuclear energy and technology.

3.2. Improve the surveillance capability of nuclear safety

Further financial support to the NNSA is necessary to support staff, focusing on enterprise, expertise and a high level of law enforcement. The further union of review, inspection and regulation, and the increased investment in hardware and software are required to enhance inspection ability and the level of law enforcement.

3.3. Promote awareness of a nuclear safety culture

Strengthen the education and cultivation of a nuclear safety culture in the owners and inspectors of nuclear power plants, striving to make them look at 'safety first', promoting the nuclear safety culture of the staff engaged in this field to reach the goal that 'one person is one barrier', advocating working with a scientifically questioning attitude and never concealing any problem in nuclear safety, and consolidating quality assurance management of the owners and staff so that everything can be traced and dealt with in terms of rules. Any incident must be checked and be the responsibility of an individual.

3.4. Enhance the cultivation of qualified staff for nuclear safety inspection

Push for the establishment of a list of registered nuclear safety engineers with occupational qualifications, and reinforce the cultivation of appropriate staffing of the technical arm that supports nuclear safety. Take effective measures to enhance their professional ability. Find ways to attrac more persons engaged in scientific research to a career in building and developing the surveillance and inspection of nuclear and radiation safety.

3.5. Improve the method of surveillance and regulation of nuclear safety

Based on the international experience and technique in this field, and considering that different reactor types, standards, technology and safety philosophies of nuclear facilities coexist in China, NNSA will improve the supervision method, setting up new modes, measures and procedures as soon as possible. More attention will be given to nuclear power plants with problems and places where the risk is higher.

3.6. Periodic safety and operation evaluation

A periodic safety evaluation is introduced to appraise nuclear power plants so as to find the weak points in operation and safety, thus advancing the management and safety of the plants.

Actively advocate the setting up of operational self-evaluation systems and evaluate their work periodically to ensure the safe operation of plants.

3.7. Attach importance to human factors and reinforce operating experience feedback

Feedback (inside and outside nuclear power plants) should be intensified to prevent and correct human error, and promote the owners to build up a feedback system that is 'multiparticipant' and 'multihierarchical'. In this way, incidents occurring in other nuclear power plants could be a warning for us to avoid similar mistakes.

3.8. Upgrade equipment safely

NNSA actively pushes the safety upgrading programme of nuclear facilities based on the owners' practical condition. The owners should reinforce the ageing regulation of the equipment and schedule medium and long term safety improvement programmes. Any modification that may influence the operation licence of buildings, systems and components of safety importance should be submitted in advance for the confirmation and authorization of NNSA.

3.9. Increase the application of probabilistic safety assessment

The operating experience of nuclear power plants throughout the world indicates that the application of probabilistic safety assessment (PSA) can improve safety remarkably. Therefore, both the administative bodies of nuclear industry and the regulatory bodies for nuclear safety attach much importance to PSA and strive to extend the application of PSA in the field of nuclear safety. PSA is employed in China to help design and operate plants. NNSA is working on the application of PSA, developing relevant technical documents, such as nuclear power plant PSA guidelines and reviewing guidelines, for PSA reports.

3.10. Research on measures to prevent severe accidents in nuclear power plants

NNSA is working on how to prevent severe accidents in nuclear power plants to enhance safety and focus research into the management of severe accidents at plants. Consequently, NNSA will provide advice on the study and management of severe accidents. Meanwhile, NNSA is drawing up requirements for compiling management guidelines for severe accidents, further specifying the relevant instruction documents for compiling guidelines for different severe accidents, drawing up regulatory requirements for severe accidents at operating nuclear power plants, and formulating the response to severe accidents at operating plants.

3.11. Strengthen scientific research and international cooperation in the field of nuclear safety

In order to maintain nuclear safety level in China in accordance with international requirements, the safety characteristics of the new generation of nuclear power plants should be actively investigated. Thus, NNSA will push international communication and cooperation, absorbing advanced surveillance techniques, developing and introducing of a safety analysis programme, strengthening research on surveillance patterns for nuclear power plants and radiation sources, developing disposal and treatment safety technology for nuclear fuel cycle nuclear waste and facilities, and researching and cooperating in site defence and terrorism attacks. As a result, the level in this field will gradually approach international standards, providing nuclear power plants in China with strong operating safety.

CHANGING ENVIRONMENTS: COPING WITH DIVERSITY AND GLOBALIZATION

(Topical Issue 1)

Chairperson

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CHANGING ENVIRONMENTS: COPING WITH DIVERSITY AND GLOBALIZATION

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1. RATIONALE/BACKGROUND

It is not surprising that the nuclear community as we know it is becoming more globalized, given that nuclear power has its roots in international cooperation. One only has to go back to the early days, when just over 50 years ago the “Atoms for Peace” programme was first announced at a plenary meeting of the United Nations General Assembly, to realize that nuclear power really was always a global community.

In the years since 1953, we have witnessed the growth of the nuclear industry, which brought with it, among other things: competition between manufacturers from different countries with different design and operating philosophies; individual national cultures and regulatory practices and unique legal systems; and different safety and industrial standards and approaches to technology transfer.

Today, the stagnation, or slowdown in construction programmes for nuclear facilities in many countries, combined with the rising costs of R&D, has provided new impetus for the nuclear community to return to a more global outlook. But this new global outlook must grapple with the diversity that grew out of the competition, the individual national cultures, and the unique legal requirements, as well as with the needs of national nuclear industries with different levels of maturity and means.

This session will address the new challenges for governments, regulatory authorities, operators, nuclear suppliers, and contractors in facing these and other issues.

2. PRESENT STATUS OF THE ISSUE

2.1. Globalization of the nuclear industry

The current realities of the nuclear industry have led to consolidations in both plant vendors and operating organizations. Power plant vendors increasingly are evolving from companies having strong national identities, into multinational enterprises. Economic deregulation of the electricity sector, as well as political integration, has led to major changes in ownership and operating arrangements of many nuclear power plants. Large generating companies have bought plants in widely separated locations, including in foreign countries, and plant owners have contracted with specialized management companies to operate their facilities. Multilateral R&D has become an important part of the future for nuclear energy.

The trend toward increased globalization of the nuclear industry began about 15–20 years ago. Generally speaking, early cooperative efforts focused on development of a reactor or a process, rather than the merging of two or more companies. In the early 1970s, the German, Dutch and British governments decided to jointly develop the centrifuge process of uranium enrichment; the resulting venture was named the Urenco Group, and is now a supplier of enrichment services. A similar such example, going back to 1989, was cooperation between Framatome and Siemens to develop the EPR (European Pressurized Reactor) design.

More recently, companies are evolving into more global organizations, often bringing together partners from earlier cooperative efforts. In July 2000, Siemens (KWU) and Framatome SA reached agreement for creating a joint company and, by September 2001, Siemens and Framatome SA had merged their nuclear activities into Framatome ANP. Also in 2001, AREVA, an industrial group that includes the operations of Cogema and Framatome ANP was formed. Although primarily a French conglomerate, it includes Siemens (through Framatome ANP), as well as shareholders from Belgium, Italy and Spain. The company is unique in that it operates in every sector of the nuclear power industry, including the fuel cycle, reactors, instrumentation, nuclear measurement systems and engineering.

In 1999, BNFL was transformed into a global nuclear company when it acquired the US nuclear services company of Westinghouse, and in 2000 BNFL expanded even further by the complete acquisition of the commercial nuclear power business of ABB.

Coming up to the recent past, early in 2004, a broad based nuclear industry consortium — NuStart Energy Development — was formed between nine energy companies to demonstrate and test the new process for obtaining a construction and operating license (COL) for future nuclear power reactors in the USA The consortium is comprised of five US commercial nuclear utilities, including Duke Energy, Constellation Energy, Entergy Nuclear, Exelon Generation, and Southern Company; a French company, EDF International North America (a US subsidiary of Electricité de France); the Tennessee Valley

Authority (a US Federal power agency); and two nuclear reactor vendors, Westinghouse Electric and GE Energy's nuclear operations.

In similar fashion, other multinational groups have formed to collaborate on longer term R&D for new generations of reactors. Examples of these include:

- INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles), an initiative of the IAEA, is continuing work on development and deployment of innovative nuclear systems for long term utilization, with particular focus on the needs of developing countries. As of September 2004, INPRO had 21 members: Argentina, Armenia, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, France, Germany, India, Indonesia, Republic of Korea, Pakistan, Russian Federation, South Africa, Spain, Switzerland, Netherlands, Turkey and the European Commission.
- GEN-IV (Generation IV International Forum), is an initiative launched by the US Department of Energy but open to other governments, industry, and the international research community to develop new concepts for nuclear reactors. This research programme, envisioned as a vehicle to develop innovative reactors that can be deployed in the next few decades, has a significant safety focus, in that inherent to the design of new reactors is the premise of their safety. Current participants are: Argentina, Brazil, Canada, France, Japan, Republic of Korea, South Africa, Switzerland, United Kingdom, and the USA.
- PBMR (Pebble Bed Modular Reactor), a high temperature gas cooled design, is a demonstration project supported by South Africa (the power utility Escom and the state-owned Industrial Development Corporation) and BNFL. The environmental impact assessment for the demonstration project was completed this year and licensing activities in South Africa continue. It is likely that safety and regulatory issues associated with its construction and operation will be significant topics for future consideration.

In today's global energy market, electricity is an internationally traded commodity. Globalization brings both benefits and new problems; on the minus side, globalization could lead to situations where it would be commercially attractive to use nuclear power to generate electricity in a country with 'lower' safety standards and less expensive production costs. The 'cheap' electricity generated could then be sold in the international market at substantially reduced rates. Only a commitment to consistently high level of standards and an agreed upon global safety regime can prevent such developments.

Globalized industries have to cope with very diverse, and often conflicting 'boundary' conditions. Such conditions often have a multidimensional character, and could be technical, political, cultural, and/or environmental, or, more likely, a combination of these considerations.

Of particular importance is the necessity to 'globalize' a strong safety culture in these new industries, particularly at the corporate level, during the transition period of organizational change and restructuring brought by the evolution of national nuclear related companies into more global enterprises. Under conditions in which an organization is undergoing other multidimensional changes, safety culture may suffer the most. The efforts to maintain and improve safety culture must be a top priority in the policies of the new global corporate entity.

2.2. Cooperation between national regulatory bodies

Simultaneously, while regulation of nuclear installations remains a national responsibility, regulators have created several international groups to exchange information and best practices with counterparts in other countries to strengthen cooperation, and to improve regulatory effectiveness and processes in their own countries. Some of these groups are regional, some deal with particular reactor types, and others are based on the size of the in-country nuclear reactor programme. Membership often is overlapping, but the key point is that there does not appear to be a common approach to regulatory issues.

The most well known of these include:

- INRA (International Nuclear Regulators Association), is a forum for senior regulators from major advanced nuclear power countries in Europe (France, Germany, Spain, Sweden and the United Kingdom) as well as the USA, Canada, and Japan. The objective of the group is to share experience and examine a broad range of safety issues with the purpose of influencing and enhancing nuclear safety from a regulatory perspective. INRA has not attempted to standardize national regulations, but works to increase consensus on approaches to nuclear safety issues.
- WENRA (Western European Nuclear Regulators Association), as the name implies, consists of the heads of nuclear regulatory bodies of most western European countries with nuclear power programmes. Bulgaria, Czech Republic, Hungary, Lithuania, Romania, Slovakia and Slovenia joined WENRA in March 2003. The group is again focused on sharing experience in nuclear safety regulation. It uses its collective knowledge to advise European institutions on nuclear safety in countries that are

applicants to join the European Union. The group also has been active in promoting the harmonization of nuclear reactor safety and radioactive waste standards in member countries.

- NERS (Network of Regulators of Countries with Small Nuclear Programmes), includes Argentina, Belgium, Finland, Hungary, the Netherlands, Slovakia, Slovenia, South Africa, Pakistan, and Switzerland, and focuses on many of the issues relevant to diversity and globalization. NERS most recent meeting (2003) included discussions on maintaining regulatory control and corporate knowledge within the regulatory body (when, for example, operating organizations contract out work and when Technical Support Offices are engaged in regulatory decision making), and quality management of regulatory bodies.
- The Ibero-American Forum of Nuclear Regulators originally was limited to Ibero-American countries with interest in nuclear power (Argentina, Brazil, Cuba, Mexico, and Spain), but was expanded in 2003 to cover regulatory issues related to radiation safety, and therefore open to other countries of the region.
- The Cooperation Forum of State Nuclear Safety Authorities of the Countries Operating WWER Type of Reactors includes Armenia, Bulgaria, the Czech Republic, Finland, Hungary, the Russian Federation, Slovakia and Ukraine (Germany and the IAEA participate as observers). At its most recent meeting in 2003, topics included elements that contribute to regulatory independence and technical competence, inspection practices, differences between PSA reports and subsequent plant modifications, and methods to make better use of operating experience when working to increase nuclear power plant safety.
- The Group of Senior Regulators from Countries Operating CANDU Type Nuclear Power Plants includes Argentina, Canada, India, the Republic of Korea, Pakistan and Romania. Meetings generally focus on generic safety issues for pressurized heavy water reactors, compliance and enforcement, safety indicators, periodic safety review, technical specifications and operating policies and principles, and other operational topics.

These groups aim to foster the interest of their particular group, and sometimes focus on single issues. The groups are informal in that they are not based on international treaties or other legally binding instruments. Generally, participation by the respective regulatory bodies in these groups is at a very senior level. Although such interaction might be conducive for cooperative efforts, it does not necessarily lead to optimal coordination of day-to-day activities by national regulators. Broader perspectives need to be pursued to seek common directions in approaches, for example, at the regional level, or on a thematic basis.

In 2003, the European Commission proposed initiatives to develop common nuclear safety and waste management regulations that would be binding on the EU states. The June 2004 meeting of the EU Council did not endorse these initiatives after they met with resistance from some states. The Commission recently announced revised initiatives, calling for discussion by EU leaders “without delay”. The Commission stressed the need for establishment “of a common system for the evaluation of nuclear safety in each member state”.

On a broader multinational level, the Nuclear Energy Agency (NEA), a specialized agency of the Organization for Economic Co-operation and Development (OECD), has a standing committee for senior level representatives from member government regulatory organizations, the Committee on Nuclear Regulatory Activities (CNRA), which aims at reaching a common understanding on state-of-the-art safety approaches.

The IAEA holds a meeting of senior regulators in association with the annual IAEA General Conference, which is mainly an information exchange activity. In addition, the IAEA hosts many other activities, during which regulators seek to develop a common understanding on technical and policy matters. The IAEA also facilitates and supports the reviews by the Contracting Parties of the Convention on Nuclear Safety.

Despite efforts to gain understanding and experience through international exchanges, rigidities and inadequacies remain in national legal and regulatory schemes. However, there is general agreement amongst IAEA Member States that the IAEA safety standards reflect a high level of safety and could serve as the global reference for the protection of people and the environment. It is very clear that these international safety standards are not at level of the lowest common denominator. Many regulatory bodies in IAEA Member States use the Agency’s safety standards as reference for developing their national regulations. In other Member States, regulators are called upon to ensure that their regulations are in agreement with the Agency standards and the levels of safety expressed in them. However, this is not the case universally, and national safety regulations and methodologies may not be fully compatible with, or based on, international standards due to individual national approaches and regulatory practices. Some advanced nuclear power countries, with long standing independent regulatory bodies, have not invited IRRT (International Regulatory Review Team) missions to review national nuclear regulatory practices against the benchmark of IAEA safety standards. In other States, steps to improve regulatory independence and introduce adequate legislation are still needed. In other instances, national regulatory regimes may lack adequate authority to oversee activities of contractors (sometimes from foreign countries) that have been hired to operate nuclear facilities. Regulators also must pay attention that globalization does not allow for any degradation of safety. They should be alert to any early symptoms of safety culture deficiency through prompt regulatory attention.

2.3. Industrial standards, technology transfer and licensing

A similar difficulty arises with respect to internationally recognized industrial standards. To date, there is no agreed upon set of comprehensive standards that can serve as benchmarks for all major nuclear manufacturers. Some efforts are slowly developing, such as agreement between the IAEA and standard organizations, such as the International Organization for Standardization (ISO) and the International Electro-technical Commission (IEC) to use a common structure and share glossaries. However, more work needs to be done to develop industrial standards that complement IAEA safety standards (ISO and IEC have no comprehensive set of international nuclear standards). Thus far, the nuclear industry has not been very active in promoting global industrial standards

Differences in industrial standards can affect issues as diverse as import licenses or technology transfer. Recipient countries may be dealing with different supplier country standards or codes (for example, ASME and RCC-M), or engineering standards (e.g. welding codes). Even simple things like incompatible pipe threading can lead to safety problems and costly delays. Suppliers, on the other hand, may not be able to retool to meet importer specifications when they are different from those of the supplier country.

Moreover, with respect to technology transfer, the alternatives for importing nations may be limited. This situation could be exacerbated when the importer has a narrow knowledge base as compared to an experienced supplier or manufacturer. Confidentiality of contract information may inhibit the ability of an importing country to realistically compare bids. Initial, and even final documentation, may be available only in the language of the supplying nation. Technology may change rapidly, resulting in the supplier or vendor re-tooling, changing the configuration, or even eliminating spare parts. In other instances, the supplier (or the contractor, or the architect-engineering firm) may not want to provide complete information transfer because of fear of losing market advantage (for example, nuclear fuel manufacturers). Similarly, the supplier may not want to incur the cost of transferring technology to the operating organization in the importing country.

Technology transfer is not always smooth, even when suppliers and recipients have reached agreement. National policies may not be coincident with those of industrial interests. For example, countries not agreeing to the NPT (nuclear non proliferation treaty) may have a difficult time with technology transfer, even including travel and access restrictions observed by supplier countries. National safety requirements can change, either in the supplying or the importing country. A vendor may not be willing or able to change a safety specification that has been approved in his own country in order to satisfy different regulations in an importing country. For example, a nuclear power plant operator might want to apply a set of tools (and even additional hardware) for severe accident management that is not in line with the practice of the supplier country.

Licensing issues may arise when a reactor design will be licensed in another country prior to the designing nation having completed its own safety assessment. This will be the case when Finland builds and licenses the French/German EPR before the reactor has been subjected to a domestic safety assessment in either France or Germany. In the case of older designs, facilities may be designed to different standards and criteria, and then need to have licenses issued to meet importing country requirements. Also, countries like Finland, Belgium, China, India, the Republic of Korea, Spain and Switzerland have imported designs from more than one supplier country and are operating more than one NPP design.

In other instances, a facility may be a hybrid, such as is/will be the case in Finnish and Eastern European plants that began as WWER facilities and have had PWR or other Western technology added. Conversely, in Iran, for example, a nuclear power plant with a German original design will have a Russian project completion; in Vietnam, a US manufactured Triga Mark II research reactor was retrofitted with a Russian design core and control system. In these instances, both licensing and design reconstruction issues (missing information with respect to specifications, safety analysis reports, calculations and computer programming, etc.) as well as supplier responsibilities may be problematic. An added dimension is the type of problems that can be encountered when working with a separate nuclear steam supply system supplier and balance of plant) architect–engineer, versus working with a single contractor with turnkey responsibilities.

2.4. Operational issues in an era of ‘big business’

As noted earlier, the current reality in the nuclear industry has led to consolidation among nuclear power plant vendors and operating organizations, such that large generating companies and management organizations are now in place at many plants. The number of small utilities operating a single nuclear unit has diminished. While the larger companies generally bring greater management and technical capabilities, there also is the challenge of merging diverse cultures in the new organization. Questions which previously had clearly defined answers can become less precise. For example:

- What is the role of the formal license holder versus the management organization with respect to daily safe operations or with respect to setting safety policies?
- What conditions are controlling the outsourcing of certain activities; who is assuming the responsibility for the work accomplished; is there sufficient knowledge left in the operating organization to control the outsourcing?
- Can the license holder delegate responsibility to another party?
- Who, or what institution, is responsible for budget planning and approval, long-term investment decisions, maintenance costs, etc.? Are such decisions made abroad by those who may not be directly accountable, or in the country where the facility is in operation?

Also, as noted earlier, the relationship between the regulator and the management organization needs to be clarified and rules need to be in place that defines their relationship.

2.5. Information technology and communication

Advances in information technology and communication have led to stronger interactions between operating organizations, regulatory authorities and other concerned stakeholders. In general, this has had a very positive effect on the level of safety and has led to greater public awareness of nuclear safety issues. In this regard, the importance of communication with the public and other stakeholders on safety and regulatory issues is being recognized by many regulatory bodies and intergovernmental organizations, such as the IAEA and the OECD/NEA. Some organizations, including operating organizations, already have set up and are operating offices dedicated to public communication. Although this is a welcome development, it brings increased expectations of the public for information concerning operations and regulations, both during normal, day-to-day activities and during 'incidents' or 'events'. Now, more than ever, it is necessary to recognize that nuclear safety is a truly global issue and that 'an accident anywhere is an accident everywhere'. Hence, greater transparency by all organizations in the nuclear community is an essential condition for establishing trust in the technology.

3. PRIORITIES FOR FUTURE WORK

3.1. Integrating diverse standards, national approaches and regulatory practices

A major issue that globalization presents is whether countries will embrace internationally accepted safety standards and show the flexibility in their legal and regulatory systems to adapt their national safety regulations and practices for the sake of global unity and efficiency. The increasing number of multinational companies and mergers has contributed to the internationalization of safety approaches, and at the same time has increased the need for globally accepted safety standards. A stable and predictable nuclear regulatory regime in which decisions are shared globally will make a positive contribution to safety. Self-assessments and international peer reviews will foster such modern regulatory approaches. The need for both intergovernmental (IAEA) safety standards and international industrial (safety) standards will continue to grow, particularly as new reactor designs go from the drawing board to construction, licensing, and operation. Industries need to be open to adopt or be consistent with internationally agreed upon industrial (safety) standards.

Many countries with new or developing nuclear power industries are basing their national regulatory standards on IAEA safety standards to reflect the “best practices in the developed countries”. They also are adopting the probabilistic criteria recommended by the IAEA for new plants. These two conditions can represent a challenge both to the vendor to be sure that the reactor design meets the latest IAEA safety standards, and to the new owner/operator to develop the institutional capacity needed for independent verification and assessment of the design being offered. As new nuclear power plant designs are being developed in this first decade of the 21st century, it is important that the latest IAEA safety standards and international industrial safety standards be incorporated during the design phase, rather than having to be considered later.

3.2. International design certification

In parallel, there is a need to examine whether an international certification of nuclear power plant or research reactor designs can be developed. International certification would give a guarantee that the design meets certain standards, which presumably should render them acceptable in other countries. In the aircraft industry, for example, there is a process to certify aircraft to operate throughout the world. Another example is the interoperability of the trans-European high speed rail system. European directives have introduced common rules for technical compatibility and harmonization in the rail industry; these rules recognize a certification system for component manufacturing in any European country. For the nuclear area, the question is who would take the role of reviewing and assessing the safety aspect of the design that is necessary to certify the proposed new NPP or RR design? A certification of nuclear reactor designs could be developed along different lines, such as: mutual approval of new designs; sharing of standards approved by regulatory bodies; or, rules for mutual recognition or approval of designs. Also a scheme could be considered in which regulatory organizations set up a consortium to perform necessary assessment and then each regulatory organization certifies or approves the design. This would require that national laws and regulations be amended to allow this process. Designs could also be considered on a more restricted scale, such as common nuclear power plant designs for a target group of countries, or common designs for systems of components.

3.3. Technology transfer

Technology transfer does not stop with hardware: it includes, or should include, availability and transfer of design information, technical knowledge, training, and operational and administrative information. Rules have to be developed to ensure effective technology transfer, both for the delivery of documentation linked to systems, and for documentation linked to components. Design documentation should be made available to the operator in the working language of the importing country, which raises questions of cost and of certification that the translation is technically accurate. Moreover, long term commitments for information flow need to be established, both with respect to advising purchasers on new insights, and purchasers providing feedback to the vendor about operational experiences.

Technology transfer also should not be limited to industry organizations directly involved in design and manufacturing. Regulatory bodies could play an important role in technology transfer. Supplier country regulatory bodies could provide the regulatory bodies in importing countries information on relevant safety and regulatory issues, advise on licensing and experience feedback, as well as training, when necessary.

3.4. Accountability

Implementation of accountability measures for the safety of the initial design or plant, for long term operation, for ageing, and for plant life extension issues has always been of concern. Globalization has increased the complexity of these and other issues. Systems documentation, for example, can deteriorate over time, or modifications can be made on best practices. Also, as the potential for hybrid designs increases and as ageing plants may be refurbished by other than the original supplier, issues concerning design integrity must be addressed. (It is worth noting parenthetically that IAEA International Nuclear Safety Advisory Group (INSAG) report No. 19, Maintaining the Design Integrity of Nuclear Installations Throughout Their Operating Life, provides a suggested approach on this issue. (INSAG-19 and other publications in the series are available through the IAEA publications web site: http://www-pub.iaea.org/MTCD/publications/publications.asp)

Guidelines should be developed on the limits or extent of accountability of the original supplier and on the responsibility of the importing operator.

As noted in Section 2, different accountability issues arise when management companies are contracted to operate nuclear power plants. Feedback from operating experience may not be channelled back to the license holder; or research on unexpected design issues may not be performed. Guidelines also may be needed to ensure accountability in such areas. These might take the form of setting up a design capability as part of the terms of a management contract, or having a formal external relationship with the original design organizations or their successors.

4. NEED FOR STRENGTHENING INTERNATIONAL COOPERATION/GLOBAL SAFETY REGIME

It should be noted here that the priorities mentioned in the previous section for Future Work address topics that warrant strengthening through international cooperation.

4.1. Knowledge management and information sharing/networking

The globalization of information is both a welcome event and a challenge. The public has easy access to information from around the world, leading to demands that the best standards of protection and safety be applied everywhere. The IAEA safety standards are recognized as the global reference point for the protection of the public and the environment, and if they are to be used to deliver this goal, then the regulators and users of nuclear technology around the globe need to have ready access to information about safety standards and the best means for applying them.

The need for knowledge management — extension and renewal of the knowledge base, preservation of existing resources, and knowledge sharing —

is increasingly recognized. In many regions, the human resources of the nuclear community are ageing rapidly. While ageing brings with it the benefits of accumulated knowledge, experience and mature judgement, there is need for succession planning and renewal of the human resource to permit the knowledge and experience to be passed on. Creation of new knowledge to extend and renew the knowledge base goes hand-in-hand with renewal of the human resources at the university level. In many States, lack of government support for nuclear education and training, and changes in priorities of universities have resulted in the loss of nuclear programmes, faculty and facilities, making this aspect of knowledge management more difficult. On the other hand, many countries are establishing national training centres to provide continuing education, and improved on the job training continues to be an essential part of developing and maintaining competencies.

Global safety is best served by exchange of all relevant information through networking between all stakeholders, while respecting some limitations because of other (often commercial) interests and institutional differences.

Still there are issues to be resolved. As noted earlier, fear of a loss of competitive advantage may hinder participation in networks and prohibit entry of some data into shared databases. Other issues include: the cost of maintaining network infrastructures, the challenges of ensuring quality inputs, the difficulties of overcoming language barriers, and determining how best to ensure effective access.

4.2. Multinational agreements

International legal instruments and intergovernmental agreements also provide a means to strengthen the global safety regime and to seek common solutions to issues. Most of these mechanisms are just beginning to be exploited. Those related specifically to safety include: the Convention on Nuclear Safety which entered into force on 24 October 1996; the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, (the Joint Convention) which entered into force on 18 June 2001; and, the Code of Conduct on the Safety or Research Reactors, which was agreed upon by the IAEA Board of Governors in March 2004 and subsequently endorsed by the 2004 General Conference. Note that unlike Conventions that are binding on the signatories, a Code of Conduct is an international legal instrument to which States may make a political commitment to apply its guidance, but are not legally bound by it.

5. POTENTIAL AREAS FOR FUTURE IAEA ACTIVITIES

5.1. The IAEA mandate

While safety is a national responsibility, international standards and approaches to safety promote consistency and facilitate international technical cooperation and trade, and help to provide assurance that nuclear and radiation related technologies are used safely. The IAEA's mandate in relation to safety is defined in its Statute. Article III.A.6 specifies two main functions the Agency is authorized to perform in relation to safety.

- To establish or adopt...standards of safety for protection of health and minimization of danger to life and property... and
- To provide for the application of these standards...

The IAEA also has a statutory function to foster exchange of information about safety. In fact, it is well placed to foster the open, effective and efficient exchange of safety related information and knowledge among all Member States, acting as a facilitator or an intermediary where necessary. Already in place, or under consideration, are mechanisms such as:

- Creation of knowledge databases — best practices, expert directories, etc.;
- Active process management — knowledge gathering, classifying, storing, etc.;
- Development of knowledge centres — focal points for knowledge skills and facilitating knowledge flow; and,
- Networking — connecting individuals with common interests to share knowledge.

5.2. Safety through international standards

The first overall objective of the IAEA with respect to safety is to make its safety standards a set of universally accepted and applied global standards.

Safety standards are a powerful tool with which States can demonstrate that they are meeting their obligations to operate their nuclear facilities in a safe manner so as to not cause damage to another State or to their own populations. The safety standards are intended for regulatory bodies and governmental agencies as well as organizations that design and use nuclear and radiation related technologies, and users of radioactive materials in industry, medicine, agriculture, research and education.

The IAEA Statute makes the safety standards binding on States in relation to operations assisted by the Agency. Many assistance activities are carried out in the framework of the Agency's Technical Cooperation programme or Extrabudgetary Programmes. Any State wishing to enter into agreement with the Agency concerning any form of assistance is required to comply with the requirements of the safety standards that pertain to the activities covered by the agreement. Good examples of assistance are the safety upgrades that have been implemented in WWER plants to make them meet IAEA safety standards. Also, research reactors supplied under such agreements have to meet the appropriate safety standards and regulatory organizations have been advised to build their organizations and competence in accordance with the requirements for legal and governmental organizations. However, the applied national regulations may not be compatible with IAEA safety standards for a variety of reasons. Simultaneously, the Agency stands ready to advise regulatory bodies on how to ensure that their regulations will comply with IAEA safety standards.

The kind of services that the Agency provides to organizations in Member States can have an element of review of the organization, facility, or activity to establish to what extent the IAEA safety standards are met. If non-compliance with the safety requirements is established, or if practices are divergent from the safety guides, recommendation and suggestion will be made to correct the issues. The services can also have an element of assistance in the sense that the Agency will provide support on what corrective actions should be taken. The ultimate objective is to bring the situation in agreement with the IAEA safety standards.

The Agency also can serve as a facilitator to develop a common working direction for the several regulator association forums that already exist, if they should desire this service. The Agency can assist the different groups with development of a common direction and foster information dissemination, either through the already established Senior Regulators meeting or by additional networking. The Agency could provide a global forum for regulatory exchange of information on issues, potential solutions, and established good practices. This information, in turn, might feed future revisions of IAEA safety standards.

As noted in the earlier discussion, there currently is no comprehensive set of industrial standards to supplement the IAEA safety standards. The Agency could develop explanatory material about IAEA safety fundamentals, requirements, and guides more keyed to an industrial audience, and stands ready to work with international standards organizations to better link the systems.

5.3. Technology transfer and accountability

The second overall objective of the Agency with respect to safety is to integrate fully the IAEA safety standards and their application systems.

The Agency is committed to provide safety related technical cooperation focused on areas in which national capabilities fall short or do not have the global authority. The Agency could serve as an instrument to facilitate design information and documentation for technology transfer to help ensure long-term safety. Issues such as modernization of a design in the country of manufacture, revising regulatory standards, and dealing with plant ageing (systems, structures and components) need to be considered as components of safe technology transfer. Other related issues include: the reconstruction of the design basis because of a need to merge systems from different designs and vendors into a single plant; licensing facilities designed to different standards and criteria; and applying safety standards from different supplier countries. Although there is a prevailing commercial interest to treat design information as a commercial commodity, the Agency could offer its good services and work to evaluate issues that could arise between the original industrial architect-engineering firm, the original vendor of the reactor, and the new entity.

5.4. Other issues

Other issues to be addressed, which largely fall outside the Agency's mandate, include: certifying the design of nuclear installations; providing long term accountability in industry; and, developing and enforcing multinational industrial standards. These issues need to be addressed by national governments and by the international community. The Agency stands ready to assist with these activities within the limits of its mandate.

6. QUESTIONS FOR DISCUSSION

What further developments are critical to achieve global recognition and acceptance of IAEA safety standards? What is the role for the nuclear industry in this acceptance and in the actual use of these standards? What is the role of the regulatory authority?

- What role can the Convention on Nuclear Safety and the Code of Conduct on the Safety of Research Reactors play in further enhancing the safety of nuclear installations? What path should be pursued for fuel cycle facilities?

- Which factors could contribute to further development of global industrial (safety) standards that would supplement the IAEA safety standards? What can be done to ensure compatibility and the complementary nature of regulatory and industrial standards?
- Which modes of international design certification are feasible? What should be the role of the Agency in this regard?
- How can technology transfer rules contribute to the longstanding safety of nuclear installations?
- How can impediments posed by commercial interests be overcome when sharing safety relevant information through (global) networks?

A PRACTICAL APPROACH TO APPLYING THE NEW IAEA SAFETY STANDARDS BASED NATIONAL LICENSING REQUIREMENTS TO CHASHMA UNIT-2

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Abstract

The paper discusses how Chashma Nuclear Power Plant Unit 2 (C-2), a 325 MW(e) PWR, plans to comply with the recently introduced national design regulation based on the new IAEA Safety Standard NS-R-1. C-2 is to be built by the China National Nuclear Corporation (CNNC) for the Pakistan Atomic Energy Commission (PAEC). The first unit (C-1), also a 325 MW(e) PWR, was commissioned in 2000. The practical experience of full compliance with the regulations does not exist in China, Pakistan or elsewhere. Establishing a licensing basis for a nuclear power plant which takes the already existing plant at the same site as the reference plant, but which has to obtain a licence under the new IAEA NS-R-1 based regulation, offers both challenges and opportunities. The paper describes the approach adopted by the utility, duly supported by the vendor and the designer, to handle the licensing issues of the C-2 plant.

1. INTRODUCTION

Pakistan and China have been cooperating for a long time in the area of the peaceful uses of nuclear energy. The China National Nuclear Corporation (CNNC) has already constructed a 325 MW(e) PWR for Pakistan. The plant, Chashma Nuclear Power Plant Unit l, or C-1, is located at the Chashma site. C-1 was planned to be the first of the two units which China had agreed to supply to Pakistan.

Prior to this, there was only one nuclear power plant operating in Pakistan, the 137 MW(e) KANUPP, a CANDU type PHWR supplied by

Canada. For almost all of its design life, KANUPP received no vendor support because technical assistance in the area of nuclear technology was denied to Pakistan. However, KANUPP was operated safely for 30 years by the Pakistan Atomic Energy Commission (PAEC). Upon completion of its design life in 2002, KANUPP carried out many safety retrofits and has been allowed by PNRA to operate at reduced power — pending additional retrofits required to complete the licensing process for life extension.

C-1, which was commissioned in 2000, has now been in operation for about four years. C-1 has been a great learning experience for PAEC right from the planning stage. It is an illustrious example of the South–South cooperation in the area of nuclear technology. When C-1 was planned, China had just commissioned one nuclear power plant (the 300 MW(e) PWR, Qinshan-1) and had two other nuclear power plants under construction on a turnkey basis. For Pakistan, it was the second nuclear power plant but the very first PWR. For the construction of C-1, PAEC entered into a turnkey contract with CNNC. Both organizations, supported by their respective countries, collaborated with each other to successfully complete the C-1 project.

To carry out the licensing process of the first unit, the Chinese nuclear regulatory authority, the National Nuclear Safety Administration (NNSA), cooperated with the nuclear licensing authority of Pakistan, which was called the Directorate of Nuclear Safety and Radiation Protection (DNSRP). At that time, DNSRP operated under the auspices of PAEC, which owned the plant. NNSA provided the necessary consultancy.

The site for C-1 was selected in the early 1970s. The first site report, completed in 1984, was for a 900 MW(e) nuclear power plant of French design. However, after signing the contract for the 325 MW(e) nuclear power plant with CNNC, a new site evaluation report was prepared. Both site reports were prepared as per the format and content of Chapter 2 of the PSAR according to the US Nuclear Regulatory Commission's (NRC's) Regulation 1.70 (Rev. 3) [1]. The safety review was carried out according to the IAEA's safety standards and the US Nuclear Regulatory Commission's Standard Review Plan (NUREG-0800) [2].

The C-1 PSAR, prepared with the assistance of the Chinese vendor and designer, was submitted in 1992. Again, the format and content of the NRC's Regulation 1.70 (Rev. 3) [1] were followed due to the unavailability of such guidance from the IAEA. During the early period of negotiations for the supply of C-1, the regulatory requirements in China were based on IAEA Safety Series No. 50-C-D (Rev. 0), whereas in Pakistan the regulatory requirements were based on the later version, Rev. 1 [3]. The Chinese vendor maintained that sufficient guidelines were not available to fully implement the IAEA's requirements. However, after several discussions, consensus was reached on an acceptable solution regarding application of the revision in the C-1 design.

The safety analysis reports were reviewed primarily by using the US NRC's Standard Review Plan (NUREG-0800) [2]. However, during the review process, DNSRP, supported by NNSA and the Chinese designer, ensured that the intent of the IAEA guidelines was generally fulfilled by the design and the safety analysis reports. The industrial standards used were mostly of US origin, but Chinese standards were also used. The basic design was also reviewed by an expert team organized by the IAEA. The review result was positive.

Since the Chashma site was planned and developed for twin units, some structures and buildings were built to accommodate two units. When the work on C-1 started, negotiations were held between CNNC and PAEC for the second unit, C-2. However, no deal could materialize at that time because the economic situation in Pakistan did not allow another major investment in nuclear power without knowing the final outcome of the first exercise. The successful commissioning and operation of C-1 paved the way for the second unit. Dialogue was reinitiated with CNNC, which showed its willingness to supply the second unit but similar in design to the first unit.

In the meantime, an independent licensing body, the Pakistan Nuclear Regulatory Authority (PNRA), came into existence in Pakistan. The regulations issued by PNRA in 2002 on the design of nuclear power plants are based on IAEA Safety Standards Series No. NS-R-1, Safety of Nuclear Power Plants: Design (2000) [4]. This safety standard was relatively new and more demanding, and the lower tier guidelines did not provide adequate information necessary for fully implementing the requirements of these standards. By that time, the NNSA had not adopted the new IAEA standard. Because of the uncertainties in the implementation of the regulation, the Chinese designer and vendor found it difficult to enter into a commercial contract guaranteeing licensability on the basis of the regulation. This led to difficulties in finalizing the technical details around which the contract could be written. An effort was made to invite PNRA to the technical negotiations with the vendor, but PNRA found it difficult to get involved as no formal submission had been made to them.

The C-2 contract was ultimately signed by making such design changes in the C-1 design as would meet the intent of the new national regulations according to the understanding of the vendor and the buyer. Therefore, the licensing process of C-2 will be a challenging exercise and an example of the application of the new IAEA safety standards based regulation to the existing design. This paper provides the details of the approach that is being followed.

2. CURRENT LICENSING REGIME IN PAKISTAN

The PNRA, the licensing authority in the country, has been formed under a presidential order called PNRA Ordinance 2003. Prior to that, the regulatory body, the Directorate of Nuclear Safety and Radiation Protection (DNSRP), worked under the control of PAEC. The new authority (an independent Government organization) issued the Regulations for Licensing of Nuclear Installations in Pakistan (PAK/909), and the Regulation on the Safety in Nuclear Power Plant Design (PAK/911) based on IAEA Safety Standards Series No. NS-R-1 [4].

In addition to IAEA Safety Standards Series No. NS-R-1, PAK/911 also includes clauses from the US NRC's Regulation 10CFR and other sources. The PNRA regulation also includes certain quantified targets which are only recommendations elsewhere and are beyond the requirements of the IAEA standards. All of this has made the national regulations quite stringent.

When PNRA issued the new regulations, it did not revise the already existing regulatory guides but adopted most of them and required that the latest NRC guidelines be used wherever PNRA had not provided the necessary guidance — notwithstanding the fact that most of the NRC regulatory guides were written before the IAEA issued their new standard. The PNRA also did not adopt any specific industrial codes.

As for the current procedure of licensing of nuclear power plants in Pakistan, a three stage approach will be followed:

(1) Site registration;
(2) Issuance of construction licence;
(3) Issuance of operation licence.

The site will be registered on the basis of review and acceptance of the Site Evaluation Report (SER) by PNRA and submission of 'no objection certificates' from various federal, provincial and local bodies with whose functions the plant may interact. After the site registration, the licensee is required to submit a report to establish that the design and safety criteria are in accordance with PNRA's regulations.

The construction licence will be issued upon the submission of the PSAR, Overall Quality Assurance Program and a PSA report, and the subsequent acceptance of all these documents by the regulatory authority.

A fuel loading permit, a prerequisite for obtaining an operating licence, will be issued after review of the FSAR and several other reports including the 'PSA Level 1 plus' report, which is defined by PNRA as a PSA Level 1 report at different power modes that include external fire and flood analysis. Finally, the operating licence will be issued on completion of the commissioning and satisfactory operation for six months and on submission of updated documents, including the FSAR.

3. DIFFICULTIES FACED IN FOLLOWING THE CURRENT LICENSING REGIME

In spite of their almost universal acceptance as reference safety standards, the IAEA's new safety standards have never been applied to the entire licensing process of a nuclear power plant, and very little experience exists in the nuclear industry on fully complying with these standards.

PAEC thinks that PNRA has taken a big stride in adopting the IAEA's NS-R-1 [4]. At the moment, hardly any nuclear steam supply system (NSSS) vendor is supplying a nuclear power plant that would systematically comply with NS-R-1.

Further, neither the IAEA standards nor the PNRA regulations are fully supported by regulatory guides. The same is the case with NNSA, which has also adopted the new IAEA standards. However, both NNSA and PNRA allow that, where regulatory guides for the new regulations do not exist, the designer and the utility are free to select a set of guides and obtain approval from the regulator to follow these guides.

The above approach helps to get around the regulator's problem of detailing the regulatory requirement, but leads to a difficult situation for the designer because most of the guides available were originally written before NS-R-1. The designer is never certain as to what exact requirements are to be met and whether it would be sufficient to follow the existing regulatory guides. The situation becomes even more complex if one has to settle the terms of a commercial contract in that situation.

In the buyer's country, PNRA maintains that it would lay emphasis on verifying the new licensing requirements. For instance, in addition to meeting the quantitative goals, PNRA is expected to emphasize such areas, as design management, management of safety, complementing a deterministic approach by the PSA, verifying defence in depth analysis philosophy, ageing management, human factors engineering, severe accident management or decommissioning. But it may take considerable effort to define the exact requirements based on these principles. At least on paper, PNRA makes no additional concessions for the duplicates of the existing nuclear power plants.

In the vendor country, NNSA has also adopted the new IAEA standards and is involved in the process of making a gradual transformation. NNSA first issued a 'safety policy' and kept it open for about two years for discussion with their vendors and designers. It is to their advantage that China now has a well established and fast growing nuclear industry, and quite a few indigenous design authorities which offer NNSA a chance to discuss and negotiate. While issuing the regulation for the next generation of nuclear power plants, NNSA has reportedly been careful about applying the regulations fully to the already planned 'duplicates' of the existing plants. NNSA may require incorporation of certain additional safety measures to make such plants licensable in China.

From the perspective of PAEC, and in view of the current national licensing requirements, the following problems are foreseen during the licensing of C-2:

(1) Because of the not-so-complete guidance from PNRA, the designer and the vendor may face problems in fully understanding and meeting the licensing requirements.
(2) The IAEA has developed a standard format and content of safety reports to which PNRA will refer. But no reference SAR has been prepared as was done in the 1970s by leading NSSS vendors, such as Westinghouse and General Electric, which published RESAR and GESAR, respectively. These reference reports were 'role modelled', as quite a few safety reports were based on them. So the preparation of the safety report based on the new standards may be difficult, e.g. incorporation of severe accident analysis and PSA can be done in several ways, and with a different level of detail.
(3) The regulators or the IAEA are yet to develop a generic safety review document on lines similar to the NRC Standard Review Plan (SRP) [2] to cause an effective review. The NRC was able to develop such a document after the practical experience of application of regulations to a large number of nuclear power plants.
(4) For the two-loop PWR design on which C-2 is based, it may be difficult to meet the quantitative targets set by the PNRA, e.g. a CDF of less than 10^{-5} per reactor-year.
(5) There may also be technological limitations because not many nuclear power plants have been built in Pakistan and the vendor country also has no practical experience of designing the plants in accordance with the new safety standards.

Because of the above considerations, the application of national regulation based on the new IAEA standards is going to be a very challenging task for all three — the regulator, the supplier and the utility.

4. APPROACH TO FOLLOW THE NEW NATIONAL LICENSING REGULATIONS

Pakistan is not a vendor country nor does it have much experience with the design of nuclear power plants. Besides C-1, which has been operating for about four years, PAEC's experience in the field of managing nuclear power plants over the last 30 years has been limited to essentially one nuclear power plant which is basically a first generation PHWR — KANUPP. When this plant was designed and built 40 years ago, there were very few regulations at the national level and the licensing requirements at the international level had also not been developed so well.

For the C-2 project, the main difficulty for PAEC and CNNC lay in establishing a design basis for which a price could be finalized and a contract could be developed because a commercial commitment could not have uncertainties in it. Otherwise, the cost of the project and the time required to complete it would be too large to prove economical. Ultimately, it was decided by PAEC and CNNC that the C-2 design would be based on the proven C-1 design with the following additional features:

(1) C-2 would meet all the NNSA licensing requirements as of 12 October 2003, the date when the decision was taken (by that time NNSA had not adopted the new regulation but was essentially following the IAEA's Safety Series No. 50-C-D (Rev. 1) [3]);
(2) Modifications based on feedbacks from C-1 would be incorporated;
(3) Advantage would be taken of the technological developments and improvements since the time of C-1;
(4) A series of measures would be introduced in the design, and the execution of the project would aim at meeting the national licensing requirements of Pakistan.

Considering the fact that, in spite of its recent phenomenal technical development and economic growth, China is still a developing country, and neither of the two countries nor the regulators of either country have any experience of the latest IAEA safety standards, this was a very practical approach. It also reflected the desire on the part of Pakistan to make progress towards a better safety regime without rendering its nuclear power programme a 'wait and see' policy.

Based on the above premise, PAEC and CNNC finalized the base price and signed agreements subject to the approval of their respective Governments. When such approval had been obtained, PAEC and CNNC formally signed the contract for the construction of the second unit (C-2) at a rated capacity of 325 MW(e) (gross) at Chashma, Pakistan.

The contract is now in effect and the licensing process has already been initiated with the submission of the Site Evaluation Report (SER) to PNRA. It is an 81 month project but the successful and timely completion of the project depends critically on meeting the licensing milestones, particularly the approval of the PSAR by October 2005, the time set in the project schedule for the first concrete pour.

The approach adopted by CNNC and PAEC was to take C-1 as a reference plant, review the design and make modifications based on the new requirements. As a result of a two year effort, it was agreed between the two parties that the C-2 design would include the following:

(1) Incorporation of more than 170 design changes on the basis of feedback from Qinshan-1 and C-1;
(2) Installation of the loose part monitoring system in the primary circuit;
(3) Use of probabilistic safety analysis to check and balance the plant design with respect to safety;
(4) Severe accident analysis leading to the design of preventive and mitigation measures and preparation of severe accident management guidelines (SAMGs);
(5) Specific measures for the prevention and mitigation of a selected set of severe accident sequences based on international experience, engineering judgement and the result of the above analysis. Typically, the list would include the following:
    - Large break loss of coolant accident (LOCA) with high pressure injection/low pressure injection failure (during the safety injection phase);
    - Large break LOCA with high pressure injection/low pressure injection failure (during the safety injection recirculation phase);
    - Small break LOCA with high pressure injection/low pressure injection failure (during the safety injection phase);
    - Small break LOCA with high pressure injection/low pressure injection failure (during the safety injection recirculation phase);
    - Loss of off-site power with auxiliary feedwater failure;
    - Steam generator tube rupture with high pressure injection and feedwater failure;
(6) Upgrading of the control room to meet the requirements of human factor engineering;
(7) Safety system bypass and inoperable status indication system in the control room;

(8) Commitment of the designer to follow the principles of defence in depth and ALARA in the design.

Both the regulator and the operator are aware of the difficulties involved in the process. Effective communication must exist not only between the designer and the utility but also between the utility and the regulator. This dialogue will focus on the approach to meet the licensing requirements. For example, as a prelude to the submission of the design report and the PSAR of the plant, two documents related to the design were prepared and submitted to PNRA. The first one gave a topic-wise résumé on how and to what extent the regulatory requirements for the design would be met by C-2. The second document provided a clause-by-clause response to PAK/911 — the safety regulation related to nuclear power plant design. PNRA reviewed these documents and has provided an informal response which has been helpful during the contract technical negotiations.

The SER submitted by C-2 is the first formal document submitted to PNRA. It is based on Chapter 2 of the PSAR according to the NRC's Regulation 1.70 (Rev. 3) [1]. PNRA has notified that the SER will be reviewed according to NUREG-0800 [2]. The PSAR to be submitted in 2005 is also likely to be reviewed by using the same NRC document. This NRC does not take into account the IAEA's latest safety standards or the PNRA regulations. Therefore, difficulties are anticipated.

The project schedule of C-2 provides six months for review of the PSAR after its submission to PNRA. To ease the review process, PAEC has made the vendor contractually obliged to provide international equivalence for all safety related Chinese codes that will be used in the design of C-2. To save time, PAEC has requested PNRA to accommodate an on-line informal review of the PSAR before its formal submission.

5. RELATIVE ASSESSMENT OF THE DESIGN SAFETY OF C-2

The design of C-2 is in essence based on C-1, which was based on Qinshan-1. The design philosophy of Qinshan-1 was similar to the Westinghouse type plants, and the safe operation of Qinshan-1 for more than ten years has demonstrated the safety and reliability of the Chinese design. Thus, the vendor has gained sufficient experience on a design which was robust to begin with. Because of the successful Q-1 and C-1 experiences, and because of the safety enhancement features added to the C-1 design, which already has large safety margins built into it, the design of C-2 will now be as safe as or even better than most of the PWR type nuclear power plants operating in the world.

Table 1 compares some inherent safety features of C-2 with some of the older two-loop PWRs which are still in operation. The enhanced system capacities (containment volume, basemat thickness) tend to increase the safety margins, allowing the plant a better chance to cope with accidents. Use of PSA to balance the plant design will further result in the enhancement of plant safety. Sufficient PSA experience already exists with PAEC because a full power Level 1 PSA has already been carried out for its Karachi Nuclear Power Plant and that of C-1 is being developed. A Pre-IPSART mission is likely to be invited next year to review the C-1 PSA.

In the area of severe accidents, emphasis has been given to all three aspects, i.e. prevention and detection of accidents and mitigation of accident consequences.

TABLE 1. COMPARISON OF C-2 WITH TWO-LOOP PWRs

Plant characteristic	ANGRA-1 [5], Brazil	Calvert Cliffs [6], USA	Qinshan-1 [7], China	C-2 [8], Pakistan
Power (MW(th))	1876	2570	966	998
Number of steam generators	2	2	2	2
Pressurizer volume (m^3)	28.3	42.5	35.0	35.0
Containment type	Reinforced concrete	Reinforced concrete	Pre-stressed concrete	Pre-stressed concrete
Containment volume (m^3)	39 600	56 633	49 000	49 000
Containment volume/power	21.1	22.0	50.7	49.0
Containment design pressure (psig)	41.4 (2.8 bar)	50 (3.4 bar)	38.22 (2.6 bar)	38.22 (2.6 bar)
Containment design pressure/power	0.0221	0.0195	0.039	0.038
Containment basemat thickness (m)	—	3.048	3.0	5.4

The following measures will be taken in C-2 to prevent severe accidents:

(1) A combination of pilot safety valves (POVs) or motor throttle valves (MTVs) will be used to replace the normal functions of power operated valves and safety valves of the pressurizer during normal and abnormal conditions. In addition, these valves will also be used to depressurize the primary system to allow emergency coolant injection to the primary system in the case of an accident;
(2) The anti-dilution mechanism or interlocks will be implemented during conditions of reactor cold shutdown and reactor coolant pumps tripped;
(3) In addition to two emergency diesel generators on independent trains, one diverse non-1E diesel generator will be provided to withstand station blackout, which may lead to the seal LOCA conditions.

To increase the accident detection capability, the following specific measures will be taken:

(a) Provision of a wide range hydrogen concentration monitoring system;
(b) Provision of instruments with their limiting capability to meet the severe accident environment.

Several steps will be taken to mitigate the consequences of severe accidents and to reduce the challenge to the containment integrity. These include:

(1) Primary system depressurization with POV valve or MTV to prevent high pressure melt ejection;
(2) Reactor cavity cooling water injection system;
(3) Passive hydrogen recombination facilities.

Containment is the final barrier to the release of radioactivity to the environment. Concerted efforts will be made to prevent this release by strengthening the containment boundary, including the penetrations, namely:

— Equipment hatch;
— Personnel airlock;
— Fuel transfer compartment;
— Process penetrations;
— Electric penetrations;
— Isolation valves inside the containment;
— Sleeve of gate valves of containment recirculation sump;

— Ventilation valves of the containment;
— Isolation valves of fire protection for the containment.

Event sequences that may result in a containment bypass will also be taken care of by:

(1) Quick primary depressurization with POV or MTV in case of steam generator tube rupture;
(2) Increase in the design pressure of residual heat removal system piping.

In addition, PAEC and CNNC have entered into a contract to jointly develop the severe accident management guidelines.

Table 2 compares plant/containment design characteristics and provisions for accident detection/prevention/mitigation measures in C-2 with some of the operating PWRs with large dry containment.

However, the effort to keep the plant safe is a continuing process and does not end with a safe design. PAEC, as the owner of the plant, is committed to take measures to ensure safe operation of the plant. Such measures would include personnel training, development of a safety culture and an effective surveillance programme. A continuing process of dialogue between the regulators and the utility has also been set up and this will greatly help in the accomplishment of the safety goals.

6. CONCLUSION

In conclusion, it must be said that the new national regulations lay the foundation for a useful exercise to improve the safety of existing and future nuclear power plants of the country. However, the application of these regulations presents a challenge to both the licensing authority and the PAEC. Conceding that C-2 is not based on advanced design concepts, PAEC, in collaboration with the vendor/designer, is making its best efforts aimed at enhancing plant safety and meeting the new licensing requirements. This will be a huge challenge because neither the licensing authority nor the vendor and the owner have any prior experience with the new regulations. It will be pertinent to give consideration to the capabilities and experience of the vendor and the utility, and the associated cost.

TABLE 2. COMPARISON OF C-2 ACCIDENT MITIGATION COUNTERMEASURES WITH THOSE OF OTHER PWRs WITH LARGE DRY CONTAINMENT

Plant characteristic	Surry [9], USA	Robinson [9], USA	Beznau [9], Switzerland	Biblis-B [9], Germany	Tsuruga-2 [9], Japan	C-2 [8], Pakistan	Remarks
Power (MW(th))	2441	2300	1130	3750	3441	998	—
Containment type	Reinforced concrete	Reinforced concrete	Steel	Steel	Pre-stressed concrete	Pre-stressed concrete	Indicates load capacity, leaktightness
Containment volume (m^3)	51 000	59 400	36 400	70 000	73 300	49 000	Containment loads, timescale of accident time budget for accident mitigation
Containment volume/power	20.83	25.64	32.25	18.51	21.73	49.10	—
Fuel mass (kg)	79 000	78 900	43 500	—	89 500	40 746	—
Containment volume/fuel mass	0.65	0.75	0.84	—	0.82	1.20	Indicates containment loads from direct containment heating (DCH)
Zirconium mass (kg)	16 500	16 335	12 000	29 750	19 500	10 767	—
H_2 mass (kg), with 100% Zr oxidation	780	718	530	1350	855	472	$Zr + H_2O = ZrO_2 + 2H_2 + Heat$

TABLE 2. COMPARISON OF C-2 ACCIDENT MITIGATION COUNTERMEASURES WITH THOSE OF OTHER PWRs WITH LARGE DRY CONTAINMENT (cont.)

Plant characteristic	Surry [9], USA	Robinson [9], USA	Beznau [9], Switzerland	Biblis-B [9], Germany	Tsuruga-2 [9], Japan	C-2 [8], Pakistan	Remarks
Average H_2 concentration (%) at 30°C, dry, 100% Zr oxidation	15.0	12.1	12.8	19.0	12.4	8.1	Potential for H_2 burn, containment loads from H_2 burn; density of hydrogen calculated at design pressure of containment, i.e. 2.6 bar
Estimated pressure (bar) due to H_2 burn, 100% Zr oxidation	9.4	7.6	7.9	11.7	6.7	4.7	Heat of reaction (18°C) = 241 750 kJ/kmol K [10]
Containment spray	Yes	Yes	Yes	No	Yes	Yes	Yes
Hydrogen control	—	—	Containment venting	Igniters/ recombiner	Combination of recombiners and inertization of atmosphere	Passive auto-catalytic recombiners and/or igniters	Reduces potential for hydrogen burn

TABLE 2. COMPARISON OF C-2 ACCIDENT MITIGATION COUNTERMEASURES WITH THOSE OF OTHER PWRs WITH LARGE DRY CONTAINMENT (cont.)

Plant characteristic	Surry [9], USA	Robinson [9], USA	Beznau [9], Switzerland	Biblis-B [9], Germany	Tsuruga-2 [9], Japan	C-2 [8], Pakistan	Remarks
Additional water injection to inside of containment	—	—	External from the firetruck: —backup water source for containment spray —flooding of containment External from river for cooling of fan coolers	—	Under preparation: water injection from RWST and fire water system	—Provision of connection to outer sources at the suction of containment spray pump —Reactor cavity water injection system for cooling of RPV lower head under severe accident	External vessel cooling for core debris and late containment failure by overpressurization
Depressurization of RCS for prevention of high pressure melt ejection (HPME) ('primary side bleed')	Transient with loss of all FW	Transients with loss of all FW	Transients SLOCA with loss of all FW	Most events with loss of all FW	Most events with loss of all FW	Most events with loss of all FW with the help of POV/MTV	Reduces chances of DCH
Estimated containment failure pressure (bar)	9.7	10.4	7.8	8.0	—	6.5	For C-2, it is calculated as 2.5 times the design pressure

TABLE 2. COMPARISON OF C-2 ACCIDENT MITIGATION COUNTERMEASURES WITH THOSE OF OTHER PWRs WITH LARGE DRY CONTAINMENT (cont.)

Plant characteristic	Surry [9], USA	Robinson [9], USA	Beznau [9], Switzerland	Biblis-B [9], Germany	Tsuruga-2 [9], Japan	C-2 [8], Pakistan	Remarks
Containment failure pressure/power	0.6467	0.8595	0.6094	0.4211	—	0.8025	—
Use of primary bleed/feed in the event of SGTR	—	—	Yes	—	Yes	Yes, by pilot operated valves (POV)/motor throttle valves (MTV)	To reduce release attending SGTR
Filling of SG with water in the event of SGTR	—	—	Yes	Under study	—	Under study	To reduce release attending SGTR

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CHALLENGE OF SUSTAINABLE DEVELOPMENT IN THE NUCLEAR FIELD

Research as a vital component of nuclear safety and radioprotection policies

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Abstract

The challenge of sustainable development also applies to the nuclear field: the careful management of natural resources, the preservation of the environment, and the response to society's expectations for increased transparency, and for the efficient control of risks associated with nuclear technologies are certainly key issues for this sector. Risk oriented R&D and associated scientific expertise are a key element of defence in depth for optimal nuclear safety and radioprotection. As such, a capacity to maintain worldwide the critical mass of research needed to address the main security related issues in support of public policies is vital for the continuing acceptance of nuclear activities, and of their development where needed. These issues concern both existing and future technologies. They are related to operational safety and radioprotection, to environmental protection and to public health issues, particularly with respect to nuclear waste management. They also concern security, at a time when the risk of terrorism in all its potential forms must be addressed. Nuclear and radiological R&D is characterized by the high cost and sophistication of experimental facilities, and by the high degree of knowledge and experience required to run such research programmes. Pooling of resources at the international and European level, and increasing cooperation between research organizations on the basis of an active policy towards scientific excellence and exemplary human resource management are essential, because research resources are growing scarce, in order to keep risk related research abreast of evolving technologies and industry practice, and of society's expectations for the control of nuclear and radiological risks. This is particularly true for the maintaining of key reference experimental platforms, such as safety dedicated research reactors, and for the development of complex safety related computer codes. The "networks of excellence" promoted through the European Union's research policy provide examples of the way in which international cooperation can develop.

1. THE CHALLENGE OF SUSTAINABLE DEVELOPMENT ALSO APPLIES TO THE NUCLEAR FIELD

The conclusions of the Johannesburg World Summit in 2002 refer explicitly to the need for people to have access to energy in order to enable economic development to progress. At the same time, natural resources have to be managed in a careful way, taking into account the needs of future generations. The negative impacts of industry and transport (including economic activities linked to energy production) also have to be minimized, in terms of pollution, harm to ecosystems, and global issues such as climate change.

In the 1970s and 1980s, nuclear energy, promoted with the image of a modern science based technology, appeared as a promising avenue for competitive, relatively clean and safe production of energy, capable of providing at least partly an alternative to fossil fuel sources. However, it became evident as time went by that societal acceptance of this source of energy was in reality rather problematic in a growing number of countries. With hindsight, this rejection could be seen as being derived from the fact that not all of the requirements of sustainable development were believed to be satisfied by public opinion. Open ended waste management problems, the occurrence of several catastrophic actual or near accidents causing worldwide concern, public health related unresolved questions, and finally the potential dual use of nuclear technologies gradually outweighed the potential benefits, such as the very high level of safety and security, and the minimal impact on the environment, including global warming aspects. In short, risks linked to nuclear energy are widely believed to be intolerable for society. This evolution of public opinion constitutes a major threat for the very future of nuclear power generation.

At the same time, today, at the beginning of the 21st century, nuclear power constitutes a significant source of primary energy in several industrialized countries on the basis of large investments made in the last century. It could also play a larger role for the next generations, on the condition that all requirements for its positive contribution to sustainable development are met, particularly in terms of societal expectations on a global level, which makes the issue a largely international rather than purely national matter. This calls evidently for further significant technology research, such as that which the Generation IV Forum is encompassing, or in the field of waste management strategies and operational options, an area where international cooperation is also gaining strength. However, this possible evolution presupposes that there will not be any new major accident involving an existing nuclear reactor anywhere in the world. Maintaining a full focus on safety in current nuclear installations, some of them ageing, is therefore a prerequisite for the future.

But the scientific and technological resolution of these problems will not be enough to lead to a positive evolution of risk perception by society. This is because, in today's risk averse era, the perception of risk magnitude is governed not just by the rather objective hazards resulting from a specific activity, but also by the more subjective confidence which the public place in the overall organization responsible for minimizing and managing the risk under consideration, and its effective achievements in terms of safety and protection of health and environment.

Nuclear technology can undoubtedly count on a number of advantages in the worldwide search for sustainable development. But it also has to face a significant challenge: can it fully regain the trust of society, a key condition for once more attracting the large numbers of young researchers, and the necessary investment capacities? Is this not in effect the main challenge for nuclear energy in the coming years?

This paper addresses successively three specific aspects of this key issue:

(1) At the national level, how can the organization of available resources be optimized in order to better meet society's expectations for the management of nuclear and radiological risks, on the basis of French experience?

(2) Which balance, and which links, should be established between risk oriented research and technology development research, in order to ensure optimal safety and radioprotection on one hand, and appropriate transparency of information on these issues towards society on the other hand?

(3) How can international organizations, and the IAEA as prima inter pares, play an active role in order to facilitate this evolution, and contribute to society's trust in the efficient management of risks worldwide?

2. A RESPONSE TO EXPECTATIONS OF THE SOCIETY: THE 2002 REFORM OF NUCLEAR AND RADIOLOGICAL RISK MANAGEMENT IN FRANCE

The reform of nuclear and radiological risk management at the level of public authorities, which took place in France in 2002, was based on two key principles:

— First, it was considered optimal to bring together the issues of nuclear safety and of radioprotection in the organization of the regulatory bodies. This led to the setting up of two new authorities at the national level. One, reporting to the Minister for Defence, is dedicated to the regulation, inspection and control of nuclear safety and radioprotection in the field of defence related activities. The other one, the Directorate General for Nuclear Safety and Radioprotection (DGSNR), reporting to the ministers responsible for environment, health and industry, is competent for most other activities, including health care and industrial applications of radioactivity. Today, the personnel of these two authorities together amounts to around 400 persons, including their inspectorate.

— Second, the choice was made to clearly identify, through the setting up of a new dedicated scientific and technical body, the role of expertise and research, and of technical radiological surveillance capability in support of national policies in nuclear safety and radioprotection. This led to the creation of the Institute for Radioprotection and Nuclear Safety (IRSN), as an autonomous public body. The mission of IRSN is to contribute to risk oriented research in its field of competence, in order to provide expert support to the national authorities mentioned above, and to carry out a number of public duties, including a contribution to training and education, in the field of exposure of populations and of the environment to ionizing radiation. IRSN has a yearly budget of around €260 million, and there are over 1500 members of staff. IRSN was, in effect, created through the merger of CEA's Institute for Protection and Nuclear Safety (IPSN) and the Office for Protection against Ionizing Radiations (OPRI).

A separation took place between the regulatory authority and the scientific and technical expert assessment system, and a distinction was made between risk oriented research for the purpose of safety and radioprotection assessment, and other research missions, which remained within the scope of CEA and of industry. These changes were aimed at clarifying responsibilities, optimizing the efficiency of the overall risk management organization at the national level, therefore encouraging public confidence in this organization. The increase in transparency, particularly through the provision of technical information to stakeholders in the framework of Local Information Committees set up in the context of each major nuclear installation, enhanced this evolution, IRSN developing its role as a 'public expert' at the disposal of interested parties (among other expert organizations) and a facilitator of the necessary dialogue between stakeholders.

This reform, therefore, appeared to serve two purposes: one was to strengthen the public authorities' response to nuclear and radiological risk challenges, through the reorganization and development of resources dedicated to this issue. The other was to provide an explicit answer to modern society's expectations of checks and balances in risk management processes, which contribute to ensure that industrial and economic processes are sufficiently safe and acceptable from the point of view of their impact.

3. RISK ORIENTED RESEARCH: A FUNDAMENTAL PREREQUISITE FOR SAFETY DEFENCE IN DEPTH

The examination of safety files relating to nuclear facilities or to other experimental or industrial installations using ionizing radiation often requires a high degree of technical expertise which, in effect, cannot be maintained at the required level in the long run if the experts involved are not closely connected to research activities, and cannot be supported by appropriate research results.

The same applies to the assessment of workplace radiation risks, or of the impact of a nuclear facility on the environment and neighbouring populations. Often, the support of significant state of the art technical resources, which only tend to be available at laboratories involved in research, is necessary to perform such assessments.

Historically, French nuclear safety and radioprotection expertise has been embedded in the research background of CEA. However, over time, a specific approach to what can be labelled ‘risk oriented research’ gradually emerged, and led in 1976 to the development of IPSN, which in 2002 migrated to the new institute, IRSN.

There are a number of specific goals of the type of risk oriented research which is needed for the purpose of safety and radioprotection assessment, which distinguish it from other aspects of fundamental research, or applied research aimed at technological development (which naturally also addresses the issue of risks). The involvement of an organization like IRSN in risk oriented research programmes seeks to:

— Enable the effective screening of proposed or existing technologies or organizations in order to identify as early as possible weaknesses or areas of knowledge gaps potentially affecting safety performance with respect to installations, human health and environmental protection. It therefore needs to be, on the one hand, wide ranging in its approach, exploiting existing knowledge as far as possible as a starting point, without having to be dependant on it and, on the other hand, capable of focusing on a given issue, with adequate resources enabling operational results to be reached. Logical end points of risk oriented research include, for example, the behaviour of new nuclear fuels, thermodynamics models, major external aggression sources, such as fire or potential intentional acts, low dose and chronic exposure mechanisms and their consequences for humans and ecosystems, geological high activity waste repositories probable performance evaluation, or at some later stage, Generation IV reactors key safety requirements.

— Provide scientific and operational expertise tools capable of probing proposed technologies beyond their design limits, in order to be able to perform their critical evaluation from an independent point of view, and to propose an analysis of safety margins to support the decision making process of the regulatory authorities. This may require, for example, the development of measurement and testing capabilities, of models aimed at representing phenomena, and of databases recording information needed to support expertise and risk assessment.
— Reduce gaps in available knowledge, and build on past experience with a scientific approach in order to improve risk assessment. This should result in publications aimed at promoting good practice in risk assessment and management. Such publications also help disseminate a risk prevention culture.
— Participate in the establishment of norms at the national as well as the international level, particularly in the field of radioprotection. A country can only present itself as a credible force for making recommendations if the delegations representing it in the preliminary scientific and technical work (often the biggest deciding factor in terms of results, several years before final approval) include high level experts with the appropriate research background, and it is able to support its proposals with hard evidence resulting from dedicated R&D programmes.
— Contribute to scientific education, through close links with universities, which may include shared research projects.

In order to reach these objectives in an effective way, a critical mass of resources in research and expertise must be reached so as to attract and retain high level scientists, in line with the needs of government, industry and other stakeholders. Regarding nuclear safety and radiological protection, the operating costs of laboratories that constitute this critical mass are especially high. This is because of the sophisticated nature of the technologies used, of the very high cost of running experimental resources in the field of radioactivity (in particular, to ensure the radioprotection of personnel where research reactors or hot laboratories are used), and of the complexity of assessing exposure to radiological risks and their possible or probable consequences (requiring the use of complex models and high technology experimental facilities). The level of resources should also take into account the strength of the technology developers or of the nuclear operators whose equipment and installations are to be assessed. It should also take into account the legitimate expectations of society, in terms of a balance of influences over the decision making process, and in terms of access to information.

In these circumstances, the share of resources committed to upstream R&D efforts within a body such as IRSN represents around 50% of its total budget. IRSN will make every effort to maintain this level of effort in the future, in order to ensure in the long run its position as a credible centre of risk related research and expertise, both nationally and internationally, in support of public authorities, and in a wider sense contributing its knowledge and expertise to the implementation of public policies related to risk governance, in particular by providing stakeholders and the public with relevant information. Even so, resources are often insufficient to cover expressed needs. Cooperation with other bodies, nationally or internationally, provides a potential to expand the field of investigation, provided the research programmes thus conducted remain compatible with the specific aims and values of risk oriented research. IRSN thus cooperates at the national level with CEA, EDF, AREVA, major medical research bodies and numerous universities, while fully retaining the control of all its research programmes. Internationally, cooperation agreements have been signed with 29 countries, involving over 100 organizations.

Research programmes conducted in the Cabri research reactor at Cadarache on the behaviour of heavily irradiated fuel, to gather experimental data on the effects of an increase in the burnup rate required by the operator, are a good illustration of this problem. In this instance, IRSN not only had to use specialized research skills, but also a major and unique research facility, the Cabri reactor, which is run by CEA within the framework of international cooperation agreements involving many scientific partners and a number of companies interested in fuel performance who contribute to the funding of the programme.

4. THE KEY ROLE OF INTERNATIONAL ORGANIZATIONS IN THE PROMOTION OF SUSTAINABLE DEVELOPMENT

Maintaining the highest safety and health protection levels of populations worldwide with respect to the use of nuclear energy throughout the production cycle is obviously a key to the future of this source of energy. Naturally, the prime responsibility for safety rests with the operators, in accordance with national regulations. However, international organizations also have a very important role to play, in order to promote best practices and to facilitate the harmonization of standards where needed, particularly where visible discrepancies between neighbouring countries may affect the level of public confidence in the coherence of nuclear safety policies.

This can be approached from several angles: the most institutional consists in implementing cooperation between States which have membership in the organization concerned, in accordance with its statutory rules and objectives.

Beyond this, government level actions must be complemented and enhanced by the wide ranging promotion of appropriate values, models and methods, through the facilitation of ever closer international scientific and technical cooperation, through the dissemination of knowledge and the encouragement to networking in a context of scarce resources, leading to progressive harmonization of good practice in risk assessment. For example, the research policy implemented by the European Commission under the Euratom Treaty, within the wider scope of the European Union's research policy, is proving effective in creating networks between research bodies, leading to the establishment of common tools and approaches.

The ambition declared by the European Council in Lisbon in March 2000 to promote the creation of a European research area and the innovating orientations proposed by the European Commission and adopted for the 6th Framework Research Programme are now proving essential. Gathering infrastructures, human resources and analysis tools within European networks of excellence that deal with major nuclear safety concerns certainly is a powerful means to preserve research capabilities and to ensure a skill level that is essential for maintaining a high safety level in Europe.

In this respect, the creation of the SARNET network of excellence dedicated to severe accidents is clearly demonstrating the willingness of about 50 European organizations to link up their actions to the integration policy decided by the European Union with a long term objective. The SARNET network will play, in this area, a major role in the identification of the most pertinent research subjects and in the coordination of work conducted in Europe, whether it concerns experimental or theoretical projects. It will contribute to maintaining the appropriate research skills and capabilities in Europe and to promoting the development and application of the ASTEC code for the modelling of severe accident sequences. As a result, apart from providing an environment conducive to knowledge sharing, the SARNET network will, with time, become a prime actor in international scientific cooperation with regard to severe accidents.

Indeed, such scientific cooperation may effectively reach the level of operational safety expertise, as shown by the joint efforts developed by IRSN and the German GRS to create the basis for a European network of expertise and risk assessment capacity, already at work in support of nuclear safety authorities in eastern Europe for many years through their specialized daughter company, Riskaudit. This cooperation has led to extensive comparative safety studies on subjects of common interest on key issues, such as thermal fatigue, and database reference information between GRS and IRSN. It is currently being extended to AVN from Belgium, aiming to make a comparative analysis of their own safety assessment methods and the main aspects considered when analysing the safety problems encountered, to enhance experience sharing, carry out common or additional work and compare their findings. This type of approach, also promoted through the annual EUROSAFE Conference held each year in Europe on the joint initiative of GRS and IRSN, is fully consistent with the IAEA approach.

Similarly, initiatives taken in the OECD/NEA context during the last three decades have encouraged the sharing of research programmes, and the exchange of scientific information between participating organizations. It is, for example, essential that a forum exists, as it does in the OECD/NEA, to address the issue of large international test programmes that require the use of research reactors which cannot continue to operate, for budgetary reasons, on the basis of a single country contribution.

In a different area, the IAEA initiative in the field of nuclear security will also be beneficial to bring together worldwide expertise in order to upgrade protection against the risk of terrorism.

And, beyond the intergovernmental and scientific fields, it is also essential that international organizations mobilize their capacity of action to encourage initiatives aimed at the renewal of public confidence in the field of nuclear risks. New approaches to the governance of these risks, involving stakeholders in a more systematic manner, and encouraging access to appropriate information can contribute powerfully. Again, at the European level, several projects are in progress in several fields including nuclear, which demonstrate the validity of new approaches with respect to risk governance. This type of approach can be particularly useful, if initiated early, where concerns of the population are expressed on health issues resulting from suspected chronic exposures.

5. CONCLUSION

Risk oriented research, and the operational expertise capacity which is derived from it, is not only an essential prerequisite for the success of in depth defence in terms of safety. Research and expertise can also provide part of the answer to modern society’s expectations of checks and balances, which contribute to make industrial and economic processes reliable, and in this way contribute positively to sustainable development. It therefore seems essential that the United Nations, the IAEA and other organizations, such as the

European Union and the OECD, support fully the intensification of international cooperation in this field, so as to facilitate the production of pertinent and commonly accepted scientific information and expertise capacity, and thus to facilitate the emergence of consensus on safety, public health and environmental questions across society.

GLOBALIZATION OF THE NUCLEAR INDUSTRY
*Developing technology — Framatome ANP's experience**

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In the last 15 years, Framatome ANP has moved from being a purely national player to being a global market leader. This is due to a series of successful mergers and acquisitions, including the acquisition of the non-military nuclear activity of Babcock and Wilcox in the late 1980s and, more recently, the merger with Siemens–KWU's nuclear activities.

Integration presented a number of challenges. There were undeniable cultural differences, reorganization was required to bring the business under control and a number of activities, such as finance, sales, R&D, marketing, engineering and manufacturing, and information systems had to be rationalized and integrated.

The key factors that contributed to the success of this integration included a management team that was clearly committed to the success of the merger and the quick and clear definition of the strategy, vision and values of the new company, which had to be effectively communicated.

A global organization which was not simply a group of three companies, each working in its own corner, was quickly established and multiregional task forces were appointed to identify possible synergies and propose how they could be put into practice.

One of the key issues is R&D, which will be discussed as an example of what has been achieved. This activity is essential when preparing the future of

* Only a summary is presented here as the full paper was not available.

the company as a whole, and one of the major challenges that had to be met was to find the best way of making use of all the skills available in it.

A special multiregional, multi-activity organization has identified the existing skills and potential synergies in each of the technical areas and core businesses.

A global R&D management process has been put in place under the strong leadership of the corporate R&D function. This process involves all the business units worldwide and has made it possible to set R&D objectives and identify the action to be taken in line with the group's strategic objectives. Short term and business oriented product development projects are handled by the business units, and a system has been created to facilitate the sharing of information. Long term and highly innovative projects are dealt with jointly by all the business units and are managed by corporate R&D.

The experts in each region are strongly encouraged to make contact with each other directly. A global technical expert network has been created and includes experts from all of the business units worldwide. Their key missions include making an active contribution to the R&D scheduling process, providing strong support to identify emerging technologies and reviewing R&D projects and their progress. This expert network is a highly effective way of improving the overall skills and competitiveness of the company.

The technical centres that existed individually prior to integration have been grouped together to ensure that synergies are harnessed for the general benefit of the entire company. The new, integrated technical centre develops basic company technologies, provides assistance with integrating the results into products and services, and actively contributes to the sharing of information within the company.

To conclude, the implementation of a global, well coordinated R&D management process dedicated to achieving transnational technical cooperation is an effective way of contributing to the integration of three companies with different cultures and management methods.

HARMONIZATION OF LICENSING PROCESSES FOR THE CERTIFICATION OF NEW REACTOR DESIGNS

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Abstract

The United States Nuclear Regulatory Commission (NRC) design certification process and its ongoing efforts to develop a regulatory structure for new plant licensing are summarized, including key attributes of both the design certification process and the governing principles of the new licensing process. The role of identifying safety goals and protective strategies as guiding principles, which can be applied to a variety of regulatory bodies and their licensing processes, is defined. A proposal to develop common safety goals and protective strategies within the international community is presented.

1. THE UNIQUE OPPORTUNITY EXISTING TODAY

The global energy market continues to view nuclear energy as a viable source of electric power. As such, new reactors are being deployed around the world, e.g. in China, India, Japan and the Republic of Korea, with advanced reactor technology continuing to be a part of the global research efforts. The business of nuclear power has become a multinational endeavour with industrial alliances forming across national and political boundaries. The fabrication of nuclear components is also an international effort with large scale components, e.g. steam generators and reactor vessels being manufactured and shipped throughout the world. In this era of international cooperation between nuclear utilities and vendors, it is incumbent on regulators to establish international collaboration on new reactor design requirements and licensing processes in order to better focus on common safety objectives and sharing of operating experiences.

International deployment of nuclear power plants, e.g. the Advanced Boiling Water Reactor (ABWR), Canadian deuterium–uranium (CANDU) and European Pressurized Reactor (EPR), continues and the nuclear industry appears to be interested in the certification and possible deployment of some of the more advanced near term reactor designs, e.g. the Advanced Passive 1000 (AP1000) reactor, the Economic Simplified Boiling Water Reactor (ESBWR) and the Advanced CANDU Reactor-700 (ACR-700). In addition, there is growing interest in the deployment of a new generation of advanced reactor designs, otherwise known as the Generation IV reactors. The likely deployment of the Generation IV reactors in the next two to three decades provides an opportunity for regulators to begin developing a common understanding of safety perspectives, safety margins, mechanistic analyses and risk informed safety requirements. Regulators from the United States of America and Canada have formally established international collaboration guidelines and initiated discussions on their respective licensing processes as they pertain to the design reviews of the ACR-700. Both regulators have benefited from this interaction and continue to look for areas where cooperation on review activities can enhance both approval processes. Some examples of this collaboration effort can be seen in parallel quality assurance reviews, shared information on probabilistic risk assessments (PRAs), and exchange of information on operating experience. We should continue to engage in these dialogues and work to develop common criteria in those areas that lend themselves to international collaboration for the licensing of new reactor designs, i.e. risk informed and performance based regulations with due consideration of lessons learned from operating experience.

Our near term goal should be to establish common licensing guidance in the areas of nuclear analysis, quality assurance (QA), PRA and severe accident management. As the Generation IV reactors mature in their viability for deployment, regulators must build on their established relationships and existing understanding of common criteria to develop a more comprehensive approach to international regulation and design certification.

Regardless of the regulatory nomenclature associated with the different licensing processes, the international community has essentially developed their respective licensing requirements and governing principles in much the same way. That is, the requirements have evolved in large part as the regulated industry has grown and matured. Early regulations were developed with a heavy reliance on deterministic defence in depth logic in order to accommodate the uncertainties associated with system performance and reliability. In some cases, this deterministic approach can shift the regulators' focus away from the critical safety issues. Today, as a result of a vast amount of operating experience and an advanced understanding of the application of PRA, we have a unique opportunity to develop criteria for licensing new reactor designs in a more realistic manner. That is, by integrating the lessons learned from over 30 years of operating experience, a highly developed knowledge of PRAs, an enhanced understanding of the reliability and capability of systems, structures and components, and the advancing scientific knowledge of regulators around the world, a more efficient and effective licensing process could be developed that preserves appropriate and prudent safety margins while allowing for regulating in a manner that corresponds to the actual risk and not to worst case assumptions.

2. THE NRC'S DESIGN CERTIFICATION PROCESS AND REGULATORY STRUCTURE FOR NEW PLANT LICENSING

In 1989, the NRC issued regulations [1] that provide alternatives to the two-step licensing process in 10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities. These alternative licensing processes are set forth in 10 CFR Part 52, Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants, and provide for approval of sites independent of a design, approval of designs independent of a site, and referencing of an approved site or design or a combination thereof in a licence to construct a nuclear power plant. The combined licence also uses inspections, tests, analyses and acceptance criteria (ITAAC) to verify that the as-built facility complies with the regulations that are applicable to the authorization to operate.

The NRC's design certification process [1] provides for the resolution of all safety issues associated with an essentially complete nuclear power plant design and finality for these issues in subsequent licensing proceedings. The application must describe an essentially complete design, which includes everything except for site specific design features, i.e. the cooling system for the turbine condenser, in order to minimize interface requirements for those portions of the design which are outside the scope of the certified design. The application for design certification must be complete, represent final design information and address all safety issues associated with the standard design. Performance of passive or innovative safety features for which little or no operating experience exists must be demonstrated by means of prototypic or appropriately scaled testing and associated analyses, to provide the assurance that these features will accomplish their functions over a full range of conditions, including normal operation, transients and accidents.

The applicant for design certification must postulate site parameters, i.e. safe shutdown earthquake, to envelop possible sites and form the basis for the design. The applicant must also provide severe accident design features that will prevent or mitigate the consequences of postulated core melt accidents. The applicant must perform a PRA, which is used to identify the risk significant design features that will become the focus of the safety review. At the conclusion of the NRC's technical review, a rule making process is used to provide an opportunity for the public to review the standard design and for the

Commissioners to determine if the NRC staff's evaluation of the design is acceptable. Upon completion of the rule making phase, the NRC issues a final design certification rule with a very restrictive change process that allows future users of the certified design to achieve the benefits of standardization.

In order to accommodate future design evolution, the NRC accepted an additional provision that allows use of design acceptance criteria in lieu of final design descriptions for areas of rapidly evolving technology, i.e. digital instrumentation and control systems. The NRC has limited the use of this process in order to retain most of the benefits of standardization and the finality of the standard design certification. In 1986, the NRC issued a Safety Goal Policy [2] that set forth an acceptable level of radiological risk from nuclear power plant operation. In order to ensure that the NRC's licensing capabilities continue to grow with the changing reactor technology landscape, the NRC continues to integrate operating experience and an enhanced knowledge of PRAs in order to develop a regulatory structure for new nuclear plant licensing.

One aspect of this regulatory structure is a technology neutral framework that provides the technical basis for the development of technology neutral regulations. The framework anchors the regulatory structure to the NRC's safety goals. The framework provides objective protective strategies, including barrier integrity, limiting initiating event frequencies, ensuring reliability and capability of protective systems, and ensuring a realistic, risk informed accident management strategy. The framework does not abandon the defence in depth strategies of the past; however, it seeks to apply the defence in depth concept in a manner that complements the PRA and accommodates the uncertainties associated with the protective strategy concept. A key aspect of the framework is to incorporate a degree of formality in the identification and structuring of goals and objectives that directly support safety performance so that, as appropriate, performance based requirements can be included in the regulatory decision making**.** Once completed, the regulatory structure for new plant licensing could serve as the basis for performing design certification reviews of Generation IV reactor designs.

The design certification process discussed previously links the rules and requirements as defined by the NRC's Code of Federal Regulations to the regulatory guidance for the technical review of these new reactors. It is within this guidance and the ongoing efforts to establish a new regulatory structure that we can begin the discussion of the development of a common international licensing process in which we can review the next generation of nuclear power plant designs.

3. INTERNATIONAL COLLABORATION ON THE DEVELOPMENT OF A NEW REGULATORY STRUCTURE

A harmonization of nuclear plant design approval processes will enhance the level of safety, promote the standardization of next generation nuclear plant designs and consistency of safety goals, and enhance the regulatory effectiveness of the international community of regulators by ensuring a consistent regulatory approach to this next generation of reactor designs.

As a first step, the international community should strive to unify its vast knowledge of nuclear technology to develop common safety goals for the approval of new reactor designs. These safety goals should be developed using the best data from a mature industry and experienced regulators to ensure the highest level of protection for the public and the environment. These safety goals will provide a safety standard for which all new reactors will be designed and evaluated. With a common understanding of our safety goals, we can then begin developing protective strategies on which to base our new regulatory structure. The development of these strategies must be a collaborative effort in which the operating experience of the international communities, probabilistic risk knowledge and severe accident research are integrated to form a sound technical basis for the licensing process. A key attribute of this effort will be the mutual understanding of the uncertainties associated with today's knowledge, such that a prudent deterministic defence in depth strategy can be applied. This process should complement the existing international standards and safety guides to the extent possible and, in areas where a conflict exists, conservative decision making and defence in depth measures should be relied upon to finalize the process.

With these higher level principles developed and adopted, we can begin to identify key aspects of the certification of new reactor designs. By using PRA results to inform the initial review, a clear top to bottom approach can be developed to focus the regulatory review on the most safety significant aspects of the design. In addition, the development, by an international panel of experts, of a systematic method to identify the state of knowledge on a particular safety feature for a new design will provide a path forward to developing the appropriate level of independent testing, analysis or a combination thereof to support the review. Regulators should also strive to identify key safety parameter envelopes for the reactor designs, which will allow for the approval of the safety system concepts and features, but will preserve the approval of site specific design features for the regulator with ultimate siting responsibility.

The results of this effort will provide an unprecedented level of international cooperation in the area of new nuclear plant design reviews and regulatory approval. The international community of regulators will have a multitude of tools and resources to draw upon as they strive to meet the demands of international design and construction of new reactor technologies within their borders. This process will also encourage the standardization of reactor designs which will promote further sharing of information and rapidly expand the international operating experience database. Regulators and international design teams will benefit greatly from standardization, as it will lend itself to substantially similar designs being licensed in multiple countries. Finally, as the international nuclear industry competes in a global economy, the resource demands on those who regulate them will grow. With this common regulatory process, the international community of regulators will find a vast economy of scale throughout the world as they share technology, research results, operating experience and, most importantly, a common regulatory strategy and understanding of the nuclear plant designs they will be tasked with licensing.

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JOINT CONVENTION ON THE SAFETY OF SPENT FUEL MANAGEMENT AND ON THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT

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Abstract

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) is the first international legally binding instrument to address the issue of waste and spent fuel safety on a global scale. It was drafted by a group of legal and technical experts during the period July 1995 to March 1997, adopted by a Diplomatic Conference in September 1997 and opened for signature on 29 September 1997. The Convention entered into force on 18 June 2001, and to date (June 2004) has been signed by 42 States, of which 34 have formally ratified the Convention, thus becoming Contracting Parties. A first Review Meeting of the Contracting Parties was held in November 2003 in Vienna, through which the Convention has become fully operational. The Joint Convention applies to spent fuel and radioactive waste resulting from civilian applications of nuclear energy and radioactive materials. Spent fuel and radioactive waste from military application are covered by the Convention only when and if these materials are transferred permanently to and managed by civilian programmes. The Convention's main objective is "to achieve and maintain a high level of safety worldwide in spent fuel and waste management". The obligations of the Contracting Parties are largely based on the international safety standards developed by the IAEA, in particular on the principles contained in the IAEA Safety Fundamentals publication, Principles of Radioactive Waste Management, published in 1995. The Convention is not only relevant for those countries having nuclear energy programmes, but for any country where activities generating radioactive waste are carried out or planned, including medicine, agriculture and research. The paper describes the origin of the Convention, its content, the potential benefits from being party to it, and summarizes the findings of the first Review Meeting.

1. INTRODUCTION AND BACKGROUND

The safe management of spent fuel and radioactive waste generated by nuclear power and fuel cycle plant operation is a key issue for the use of nuclear energy. Radioactive waste is also generated whenever nuclear technology is applied in medicine, industry and research, which implies that a need of ensuring safety in dealing with radioactive material is of importance for all the countries involved in such activities, even if they do not have or plan nuclear industrial programmes. Recognizing this, the international community promoted a Convention directed to ensure that sound practices are planned and implemented worldwide for the safety of both spent fuel and radioactive waste management.

In March 1995, the IAEA Board of Governors first endorsed a proposal to convene a Group of Experts to draft the Convention. The Group, made up of 128 representatives from 53 countries and observers from four international organizations, met seven times from July 1995 to March 1997 and drafted the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (in short, the Joint Convention).

The Joint Convention was adopted by a Diplomatic Conference purposely convened in Vienna from 1 to 5 September 1997 and opened for signature on 29 September 1997, the first day of the 41st regular session of the IAEA's General Conference. The Convention entered into force on 18 June 2001, i.e. 90 days after the deposit with the IAEA of the 25th instrument of ratification, as provided for by Article 40. To become a Contracting Party, a country has to sign and ratify the Convention. To date (June 2004), the Convention has been signed by 42 countries and ratified by 34.

The Joint Convention is made by, and belongs to, the Contracting Parties. The IAEA, other than being the Depositary, provides the Secretariat and promotes the Convention, with a view to having all countries holding radioactive material to become Contracting Parties.

2. NATURE AND SCOPE OF THE JOINT CONVENTION

The Joint Convention is the first international binding legal instrument in the area of nuclear spent fuel and radioactive waste safety. It is a sister convention to the Convention on Nuclear Safety [1], which covers the safety of nuclear power plants, adopted in Vienna on 17 June 1994. It is incentive in nature, i.e. it does not invoke penalties for non-compliance by the Contracting Parties, but is solely based on their common interest to achieve and maintain a high level of safety in nuclear spent fuel and radioactive waste management.

The overall objective of the Joint Convention is to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management, through the enhancement of national measures and international cooperation, so that at all stages of operation and in whatever condition, individuals, society and the environment will be protected from the harmful effects of ionizing radiation.

The reason why spent fuel and radioactive waste are *jointly but separately* covered in the Convention is that spent fuel is regarded by some as a material to be disposed of, like radioactive waste, and by others as a resource material suitable for the recovery of uranium and plutonium. As such, the management of spent fuel and radioactive waste shares several safety measures and requirements but also demands provisions that are peculiar to each of them.

The Convention applies to the safety of management of:

— Radioactive waste and spent fuel from nuclear power plants;
— Radioactive waste from fuel cycle plant operations and from research laboratories;
— Radioactive waste from the use of radionuclides in medicine and industry;
— Spent sealed sources;
— Discharges to the environment from regulated nuclear facilities;
— Waste from mining and processing of uranium ores.

The Convention does not apply to the spent fuel held at reprocessing plants for reprocessing. This provision recognizes that spent fuel awaiting reprocessing is just a transitional material within the nuclear fuel cycle, not to be specifically ‘managed’ but mechanically and chemically processed. The spent fuel held at a reprocessing plant can be included in the scope of the Convention should a Contracting Party specifically declare the reprocessing to be part of spent fuel management.

The Convention does not cover waste containing only naturally occurring radioactive material (NORM) that does not originate from the nuclear fuel cycle, unless the Contracting Party declares it to be a radioactive waste.

Spent fuel and radioactive waste generated within military and defence programmes are also outside the scope of the Convention, unless a Contracting Party declares such materials to be included in it, or when they are permanently transferred to and managed within civilian programmes.

3. PROVISIONS AND OBLIGATIONS

The obligations with respect to safety in the Convention are largely based on the principles contained in the IAEA Safety Fundamentals publication, Principles of Radioactive Waste Management, published in 1995 [2], as well as in the supporting international safety standards further developed by the IAEA.

The Convention contains 44 Articles. A number of them treat the legislative, regulatory and organizational framework to be established in a country in order to ensure safety, which are generally based on the requirements established in the relevant Safety Series publication of the IAEA [3–6].

Special attention is given to the transboundary movements of spent fuel and radioactive waste, in order to ensure that shipments involving two or more States take place in a manner consistent with the internationally accepted safety principles, taking into consideration the reciprocal rights of the States of origin, transit and destination. The Convention incorporates de facto the major provisions of the Code of Practice on the international transport of radioactive waste, issued in 1990 by the IAEA [7].

Many of the articles deal with technical requirements for the safety of spent fuel and radioactive waste management. They cover facilities in operation and under decommissioning, as well as the siting, design and construction of new ones, including disposal systems and their post-closure institutional and technical control.

The Joint Convention is also the first binding international instrument addressing the safety of disused sealed sources, the improper use of which has raised concern among the international community. In particular, provisions are made to facilitate the return of spent sealed sources to a competent organization for reuse, storage or disposal.

Since the Convention is solely intended to stimulate improvements in safety, the fulfilment of the obligations is not based on control mechanisms but on a procedure of mutual peer review, carried out through meetings of the Contracting Parties.

A significant obligation for a Contracting Party is to go through this peer review process. It consists of:

— A Review Meeting, held every three years by the Contracting Parties;
— A National Report, to be submitted by the Contracting Parties for review at Review Meetings.

In the National Report, the Contracting Party is required to explain its overall approach to the safety of spent fuel and the safety of waste management, including the existing legislative and regulatory structure, to describe policy and practices on the matter, including past practices, to provide information on spent fuel and waste management facilities in operation and under decommissioning.

Important issues to be addressed in the National Report are the criteria used for waste categorization and the inventory of the radioactive materials covered by the Convention, including waste that has been disposed of or resulting from past practices.

Provisions are established in the Convention to protect from disclosure information that a Contracting Party identifies as confidential.

National Reports are submitted by Contracting Parties prior to the Review Meetings, and distributed to all the other Contracting Parties, in order to enable their review. The Contracting Parties may seek clarification on the circulated National Reports through a written question and answer process. This peer review process is finally completed at the Review Meeting, where the Contracting Parties have the opportunity to present and discuss their National Reports.

Some aspects of this review process at the first Review Meeting are discussed below.

4. EXPECTED IMPACT OF THE CONVENTION

There are nowadays two aspects that characterize worldwide the management of radioactive waste: the variety of safety policies and national provisions, also among countries with the same level of nuclear development; and a grey area of activities and practices involving two or more States, such as transboundary shipments, discharges, emergency preparedness or sealed sources use, for which an enhancement of international cooperation is desirable in order to ensure safety on a larger scale.

In addition to the above, there is a number of less developed non-nuclear countries where radioactive waste is still generated from the applications of nuclear technology in medicine, industry or research. In these countries, lack of adequate infrastructures for radioactive waste management, both on the technical and institutional sides, may lead to an unsatisfactory level of safety and radiological protection.

The Joint Convention is intended to be an instrument to effectively address the above points. In so far as an increasing number of countries fulfil the requirements set up in the Convention, significant outcomes can be progressively achieved in waste management, in particular:

— Improved harmonization worldwide of safety policies and provisions;
— Strengthening of mutual rights and responsibilities among the involved States in dealing with activities carried out internationally;

— Homogeneity of infrastructures and practices worldwide for ensuring safety;
— Progress towards the adoption of common safety and waste classification criteria.

As is well known, radioactive waste and its disposal are commonly perceived as one of the most delicate environmental problems of our time. Evidence of this concern is seen in the difficulty encountered in selecting suitable sites for the final repository for this waste.

The Joint Convention, as part of the growing international effort for enhancing on a global scale the safe management of radioactive waste, is a constructive step to addressing the problem of public confidence on radioactive waste practices and policies.

5. RIGHTS AND BENEFITS OF CONTRACTING PARTIES

Upon becoming a Contracting Party, a country is not only subject to obligations. Thanks to the transparency of the review process established by the incentive nature of the Convention, it also acquires rights and gains benefits from it.

First of all, a Contracting Party has the right at all times to be informed about programmes, policies and practices on spent fuel and radioactive waste management of any other Contracting Party whose related activity can have an impact on safety in its territory.

Benefits from joining the Convention are gained by all countries generating radioactive waste, no matter what the size and the nature are of their involvement in nuclear energy applications.

In particular, becoming a Contracting Party to the Convention means that:

— Countries with significant nuclear power programmes will benefit mainly on the political or social side. Internally, their voluntary compliance with international obligations for the safety of the management of spent fuel and radioactive waste, confirmed by a built-in international peer review, can improve public confidence in those activities and positively affect the social acceptance of nuclear energy. Internationally, by voluntarily explaining how they meet the requirements of the Convention through the reporting process, they demonstrate at the same time the transparency of their activities in waste management and the reliability of their technology.

— Countries with small nuclear power and/or research programmes or countries having radioactive material only from nuclear applications in medicine, agriculture or conventional industry, can in addition benefit from the exchange of information and the technical knowledge gained by the reporting procedure set up by the Convention, through which the expertise of larger countries is made available. Technical assistance may then be facilitated between Contracting Parties in meeting the obligations under the Convention, in particular when less developed countries are involved.

The incentive nature of the Joint Convention makes it an *in-progress instrument* to assist in ensuring global safety. This means that the fulfilment of safety requirements is by no means a precondition for a country to be a Contracting Party, but rather a consequence of it. Being part of the Convention clearly demonstrates the national commitment to safety in the management of spent fuel and radioactive waste, irrespective of the country's current situation. A country can then benefit from the mechanism of the Convention, namely, from the review process, to verify whether its safety level is adequate or appropriate steps should be taken to improve it.

6. STATUS OF IMPLEMENTATION OF THE CONVENTION

6.1. Contracting Parties

The following 41 countries and bodies are currently (February 2006) Contracting Parties, having ratified or formally approved the Convention:

Argentina	Finland	Latvia
Australia	France	Lebanon
Austria	Germany	Lithuania
Belarus	Greece	Luxembourg
Belgium	Hungary	Morocco
Brazil	Iceland	Netherlands
Bulgaria	Indonesia	Norway
Canada	Ireland	Peru
Croatia	Italy	Philippines
Czech Republic	Japan	Poland
Denmark	Kazakhstan	Romania
Estonia	Korea, Republic of	Russian Federation

Slovakia
Slovenia
Spain
Sweden
Switzerland
Ukraine
United Kingdom
United States of America
Uruguay
EURATOM

6.2. The Preparatory Meeting

Pursuant to Article 29 of the Convention, a Preparatory Meeting was held in December 2001, attended by 27 Contracting Parties who had ratified at that date.

The Preparatory Meeting had been established to provide rules, procedures and the time schedule for implementing the review process. In particular, guidelines had been agreed for the structure and content of the National Reports to be submitted by the Contracting Parties, and on how to conduct the Review Meetings.

Among rules and procedures decided by consensus at the Preparatory Meeting, it is worthwhile to mention the following:

— In order to make the review of the National Reports more efficient, it has been decided to establish Country Groups for each Review Meeting, in which the National Report of each member of the Group can be considered in detail. The Groups are not made up on a geographical basis, but on a balance of nuclear power plants operated or under decommissioning in the included countries.
— An organizational meeting will be held six months before each Review Meeting in which, inter alia, decisions will be taken on the mechanism to establish the Country Groups and their modus operandi, and to elect officers for the Groups and the Review Meeting.

6.3. The review process and the first Review Meeting

The first Review Meeting of the Contracting Parties was held at IAEA Headquarters. Thirty-three Contracting Parties participated in the Review Meeting (Lithuania ratified after the meeting). Pursuant to Article 32 of the Convention and the related rules agreed upon at the Preparatory Meeting, each Contracting Party had submitted its National Report to the other Contracting Parties six months prior to the meeting, in order to enable them to review it and make written questions. Answers were also provided in advance of the meeting.

At the Review Meeting the Contracting Parties were assigned to one of five Country Groups, in which oral presentation of the National Reports and discussion on written questions and answers took place.

The following Country Groups were established at the first Review Meeting:

— Group 1: Belgium, Greece, Ireland, Latvia, Slovakia, Slovenia, USA;
— Group 2: Australia, Bulgaria, Denmark, France, Luxemburg, Romania, Spain;
— Group 3: Morocco, Croatia, Netherlands, United Kingdom, Sweden, Czech Republic, Japan;
— Group 4: Argentina, Belarus, Germany, Norway, Switzerland, Ukraine;
— Group 5: Austria, Canada, Finland, Hungary, Republic of Korea, Poland.

6.4. Effectiveness and findings of the review process

The heart of the Joint Convention is the review process. In principle, the success of the envisaged mechanism to carry it out depended upon several factors:

— To have the Contracting Parties submitting National Reports able to provide a self-assessment of their compliance with the requirements of the Convention;
— To have the Contracting Parties reviewing other countries' National Reports by seeking clarification should they identify areas of uncertainty, so making effective the peer review process;
— To have the Contracting Parties willing to respond diligently and openly to the questions raised on their National Reports;
— To have the Contracting Parties actively participating at the Review Meeting, in which the process is accomplished by oral presentations and further constructive discussions on the questions raised and received by the Contracting Parties.

Generally, it was acknowledged by the Contracting Parties that the review process at the first Review Meeting was satisfactory, even if some improvement in the process could be sought for future meetings.

The National Reports that were produced covered adequately in most cases the subject matter and allowed an assessment of the safety of their policies and practices. Among the Contracting Parties, there was a wide spectrum of size and scope of nuclear programmes.

There were Contracting Parties with major nuclear power programmes, others with only hospital waste and disused sealed sources. The National Reports, therefore, varied appreciably in size, scope and complexity. For some of them there is, however, room for improvement, both in the structure and points addressed — profiting from the experience gained with the first review process.

Almost all the Contracting Parties (27 out of 33) voluntarily placed their National Reports on their web sites and that of the IAEA (Rasanet.iaea.org/conventions/waste-jointconvention.htm).

Participation in the written question and answer process was successful. More than 3000 questions in total were asked of the 33 Contracting Parties by the others, showing the substantial interest of all countries to seek and share information on the safety of spent fuel and waste management. Technical issues and policy matters were more or less equally queried.

At the Review Meeting the Contracting Parties, presentations were generally of high quality and informative at the plenary sessions, while the discussions within the Country Groups were variable in effectiveness.

The Contracting Parties agreed on a number of adjustments to the procedures and guidelines for the Review Process, to address the issues that were found to be unsatisfactory. These are detailed in the President's Report of the Meeting [8].

The meeting also recognized that the fulfilment of the Joint Convention's objectives requires the participation of all the countries which have spent fuel and/or radioactive waste, and that a major effort has to be made to have more Member States become Contracting Parties to the Convention.

7. CONCLUSIONS

The Joint Convention has been recognized by the international community as an instrument to ensure the safe management of spent fuel and/or radioactive waste worldwide. With the fulfilment of this objective, a uniform and higher degree of protection of individuals, society and the environment from ionizing radiation can be achieved on a global scale.

The Joint Convention is incentive in nature, which means that it is designed to be an instrument to stimulate an open self-assessment of safety levels by the countries who become Contracting Parties, through a transparent reporting and peer review mechanism allowing information and a better interaction among States on matters of safety.

By joining the Convention, a country also certifies nationally and internationally its commitment to safety of spent fuel and/or radioactive waste management, thereby contributing to the improvement of public confidence about waste management practices and policy.

The success of the Joint Convention needs a strong involvement of all potentially interested countries, both in terms of number and of 'spirit' of the participation.

The Contracting Parties that attended the first Review Meeting demonstrated generally a positive and open-minded attitude in dealing with the review process, although the procedure might require a further refining.

To have more Member States become Contracting Parties is also essential for the purpose of the Convention. The IAEA Secretariat is strongly committed to this objective.

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CHALLENGES FOR THE GLOBAL NUCLEAR COMMUNITY IN CHANGING ENVIRONMENTS

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Abstract

As the world has become more and more globalized, diversified challenges surrounding the nuclear community are no longer restricted to one or several countries, but have become prevalent worldwide. As a means to overcome many of these obstacles, and thus to foster the future viability of nuclear power, some concerns and recommendations for the IAEA's future activities are provided, along with an outline of the global nuclear community's role in working to realize a new renaissance in nuclear power.

1. INTRODUCTION

As the world is rapidly changing in many areas, the nuclear community is also greatly affected by varied environments. Some of these are favourable to the nuclear community, some not. Of these, the following major factors will influence the viability of nuclear power in the future.

The first factor challenging us is the recent drastic increase in the prices of fossil fuels, such as petroleum and coal. According to many experts, although this big spike has been accelerated by speculation in the futures market, the main reasons are actual and threatened supply problems, combined with recent international political troubles, such as the attacks on Iraqi pipelines. Some also attribute the rise to the dramatic growth of demand in Asia. Based on the instability of these factors, it is generally expected that this inflated fossil fuel price will persist for the time being.

Next is the fact that some developed nations have been consistently enlarging their deployment of renewable energy sources as a means to reduce greenhouse gases and protect against future shortages of fossil fuels. Under such favourable circumstances, a remarkable growth rate in renewable energy in OECD countries has recently been achieved with an average annual growth of 27.5% for solar energy and 21.9% for wind energy from 1990 to 2001 [1].

However, despite their high growth rates, the contribution of these renewable sources to the total energy supply is still very minor, with a share of less than 10%. More importantly, most of the renewable energy comes from biomass and hydropower, and the share of solar and wind energy, so called 'new' renewables, is marginal.

Based on these facts, it is anticipated that there will be some limitations in the rapid growth of renewable energy. This remains true at least for the short term. On the one hand, presently in many countries, renewable power such as solar and wind energy cannot be produced without a large amount of subsidies. On the other hand, the Kyoto Protocol on greenhouse gases is being delayed much more in its coming into effect than originally expected because of the many barriers blocking its path, such as the withdrawal from the agreement by the United States of America and Australia.

The third factor lies within the nuclear community. According to a survey, over the last decade, the performance of nuclear power plants has greatly improved worldwide — the average capacity factor went up to 78.9% in 2002 from 68.2% in 1992, and last year, 56% of the world's nuclear power plants recorded a capacity factor higher than 80% [2]. Despite this excellence in performance, however, unfortunately it is true that in some countries public sentiment on nuclear power has not improved, and in some cases has even deteriorated.

Few developed countries would like to take on the risk of deploying advanced light water reactors (ALWRs) due to the lack of confidence in their economic competitiveness and also due to unfavourable social circumstances. On the other hand, some developing countries, especially in Asia, have plans to add or introduce nuclear power, but there still remain many difficulties in inducing investment and establishing related infrastructures.

In addition, deficiencies in technology advancement and international collaboration on back end fuel cycles, including high level radioactive waste disposal, still pose a big obstacle to the realization of a new nuclear era.

2. THE COMMON DESTINY OF THE GLOBAL NUCLEAR COMMUNITY

In this context, whether or not these changing environments surrounding the global nuclear community will be properly addressed is the key to a new renaissance of nuclear power. In other words, the world nuclear community shares a common destiny, and thus, for the sake of our future prosperity, strengthening international collaboration is essential.

Nowadays, energy supply is becoming one of the most pressing issues worldwide. At a time when the world is experiencing a new oil crisis, nuclear power is poised to give a major boost both to the world economy and to the preservation of the environment. To ensure the success of nuclear power, it is crucial that it be universally assessed as being reliable and sustainable.

For the reliability and sustainability of nuclear power, it is necessary for the global nuclear community to reinforce the current international information network systems, to establish new global standards and criteria on radioactive waste disposal, and to provide an internationally cooperative system for the development of public acceptance strategies.

In addition, to make nuclear business more attractive to countries which are hesitant about pursuing construction of nuclear plants, a variety of business strategies should be developed and applied based on international cooperation among the nuclear industry community, depending on each country's unique conditions.

3. CHALLENGES FOR THE GLOBAL NUCLEAR COMMUNITY

Up to now, the global nuclear community has exerted every effort to make nuclear power safe, economical and environmentally friendly. To realize a new renaissance of nuclear power, however, more than ever expertise and resources from the global nuclear community should be concentrated on appropriately responding to the following challenges.

3.1. Improvement of the international network to ensure operational safety

The first challenge is to ensure the safety of operations at nuclear facilities. In spite of the numerous activities to maintain or upgrade the safety of the nuclear power plants currently in operation, unfortunate events have still occurred which have threatened the safety of nuclear technology. Some events which have recently occurred are severe corrosion of the reactor vessel head at Davis Besse, inappropriate data handling at Tokyo Electric Power Company and severe fuel damages at Paks.

Meanwhile, the experience gained from these events offers a very important lesson to other utilities, and their access to detailed information on these lapses will help prevent a recurrence of such events. Of course, there are several international organizations such as the Institute of Nuclear Power Operations and the World Association of Nuclear Operators (WANO) to share operating experiences and information. However, these systems have some limitations in that it takes much time for any information to be transferred from the providing utility to others, and important information can be omitted because reporting is not mandated. These problems, to my mind, result partly from the language barrier which accompanies the translation of one's mother tongue into English.

Thus, for these systems to be more effective, it must be required that all utilities joining the network be obliged to provide important information based on the appropriate criteria, which should be established, and the language problem be appropriately handled in order to facilitate more rapid communication among the utilities. In my view, the IAEA or WANO should play a leading role in meeting this need.

3.2. Consistent and clear global standards for radioactive waste disposal

The second challenge is to develop a clear and consistent global strategy for the disposal of spent fuel, including high level radioactive waste. Recently, how to dispose of spent fuel has become a common dilemma for most countries, and is one of the most essential factors standing in the way of full public acceptance.

For example, while we as experts can state with all certainty and sincerity that a disposal site is geologically safe, technically feasible and environmentally reasonable, public scepticism still increases.

Accordingly, to minimize prolonged painful but fruitless arguments on this issue, and thus to gain more confidence from the public, above all, clear global standards and technology advancements for radioactive waste disposal should be provided through international research and cooperative activities. During such a process, it is desirable for the IAEA to take the lead.

Additionally, as a means to support any country that has difficulties in individually resolving the disposal issue alone, securing an international disposal site or facility for common use among the Member States of the global nuclear community would be advantageous from all standpoints.

3.3. Global information network for promoting public perception of nuclear power

A third challenge involves improving the public's perception of nuclear power. Recently, special interest groups, including non-governmental organizations, have had a great influence on nuclear policy making in each country, and this trend seems likely to prevail worldwide.

Thus, I suggest that an information system on public acceptance be created, in which every country's experiences are integrated in order to better form strategies to combat these nuclear naysayers. It will also be necessary to conduct international discussion forums to come up with improved public acceptance strategies, such as strengthening the availability of Internet based resources.

In many cases, incorrect and biased information fabricated and distributed by some anti-nuclear groups has made it more difficult to gain public acceptance. On this point, providing trustworthy and endorsed information, based on truth and facts, together with newly developed strategies for public acceptance, would greatly help to improve the public's understanding.

3.4. Training of nuclear experts for the future

The fourth challenge is to consistently preserve nuclear expertise. This is essential not only for the safe operation of nuclear plants, but also to relieve many headaches in the future regarding waste disposal, plant life extension and development of new plants. In order for us to be successful in this regard, qualified personnel must be maintained, and thus investment in training for the younger generation is of paramount importance.

In recent years, many countries with nuclear programmes have seen a decrease in the number of new graduates related to nuclear fields. To overcome this trend, more efforts to attract young people have to be made at the level of international cooperation, as well as in each individual country. In this regard, I thank the IAEA for motivating young people to get excited about careers in the nuclear field with such supports as for the biennial International Youth Nuclear Congress.

3.5. Need for taking the lead and stronger global cooperation for implementing new nuclear projects

A final challenge is how to boost construction of new nuclear plants in the foreseeable future. If we do not make use of the current environment to actively pursue the building of new nuclear plants, while the big spike in oil prices persists, a new nuclear renaissance will never be realized.

Although several new advanced reactors have already been developed and are ready to be marketed, most developed countries are reluctant to implement new nuclear projects. This, in my view, can be attributed to their lack of confidence in nuclear energy's economic competitiveness, as well as internal problems in each country.

Fortunately, however, these types of worries have been mitigated to a certain degree by three countries: Finland, Japan and the Republic of Korea. All three are now going forward to build the first ALWRs, namely the EPR (Olkiluoto 3), APWR (Tsuruga 3 and 4) and APR1400 (Shin-Kori 3 and 4), respectively. The three projects are all currently under way, with a goal of beginning commercial operations around 2010. Moreover, recently, the AP-1000, a passive ALWR, has received Final Design Approval (FDA) from the United States Nuclear Regulatory Commission. I am confident that these leading efforts will be a cornerstone for the revitalization of nuclear power.

Based on this fact, developed countries are highly recommended to take the initiative in deploying advanced plants.

On the other hand, nuclear power is considered by some developing countries to be a preferred energy option for meeting their sharply increasing energy needs. However, to deploy nuclear power plants in such areas, some prerequisites must be satisfied. First of all, every country has to establish a solid infrastructure and maintain a certain level of technology to ensure the safe operation of nuclear power plants. The other critical issue is how to secure such a large amount of capital for the construction of nuclear facilities.

To fulfil these requirements, a large package of assistance from developed countries should be provided, such as transfers of technology and experience for operations and regulations, and the training of qualified personnel. From a financial standpoint, constitution of international consortia or a new international fund must sincerely be considered.

4. THE REPUBLIC OF KOREA'S ROLE IN THE CHANGING ENVIRONMENT

As most of you know, the Republic of Korea has been a Member State of the IAEA since 1957. Thanks to our Government's strong and consistent nuclear policy, and with great help from the international nuclear community, especially the IAEA, the Republic of Korea has now become one of the world's leading nuclear power generating countries.

Presently, we are operating 19 nuclear power plant units, which collectively supply about 40% of the nation's electricity generation. In addition, seven units, including two APR1400 units, are under construction.

On the performance side, recently we have shown an encouraging record. In 2003, the average capacity factor for the 19 units in operation reached a record high of 94%, with a yearly average of over 90% for the past four years in a row [3].

Additionally, after tireless efforts to establish a complete nuclear infrastructure in the Republic of Korea since our first unit started operations in 1978, we have now arrived at a level of complete technology independence in building and operating two models: the 1000 MW class KSNP and the 1400 MW APR1400. Thus, we are now extending our roles to helping with overseas projects, such as transferring technology gained and offering comprehensive support for a whole nuclear power plant, all over the world.

Based on our abundant experience and solid infrastructure, KHNP will exert every effort towards the global revitalization of nuclear power, in cooperation with the global nuclear community.

5. CONCLUSION

In this uncertain era, the world nuclear community is facing diversified environments, including difficult social issues. Those challenges are not restricted to one or several countries but, as the world has become a global village, these issues have become prevalent worldwide.

It has become apparent that how we respond to these challenges is the key to the future of nuclear power.

As a means to overcome many of these obstacles, and thus to foster the future viability of nuclear power, we need to appropriately address the issues mentioned previously that lie before us, especially by strengthening international cooperation in many areas.

In the long term, it is also important to establish a common vision among all members of the global nuclear community: that nuclear power is the optimal solution to the historic mission that a sustainable and environmentally friendly energy source should be secured for our descendents.

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Session Summary

CHANGING ENVIRONMENTS: COPING WITH DIVERSITY AND GLOBALIZATION

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This session explored issues and challenges arising from the globalization of the nuclear industry. There was recognition that the industry has moved towards a smaller number of vendors and nuclear safety standards needed to evolve towards more harmonized international requirements. Also, in the future, nuclear regulatory systems need to approach common, harmonized approaches to deliver consistent nuclear safety regulations.

There was also recognition that to support new nuclear design concepts, and new regulatory approaches, new research and development is needed. There was also a need for R&D to be widely shared. New approaches based upon international design certification processes were proposed as a way of providing effective and efficient harmonization of regulatory standards for new reactor systems.

The key issues to emerge were:

(1) Globalization calls for more harmonization of regulatory requirements, where appropriate. Efforts in this direction are pursued at the regional levels, acknowledging that harmonization does not mean uniformity. The role of the IAEA safety standards in building an international nuclear safety regime has also increased.

(2) The regulatory community will benefit strongly from cross-fertilization between regional and multinational efforts, and the international developments of more user friendly safety standards that take into account the feedback from different users. Consideration should also be given to mapping the coverage and identifying differences and gaps between IAEA and industrial safety standards.

(3) There is a need to build on the IAEA safety standards to provide vendors, operators and regulators with international standards for design and operation of nuclear installations:

- There is a need to develop a process whereby regulatory bodies can get together to assess and agree on a design so that the design can be accepted in any country;
- There was disagreement as to whether design certification was an appropriate way forward. Design certification is only part of the process. Ultimately, national regulatory bodies are responsible for licensing the plants.

(4) It was also agreed that globalization and the provision of reactors to States with no 'vendor' knowledge need to address the question of who owns the 'design'. That is, there is a need to maintain detailed knowledge for 50–60 years.

Communication with the public was addressed in most presentations as an issue that warrants a dedicated strategy.

OPERATING EXPERIENCE:
MANAGING CHANGES EFFECTIVELY

(Topical Issue 2)

Chairpersons

L. ECHÁVARRI
OECD/NEA

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OPERATING EXPERIENCE AND THE EFFECTIVE MANAGEMENT OF CHANGE

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1. RATIONALE/BACKGROUND

It has been 25 years since the Three Mile Island accident in the United States of America and 18 years since the Chernobyl accident in the former USSR. These two major events had far reaching effects on national and international cooperation in sharing lessons learned from operating experience. As a result of Three Mile Island, the nuclear industry of the USA pooled its expertise by creating the Institute for Nuclear Power Operations (INPO). This initiative was supported by several other nations that had nuclear industries. Later, as a result of the Chernobyl accident, the IAEA increased its emphasis on operational safety by establishing the Department of Nuclear Safety and the world's nuclear industry created the World Association of Nuclear Operators (WANO), a truly international utility organization to promote technical cooperation and sharing of lessons learned and good practices. INPO and WANO were created by the nuclear utilities and have worked seriously throughout the years, focusing on human factors and organizational issues. Fundamental roles in this endeavour have also been conducted by the IAEA and the OECD Nuclear Energy Agency (OECD/NEA) and other international organizations.

Since these two events, no further major accidents have taken place. However, several significant incidents have occurred, including some in very mature national nuclear programmes. These incidents have caused significant economic losses in addition to a consequent decline in the related public confidence and acceptance of a future reliance on nuclear power.

It is often assumed that the lessons learned from Three Mile Island and Chernobyl have been adequately understood and incorporated into the day-to-day routine of operating a nuclear power plant. In summary, one of the major lessons from the Three Mile Island accident was that human factors could overcome the design safety systems and lead to an accident. The major lesson of Chernobyl was that organizational factors with a lack of adequate technical knowledge and safety culture could also lead to a significant accident.

Hence, two important common root causes were identified: inadequacies in human performance and organizational factors.

The IAEA publication INSAG-15, Key Practical Issues in Strengthening Safety Culture, issued in 2002, states that:

Most incidents and accidents in the nuclear industry have occurred because someone has failed to take the relevant precautions or has failed to consider or question, in a conservative way, decisions that they have made, or the steps which were taken to implement them.

Since the two major events mentioned above, and with the increasing attention of the nuclear industry in developing and enhancing operational safety assessment programmes, the number of significant events has been reduced and the operating plant performance indicators have been steadily improved.

With the reduction in opportunity to learn from significant events, more management consideration and increased attention is necessary to the learning opportunities to be gained from events of lower significance, often referred to as minor events, near miss events and low level events. Although a lot has been written on this topic, there has been little defined regulatory guidance or requirements in this area. Also, within the industry there is still some confusion in understanding the importance and need of such an assessment process. There is a tendency to react to events that have occurred, and little importance or commitment is evident in attempting to proactively manage the future by identifying issues or likely issues before they develop.

The use of a proactive approach becomes more and more important as the rate of technological and business change increases through our naturally conservative industry. Since the two major events highlighted above, there have been radical technological changes, especially in electronics and information technology. There have also been radical changes in the business environment, with reductions in staffing levels and reliance on outside expertise becoming prevalent. Some of these changes have already been factors in recent events, as will be highlighted later.

Throughout the world, the performance of nuclear power plants continues to improve in the majority of areas, including reliability and safety, and improved operating plant performance indicators throughout the nuclear industry demonstrate this. These facts are commendable; however, there is a need to consolidate this performance in the face of the current trend of deregulation and competition in the electricity market, factors that are outside the direct control of the management of the nuclear utilities.

If the reduction in the number of reportable events is analysed, it could be deduced that sometimes the plants that are operating with almost no events deserve greater attention. There could be a misconception in analysing and ranking the performance of these plants by using only this group of indicators. With the apparent pressure of demonstrating an improved business performance, sometimes significant events are classified as being only *reportable inside the plant or utility* and reluctantly only few may be sent to the international community to be included in international databanks. Sometimes outside pressure has to be applied to encourage plants to report so that others can also benefit from the lessons learned.

With the focus on reporting only significant events, opportunities to consistently and routinely identify and analyse minor events, including near misses and low level events, may be missed in some organizations due to non-existent internal plant policy or mandatory regulatory requirements to analyse and review trends.

To be proactive in the management of safety, opportunities have to be taken to identify trends of deteriorating performance before events can occur. Indicators based on significant events show encouraging trends and are, therefore, considered very positive. However, they can hide one very important aspect since the level of the threshold for reporting of events remains at the same position. The majority of possible lessons learned, i.e. the minor events and near misses lie below this threshold, populating an area of augmented proportion of required awareness and assessment. Considering the number of operating nuclear power plants around the globe, hundreds of thousands of such events — considered very minor — occur every year. Some nuclear power plants do not have a comprehensive approach to assess such events. INSAG-15 highlights the need for developing a reporting culture:

Failures and near misses are considered as lessons learned which can be used to avoid more serious events. All employees need to be encouraged to report even minor concerns — in a good reporting culture, it is accepted that *it is the failure to report any issue* that may adversely affect safety.

Significant benefits could be obtained in strengthening and enhancing the management of safety and reliability if this information is identified and adequately utilized. This involves the less important events not individually reported to the regulator or to the industry and the low level events and near misses. They should be reported at least in-house, introduced into the operating experience programme and analysed collectively to identify trends. The lessons learned from this in-house collective analysis should then be shared within the nuclear industry to alert the operating organizations from antecedents, precursors and pitfalls.

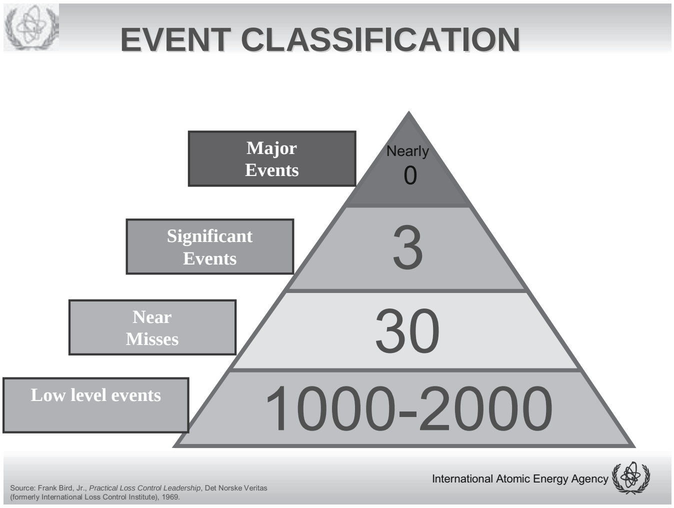

FIG. 1. IAEA event classification.

The information given in Fig. 1 is very well known and is shown to demonstrate its validity and usability. The numbers could vary here and there by some amount, but the most important message should not be overlooked or disregarded: there is a significant number of minor events that, if not identified, analysed and trended, lie dormant, waiting for different circumstances or failed barriers to recur as incidents or accidents.

Similarly, the operating experience programmes in place are only using a very small part of the available experience accumulated over the years by the nuclear industry. Mainly, they are only focusing on event information. It is now considered timely to also attempt to identify the good events; the embedded lessons learned in this amount of good experience that has driven so many plants to successful and safe operation. By proactively identifying the attributes of these successful events and sharing them within nuclear installations, it will be possible to contribute further to improve the organization's processes leading to higher levels of safety and reliability.

2. PRESENT STATUS

2.1. Current situation

Several of the nuclear power plants visited by the Operational Safety Review Teams (OSARTs) of the IAEA did not have an adequate process in place to learn lessons from the minor events, while at others, strong programmes were recognized as good practices.

Considerable emphasis was placed on reducing the number of reportable events and some international performance indicators demonstrate this continuous decreasing trend in the number of reportable events. It is obviously desirable for any nuclear power plant to operate without significant events. However, some potential events may be incorrectly analysed or remain undetected, or misunderstood if classified as a special operating condition, maintenance or engineering problem, and as such they may be reviewed under the umbrella of another plant assessment process (for example, in the design change or maintenance work request programme). As a result, they may then not be considered in the operating experience programme. During safety review missions, the existence of a very broad range of disparate processes to deal with those minor events has often been identified. However, it must be recognized that in some cases a sound process was in place and several thousand minor events were being reported in the programme per year.

Maintaining the reporting threshold within the plant or utility of those events reported to the regulator or the international industry has the considerable potential to send the wrong (or at least ambiguous) message to the operating floor. This concept may engender a false and potentially dangerous perceived reporting philosophy in that the operators only report circumstances to their supervisors and managers that would be reportable under the regulatory requirements. Several plants/utilities have developed comprehensive reporting criteria that not only define categories of reportable events to outside bodies but also identify categories of so-called *non-reportable events* which are events of less significance that should be reported into the plant programme. This includes all events of less safety significance, usually with a very low threshold of anything that may concern the person identifying the issue. The term ‘minor events’ is often used to identify low level events and the near misses.

An IAEA Safety Guide, A System for the Feedback of Experience from Events in Nuclear Installations, that provides guidance and recommendations on the use of operational experience, is available in the IAEA’s suite of Safety Standards. This will support the Nuclear Safety Standards Requirements NS-R-2, Safety of Nuclear Power Plants: Operation.

The IAEA has also developed a technical document, Trending of Low Level Events and Near Misses to Enhance Safety Performance in Nuclear Power Plants. This gives examples and definitions, suggesting different means to identify and report such events. One of the key issues discussed is the promotion of the implementation of the event reporting process within the plant: how to motivate people to report, how to communicate the results, how to demonstrate to the operating floor that this new process will add value and benefit nuclear safety.

In addition, the IAEA is developing a suite of documents providing guidance on the general principles of an operating experience feedback process. These documents will focus on the lessons learned from experience in establishing effective programmes together with successful experience. For example, a technical document, Effective Corrective Actions, has recently been developed.

The IAEA PROSPER service has been developed from the successful IAEA-ASSET programme to assess the effectiveness of the procedures, processes and programme implementation adopted by plants to ensure lessons learned are used proactively to enhance operational safety performance.

The IAEA PROSPER service, a peer review of the operational experience feedback process, verifies the adequacy of the plant operating experience processes and corrective action programmes. It offers suggestions to assist the plant or utility to conduct a comprehensive self-assessment, reviews the effectiveness of the plant processes and their implementation, and provides the plant/utility with suggestions for improvement where considered necessary. It also identifies good practices for possible replication throughout the industry. PROSPER utilizes a small team of six experts (including two IAEA staff), and is conducted over approximately eight working days. The effectiveness of the entire internal and external operating experience programme is reviewed. The IAEA has conducted this service at Hartlepool nuclear power plant, United Kingdom (as a pilot mission), at Metzamor nuclear power plant in Armenia and at EDF Operations Headquarters in France. Two further requests for PROSPER missions in 2005 have been officially received by the IAEA: for Santa María de Garoña nuclear power plant in Spain and for Chasma nuclear power plant in Pakistan. For 2006, two missions are being programmed, for Angra 1 nuclear power plant in Brazil and for the Karachi nuclear power plant in Pakistan.

To complement the activities of the PROSPER service within the Operational Safety Review Team (OSART) service, a new module for the review of operating experience has been developed that reflects international good practices. This new module is used by a dedicated expert to review operating experience and is now a standard part of the OSART missions.

2.2. Recent events

Considerable discussion and analysis has taken place during conferences, seminars, workshops and reviews on the main causes of recent events in the nuclear industry: the Davis Besse nuclear power plant reactor head event in

USA, the Brunsbüttel nuclear power plant hydrogen explosion event in Germany, the TEPCO falsification event in Japan and the Paks nuclear power plant fuel event in Hungary. In several cases, these discussions identified the lack of an adequate and effective operating experience philosophy compounded by deficient management of safety issues as one of the contributing factors in the events.

This is not necessarily a unique situation confined to the nuclear industry. For example, the analysis conducted by the Accident Investigation Board of NASA into the root causes of the Columbia shuttle accident highlights similar concerns.

At Davis Besse nuclear power plant, deposit indications of boric acid leaks had been noticed in 1998 but further extensive inspections were not performed and proper measures against defects were not taken. Subsequently, a cavity was discovered with only the layer of the stainless steel liner remaining to contain the primary circuit. While the equipment deficiency was rectified relatively quickly with a replacement head, the financial penalties caused by delayed return to service due to the need to correct organizational and managerial deficiencies were considerable.

At Brunsbüttel nuclear power plant, indications of water leakage within the reactor containment were detected. Plant management made a decision to continue operation because they considered the leakage had been isolated and was insignificant. A subsequent inspection showed that a piping section of a reactor head spray line had been completely destroyed by a hydrogen explosion.

At Paks nuclear power plant, the cooling to a fuel cleaning device containing 30 nuclear fuel elements was lost due to incorrect operation and inadequate design of the cooling facility. This led to the complete destruction of the fuel elements in the cleaning device. Cleaning operations of five previous batches of fuel had been completed, yet the event showed a number of unidentified significant deficiencies in the whole process.

At TEPCO, various records of maintenance inspections and work were inadequately recorded, analysed and reported. Some records were even found to have been falsified. These included records on important equipment, such as the core shroud of the reactor. Others involved the falsification of containment test procedure in order to present acceptable results.

If these events associated with important equipment (reactor internals, fuel, containment) are analysed, some common causes and contributory factors can be identified, such as:

— The decision making process in a situation that conflicted with the planned production process;

— Reliance on recent successful operating performance history;
— Lack of full consideration and analysis of all available information, with potential consequences;
— Insufficient review to ensure that all pertinent information was considered and analysed;
— Insufficient challenge of assumptions or a desire to look for alternate acceptable explanations that supported continued operation.

In all of these four events, an apparent lack of respect for the reactor internals and components could be deduced.

Recently, an event involving a leak of high temperature steam from a secondary circuit pipe due to erosion/corrosion killed five contract workers and injured several others. Erosion/corrosion in secondary steam and water systems is a well identified phenomenon and significant operating experience is available.

All these factors and contributors demonstrate insufficient consideration of the operating experience feedback programmes, either to proactively identify situations of potential safety concern learned from experience by others or to identify and rectify early in-house indications of issues through apparently minor deficiencies. Also, some of these important problems had initially been treated as minor deficiencies within the close boundaries of normal engineering or maintenance and were not analysed more broadly to identify possible human and organizational operating experience factors.

The inadequate and ineffective use of operating experience, together with the desire of senior management to minimize the number of operational events reported, may send a message of complacency to all the organization — a message that is often supported by a decreasing graph of reportable events in a monthly performance report. This is often a perfect combination to contaminate the entire organization with ambiguous expectations and perceptions.

It has often been stated that the managers set the tone for how the operating floor will play the game, and that it is not what it is said in slogans that will affect plant personnel attitudes, but the actions performed by the managers towards their objectives. The final practical result of the perceived message may again lead to inadequate analysis of issues or insufficient challenge of the subsequent explanations. There may be a tendency to only report good news and even hide the results that demonstrate poor performance, thus preventing the identification and implementation of effective corrective actions.

3. PRIORITIES FOR FUTURE WORK

Priorities for future work include to:

- Continue to encourage and promote the use of operating experience feedback in nuclear installations, especially in support and regulatory organizations, vendors and contractors, fuel fabrication facilities and research reactors, etc., through workshops, seminars, information exchange and assistance;
- Provide an effective assessment service to assist the nuclear industry to identify and correct deficiencies in their programmes and also to promote good practices;
- Promote new initiatives and developments in analysing operational experience and good practice;
- Develop technical documentation to promulgate the lessons learned to the nuclear industry. Topics include the following:

  - Knowledge management: ensuring that lessons learned from previous events remain embedded in safety programmes and that the new generation of nuclear personnel receive the benefit of the experience of the past;
  - Effect of change: analysis of the effects of change, both technological and organizational;
  - Lowering the threshold of reporting and analysis: investigating error precursors and error likely situations;
  - Assessing success: identifying and analysing success to ensure that lessons are learned not only from failures but also from good performance;
  - Utilization of lessons learned from major events that have occurred outside the nuclear industry;
  - How the lessons learned from in-house collective analysis of low level events and near misses should be shared.

4. NEED FOR STRENGHTHENING INTERNATIONAL COOPERATION

The exchange of operating experience is one of the most important benefits the utilities receive from international experts during peer review missions; the added value to the organization is significant. Nevertheless, there are still some countries that very seldom request such visits to their operating nuclear power plants. Given that, due to several factors including language barriers, less than an adequate number of *plant* personnel participates in workshops, seminars and similar meetings, the acquisition of international experience remains limited to the internal plant process to disseminate them.

Benchmarking is an excellent process for comparing one's current practices and operating experience with those of industry leaders in order to achieve improvement. Benchmarking helps determine what factors contributed most to success, and how these common contributors to success can be implemented to achieve improvement through change.

The international exchange of good practices and benchmarking should continue to be promoted. With the drive for economy in many areas, there is a growing reluctance in some areas to participate in IAEA activities such as PROSPER, OSART and technical meetings. The advantages of international exchange need to be re-emphasized to counteract possible insularity.

International nuclear organizations should continue to strengthen coordination in the common goal for industry safety and reliability improvement. While a diversity of approaches may be beneficial to verify the adequacy and suitability of recommendations and good practices, there continue to be opportunities to combine efforts and avoid duplication of information exchanges. The nuclear facilities throughout the world should take advantage of this coordination and benefit from the combined effort of the international organizations.

5. RECOMMENDATIONS FOR FUTURE IAEA ACTIVITIES

— Senior management commitment to an effective operating experience feedback programme needs to be encouraged and strengthened. This commitment should be able to withstand the external pressure to reduce resources and effort under the considerable commercial pressure that the industry faces. The IAEA PROSPER service and OSART enhanced operating experience module could assist Member States to effectively implement and enhance more comprehensive self-assessment and corrective action programmes at their nuclear power plants.

— As the number of significant events decreases, lower reporting thresholds are necessary to ensure that precursors to possible future significant events are identified and eliminated in a proactive way. The industry should continue to promote the proactive approach to the use of minor/low level/near miss event information in eliminating issues before they develop into significant problems. The identification and analysis of information, such as error likely situations and event precursors, needs to be encouraged and guidance developed. The lessons learned from in-house collective analysis of low level events and near misses should be shared.

— The lessons learned from previous significant events must be embedded into current and future processes and programmes. Due to the maturity of the nuclear industry there has been a significant turnover of personnel over the past few years. An enormous amount of knowledge and experience can be lost if this change is not managed effectively. Corporate memory should be maintained. Effective transfer of experience, knowledge management and training programmes need to be developed to ensure the prevention of recurrent events. International organizations should review past events and ensure that guidance to the industry remains relevant and is updated accordingly in the light of current thought.

— Future initiatives in the utilization of operating experience should ensure that cultural, commercial and technological change is considered. Change is continuous and also the pace of change continues to increase and, therefore, reaction to the new issues and challenges needs to be equally adaptive. It is important that the utility remembers its overall responsibility for nuclear safety of the plant even though the current trend is for more reliance on outside resources, such as contractors, technical support and organizations. International organizations need to be able to respond to the pace of change and ensure that their standards and guidance are reviewed and amended in an effective and timely manner.

— The number of events entered into international databases should be increased to ensure that valuable lessons learned are available for all to consider. Initiatives need to be taken to encourage plants to report events for their learning opportunities, not just their significance. More emphasis needs to be placed on good practices and how they have been achieved. International organizations should review the objectives and management of their reporting and event information programmes to ensure that available lessons to be learned are highlighted and made available to others. Successful prevention initiatives should be considered.

— The objectives and emphasis placed on performance indicators need to be reconsidered. More emphasis needs to be placed on their usefulness as tools to manage successfully rather than their use as indicators of success. They should not be considered just a measure/demonstration of success that can be manipulated as required. International organizations should reinforce the need to utilize performance indicators to identify opportunities for improvement rather than as measures of success or failure.

- — The use of operating experience to enhance their own internal management of safety should be encouraged in support organizations, regulatory authorities and other nuclear industries. International organizations should encourage support organizations, regulatory authorities and other supporting industries, such as contractors, fuel fabrication and waste treatment facilities, to fully utilize operating experience feedback in their own daily business. Operating experience demonstrates that some events not only involve the plant itself, but also have contributing factors originated in supporting organizations.
- — Existing operating experience programmes generally only use a very small proportion of the available experience accumulated over the years by the nuclear industry. Their main focus is on events. Good events/ practices also need to be identified and promulgated so that the lessons learned from good experience which has driven so many plants to successful operation may be adopted by others. By proactively identifying the attributes of these successful events and sharing them within the nuclear industry, further improvement of organizational processes may be achieved, leading to enhanced levels of safety and reliability.

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LEARNING FROM DISASTERS

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1. INTRODUCTION

Every few months, somewhere around the world a major 'man-made' industrial disaster or serious near hit takes place. They affect every major industry, including the nuclear, chemical and petrochemical industries, where the impacts can affect not only the workforce immediately involved, but also the wider community. It has become increasingly clear that these types of events have deep-seated, organizational and cultural root causes and it is these which this paper attempts to address.

Because these root causes are not common to any one technology or organization, there is an enormous volume of available learning across a wide range of industry sectors. This paper is based on research in BNFL which has examined a number of events (actual events and near hits) in a variety of industrial sectors. For the purposes of this paper, we have chosen five examples for discussion and analysis. These have been selected from a larger number of events studied, by applying screening criteria to ensure their relevance and potential for learning.

The events discussed here are:

- The Columbia shuttle disaster (United States of America, 2003) [1];
- The Longford Gas Plant explosion (Australia, 1998) [2];
- The JCO criticality accident (Japan, 1999) [3];
- Railway disasters in the United Kingdom between 1991 and 2003, particularly the Ladbroke Grove train crash and earlier events [4];
- The Piper Alpha offshore petrochemical disaster (United Kingdom, 1988) [5].

It should be emphasized that in discussing these and other events, we have drawn on the findings of reviews and inquiries, including those referenced above. We have attempted to do this in a spirit of learning. In each case, the organizations involved were subject to pressures and difficulties (many of which we attempt to identify) and it is not the intention of this paper to establish blame or to criticize organizations or individuals. Against this background, the paper will first discuss some of the approaches which have proved valuable in understanding and analysing such events. This will be followed by a precis of the events listed above and a summary of their causes as identified in the references. The final sections of this paper attempt to draw out the common factors involved and provide views and recommendations on what might be done to address some of the issues identified. This includes suggestions for actions which might be pursued by the IAEA and other international bodies.

2. PEELING BACK THE LAYERS

Events with complex causes involving not just ‘front line’ failures, but deep-lying organizational and cultural issues are sometimes referred to as ‘organizational accidents’. The work by Turner and co-workers [6] has been further developed and explained in a simple and compelling way by Reason [7]. He has argued that organizational events can be visualized in terms of successive layers or defences, each of which serve to prevent a hazard from manifesting itself as a real event. He likens this to layers of Swiss cheese, using the analogy that the holes in each layer represent the imperfections in each line of defence. He argues that occasionally the holes in the successive layers of Swiss cheese can align, leading to a direct path from hazard to consequence. The conclusions for the analysis of complex events is to recognize that there are many such layers — starting from the obvious (like a single error or a lack of training), but working ever deeper into more complex, organizational issues (such as a failure to develop and embed organizational values or setting in place a deficient organizational structure). Although the analogy should not be pushed too far, this simple way of visualizing degraded layers of defence has been found to be very helpful in examining real events. To minimize the risk of a real event, not only is it vital that many successive layers are present, but that they contain as few ‘holes’ as possible. This leads to the concept of the ‘latent pathogen’: the hole in the layer or barrier which has not been identified and addressed and which is brought into play by some unpredicted or unrecognized sequence of events. It suggests that proactively engaging in recognizing and rectifying the potential deficiencies in each line of defence is a vital process if risks are to be minimized.

Other excellent discussions of some of the techniques and issues which might help us to understand the causes of such accidents are contained in Refs [8] and [9].

In studying the accidents and near misses referred to in Section 1 of this paper, we have sought, for each event, to recognize the causes in terms of the above hierarchy. It is not always possible to identify the successive layers with precision, both because information is complex (and sometimes lacking) and because it would overstretch the concept behind the simple model to do so. However, we have found it helpful to consider the defences in three broad categories:

(1) Plant related, 'front line' issues;
(2) Organizational and cultural issues going deeper than one plant or plant area;
(3) Fundamental, structural and value related considerations spanning and influencing an organization.

3. THE EVENTS

3.1. Columbia shuttle disaster

The mechanical causes of the Columbia shuttle disaster are very well known. In brief, during launch a small piece of insulating foam (about the size of a laptop) and weighing less than 1 kg came off an external tank and collided at about 500 mph (about 804 km/h) with the leading edge of the left wing of the orbiter. As a result of the damage caused, the shuttle overheated and disintegrated on re-entry into the Earth's atmosphere, while travelling at 14 000 mph (about 22 530 km/h) and at a height of 205 000 feet (about 62 484 m). The crew of seven were killed. Some 84 000 pieces of debris were recovered. Luckily nobody on the ground was injured, but had the debris (hitting the ground at 10 000 mph, or about 16 093 km/h) dropped 70 miles (about 112.6 km) north (over Dallas/Fort Worth), the consequences could have been much worse.

The disaster was the subject of a major investigation [1]. Chapter 7 of the report, The Accident's Organizational Courses, and Chapter 8, History as Cause, are particularly revealing in the context of this paper. It was concluded that NASA knew that foam had detached and that this had happened many times before without leading to disaster, and so assumed that the same would be true this time. The 'front line' defences which were ineffective in this event involved missed danger signals (e.g. potentially important temperature indications on launch), failure to follow up the potential consequences of the impact with the wing (attempts to get in-flight images were missed). The report drew out the following more fundamental issues:

— Clear technical standards, independently assessed and owned, were not in place.
— An informal chain of command for safety related decisions had developed as part of a highly complex management organization. There was no independence from operational pressures for those who made safety decisions.
— A culture had emerged which required ‘proof that it’s unsafe’ before action was taken rather than the reverse. A healthy fear of failure was no longer evident.
— Communication of key issues was inhibited partly as a result of the complexity of the organization. A ‘good news’ culture had developed.
— There was no independent and effective oversight of key safety related issues which had authority and independence. In other words, the organization appeared to have lost its ability to step back.
— Major changes had taken place in the organization with programme managers increasingly taking the prime roles. This was reinforced by a major move to the use of contractors with rewards to them for being on schedule. There had been a major reduction in corporate memory, with the loss of experienced in-house engineers. In other words, NASA was no longer an ‘intelligent customer’. It had slipped into this position without realizing the safety implications.
— The emphasis had become one of ‘faster, better, cheaper’ and ‘stick to programme’. In the view of the Commission, this was strongly reinforced by external budgetary pressures (a 40% reduction over the years) and schedule pressures (e.g. to minimize further delays and cost overruns in the international space programme). All this was reinforced by a lack of vision and commitment on the part of the Government.

3.2. Longford Gas Plant explosion

On 25 September 1998, a major explosion at this plant in Australia killed two men, injured eight others and cut Melbourne’s gas supply for two weeks. It was the subject of a report by a Royal Commission, published in 1999, and an excellent analysis by Hopkins [3], on which this summary is largely based.

The Longford Plant takes gas coming ashore from platforms in the Bass Strait together with hydrocarbon liquids and water. The plant removes water, most of the liquifiable components and the small amounts of hydrogen sulphide present. Separation occurs through a series of heating, cooling and pressure changes. Occasionally, variations in the mixture coming ashore cause disturbances in operating conditions. This accident occurred when a significant variation, coupled with a failed automatic valve, led to a major buildup of condensate. As part of the process control, pumps shut down automatically, leading to reduced oil flow and operators were unable to restart them. As a result, a 14 T heat exchanger became extremely cold (–50° C). Operators then reintroduced warm oil, leading to catastrophic brittle fracture, an explosion and a fire.

Hopkins listed many lessons which he believed emerged from Longford. Some of these can usefully be regrouped into the three levels discussed above. In emphasizing the need for companies to be mindful, he rejected strongly the contention that simple operator error or inadequate training were the sole causes of the accident. Among the main learning points he identified were the following:

— A series of local plant level shortfalls occurred. These included failure to carry out systematic risk assessments (HAZOPs); poor communication, particularly at shift handover; a lack of management and operator awareness of the safety issues, demonstrated by inadequate procedures and training; the acceptance of informal rule-violating practices to get the job done (e.g. response to alarms); and the buildup of maintenance backlogs.
— Several broader issues were also identified. For instance, a major loss of corporate input over high hazard issues had progressively occurred. In 1992, for example, engineers had been removed from the site, leaving the Longford operators much more isolated from engineering support. Such major changes (both organizational and technical) had apparently not been subject to risk assessment. Some issues, such as the failure to carry out a HAZOP on the plant, the buildup of maintenance issues and the loss of engineering expertise, may have been at least partly attributable to the need to cut costs.
— Hopkins concluded that internal oversight/auditing was weak, as demonstrated by audits. As he put it: A large scale audit which fails to uncover problems is not a credible audit, and company auditing provided only good news and failed to identify problems which became very obvious after the event.
— In his causal analysis, Hopkins also addressed Government, regulatory and societal influences on the event. The effect of these was difficult to assess, although the impact of market forces and privatization were seen as potentially relevant issues. Overreliance on the plant for security of gas supply may have exerted production pressures. A major and clearer issue was the existence of a weak regulatory system which did not require safety cases from operators.

3.3. JCO criticality accident

This criticality accident occurred on 30 September 1999 at a uranium reprocessing plant in Tokaimura in Japan. Two operators involved in plant operations were killed by the radiation released by the criticality and a third was highly irradiated but survived. Evacuation within a 350 m radius of the plant took place and sheltering was required within a 10 km radius. The accident was the first criticality accident ever experienced in Japan and the consequences to the Japanese nuclear industry in the form of a reduction in trust of the general public are still apparent today.

The media reported soon after the accident that the criticality had been caused by the workers deviating from the approved procedure. In fact, the operators were dissolving fuel in stainless steel buckets and then bypassing equipment designed to preclude criticality and pouring the material into a large mixing vessel through a funnel. The fuel on this occasion was at a much higher fissile content than the operators were used to working with and the 16.6 kg of uranium material became critical, resulting in a large release of radiation.

In the subsequent investigation, it became clear that the event was not a simple non-compliance by three 'rogue' workers. In fact, many organizational factors had slowly but surely led to the erosion of criticality procedures and awareness of criticality issues among staff. An investigation was carried out by the Government and also by a task force put together by the Division of Human–Machine Systems Studies of the Atomic Energy Society of Japan which brought together a number of human factors specialists from inside and outside the nuclear industry. The latter investigation concentrated on the organizational factors leading to the accident [3]. Some of the key factors leading to the accident appear to involve the following:

— At the time of the accident, the supervisor was in another plant getting ready for a further programme of work in which the operators were also involved. All supervisory focus was on that programme and the fuel operation was being fitted in before new workers arrived at the other plant. The operators were under pressure to get back to their own building to make ready for this.

— The campaign of fuel production was the first in three years and the chosen operators were inexperienced. It was also the first with this level of enriched uranium, i.e. 18.8% rather than the usual 5% or 12%.

— The manual described a batching process of 6–7 batches, but did not have any safety procedures detailed for this level of enrichment. The company had not trained the operators in criticality, as they had found in past training courses this subject to be 'too difficult' for operators. They relied totally on the operators following the procedures for safety although deviations from the manual had developed over time.

— The organizational factors setting the culture in which the process took place included the following:

- Over the 13 years since the beginning of the process, the procedures had been modified from campaign to campaign, slowly deviating from the original approved procedures that used the full criticality-safe features of the plant. These deviations were aimed mainly at reducing the time for completing the process. Approvals had been endorsed by the production and quality committees, but no oversight in terms of nuclear safety had been sought except retrospectively. Unacceptable modifications to the procedures were approved by the company and put into their manual.
- A number of organizational changes involving downsizing had left some managers with conflicting roles and responsibilities. The Atomic Energy Society report also suggests that the safety managers did not have enough authority to discharge their duties. Furthermore, it appears that the technical safety capabilities of the organization had been reduced such that access to criticality safety advice was poor. Through these organizational changes, nuclear and radiological safety was not given high priority.
- The company concentrated strongly on industrial safety — in fact, they were considered a ‘safe’ company as they had been without a lost time accident for three years. Their other control procedures were based on QA. For example, the Atomic Energy Society of Japan’s investigation identified that the workers had been fastidious in cleaning out the vessels they were going to use before starting the unsafe procedure. This suggests that the operators were capable and willing to follow procedures they felt to be important.

In summary, as a result of company changes and organizational decisions, the internationally accepted barriers to criticality safety had been undermined. Organizational change had eroded the criticality competence, drastically reduced oversight, and had developed a culture of production and quality focus that did not take sufficient account of nuclear safety. In addition to this, the regulatory structure did not provide an independent oversight, as processing plants such as JCO were exempt from periodic inspections, and this was compounded by the fact that the responsible inspectorate (STA) had significantly fewer inspectors than the power plant regulators (MITI). Overall, the Japanese Atomic Energy Society felt that the focus of authority and responsibility for nuclear safety was unclear between the Japanese Nuclear Safety Commission, regulators and business operators.

3.4. United Kingdom railway disasters (particularly Ladbroke Grove)

In October 1999, Lord Cullen was asked to draw lessons from accidents on the United Kingdom railway system. In addition to drawing together conclusions about the accident at Ladbroke Grove (near Paddington Station in London) in 1999, he looked at seven accidents over the period 1991–1999 [4].

The crash at Ladbroke Grove, which was the prime focus of his report, occurred when a local train passed a red signal and collided with a high speed train. The collision occurred at a combined speed of about 130 mph (about 209.2 km/h). It led to the death of 31 people and 400 injuries, some of them critical.

The immediate cause of the accident was believed to be poor positioning and sighting of the signal, which may have not only made it difficult for the inexperienced and apparently poorly trained driver directly to see the signal, but may have misled and confused the driver. Other immediate causes involved failure by signallers to take action, associated with deficiencies in the running of the signalling control centre.

The Cullen investigation was extremely thorough and probed deeply into underlying causes. Drawing together those associated with this accident and the others investigated led to conclusions including the following:

- There were important deficiencies in the competence and training of the workforce, particularly the high numbers of contractors used since the industry had undergone major restructuring following privatization.
- Deficiencies in standards contributed to the immediate causes of several of the accidents investigated. More generally, shortfalls in risk assessment and acceptability and ownership of safety cases were seen to be important issues. Cullen made the important points that safety cases should be 'owned' by those who use them, that they should be involved in their preparation and that they should be non-bureaucratic, 'living' documents.
- Communication issues figure strongly in the findings in a number of guises. This was relevant to the immediate causes of some of the accidents, but Cullen pointed to deeper issues relating to open, blame-free involvement and feedback from the workforce over safety matters.
- Although events were often thoroughly investigated by the railway industry in the United Kingdom, the means by which learning was transmitted and utilized in operations, standard setting and in training was identified as an important issue.

— The investigation brought out a very significant range of factors relating to organization and structure and the need for stronger controls in managing major changes. For example, the move to use a very high proportion of contractors in the industry had not been accompanied by the necessary level of customer control. Thus, standards relating to the selection and competence of workers were found to be deficient.
— The changes in the industry had led to other issues probably relating to the pressures in the industry to meet performance objectives. Fragmentation had impacted on leadership and Cullen particularly emphasized in his recommendations the need for committed, visible leadership from the highest levels in companies. Organizational incentives, such as disparity in sanctions between failures in performance and failures in safety, may well have conveyed the impression that performance was always the top priority. The changes had also hindered learning, led to compartmentalized thinking, a shortage of competent personnel and had led to a loss of clarity over roles and accountabilities in a range of areas, including responsibilities for safety cases.
— Not only had internal oversight through auditing and the ability to take a 'helicopter view' of safety been largely lost, but the safety regulator's role was seen by Cullen to have been weakened. In addition to resource issues, the changes in structure had made the regulator's job much more difficult.

Following the Cullen investigation, there have been other serious incidents and accidents on the United Kingdom railways, for example, the Potters Bar derailment in 2002, leading to 7 dead and 70 injured, or the derailment at Hatfield in 2000, leading to 4 dead and 70 injuries. Both of these were directly associated with defective track, but manifested many of the issues highlighted by Cullen. Although the level of awareness and attention to the issue has grown very significantly, recovery from a deep-seated set of organizational and cultural deficiencies can take a long time to put right.

3.5. Piper Alpha

The Piper Alpha disaster occurred on 6 July 1988 on an oil production platform in the North Sea, about 200 km off the coast of Scotland. An initial explosion was followed by a crude oil fire and a second explosion then led to a massive intensification of the fire. In all, 165 out of the 226 people on board the platform died, as well as two rescue workers. Although this event is not as recent as the others discussed here, it has had a fundamental impact on the offshore oil and gas industry. Many of the findings about root causes are as relevant today as they were then, and the investigation which followed the event in many ways set a benchmark for our understanding of the deeper causes of accidents. It was for these reasons that we have decided to include the Piper Alpha disaster among the events selected for discussion in this paper.

Because of the devastation, the sequence of events which led to the disaster was difficult to interpret in detail. This report by Lord Cullen [5] concluded that the most likely explanation for the accident was that when a condensate injection pump tripped, night shift personnel took steps to restart another pump which had been shut down for maintenance. Unknown to them, a pressure safety valve (PSV) had been removed and replaced by a blank flange. This was not leaktight and escaping gas ignited. The explosion put the main power supplies and the control room out of operation. Various emergency systems were either inoperable, failed to operate effectively or required manual intervention to start. A second explosion, probably due to the rupture of a riser on a gas pipeline from another platform as a result of the initial fire, might have been mitigated if oil production on other platforms had been shut down earlier.

— The immediate cause of the disaster arose from a lack of awareness of the removal of the safety valve. This resulted from failures in communication at shift handover and in the permit to work system. Cullen concluded that these were not isolated mistakes, but arose from failures to follow procedures and the development of unsafe practices. In particular, responsibility was placed on contractors for ensuring that their employees were trained. Some contractors acted as ‘performing authorities’, but training was weak and some day-to-day checks on competence were superficial. This deficiency may have been particularly significant for short term contractors used during major overhauls.
— Cullen took the view that good policies were in place but there was little emphasis on ensuring that these were implemented in practice. Overall, therefore, a major issue in this disaster appeared to be failure of leadership to communicate the company’s requirements and commitment, and insufficient leadership attention to encouraging a questioning and conservative approach to safety related matters.
— There appeared to be a failure to learn, since there had been significant precursors to the event. To quote Cullen, management failed to use the circumstances of particular incidents to drive home the lessons of those incidents to those who were immediately responsible for safety on Piper on a day-to-day basis. As with the Longford disaster, there tended to be a hands-off approach, which involved little or no effective higher level feedback and oversight from the broader organization.

— The inquiry reserved significant criticism of the scrutiny provided by the regulatory regime which had been in operation. As a result of the accident, major organizational changes to this were put into place. The development over a relatively short period of the massive North Sea oil and gas fields may well have led to the development of systems and structures which left much to be desired in safety terms, but regulatory oversight (at that time by a Government department) was weak.
— The intensive and competitive environment in which North Sea operations were being carried out probably had a significant part in the event. Certainly, production pressures immediately prior to the accident were brought out in the report. There was an unusually high level of work at the time of the disaster, including major construction work, additional maintenance work and a 'change out' of a major plant item. It was also noted that at a time when strengthened management and supervision would have been called for, five senior posts were either vacant or filled by temporarily upgraded staff. The decision to continue production at the prevailing rate during this difficult period was referred to in the inquiry report as puzzling.
— It should be noted that as a result of Piper Alpha, Lord Cullen came to several very important broad conclusions about achieving safety excellence. For example, he emphasized the need for unfailing commitment by top management (and the CEO in particular) to create a corporate atmosphere or culture in which safety is understood to be (and accepted as) the number one priority, the need for clarity of organizational responsibility and the vital importance of ensuring involvement of the workforce so that issues are raised and acted upon. These comments are as relevant today as they were 15 years ago.

4. DRAWING OUT THE ISSUES

Analysis of these events and the others which the authors have reviewed allow some common underlying factors to be identified. Although the details are obviously different from one event to another, the authors were struck during the analysis by the strong similarities (and thus opportunities for broader learning) which emerge.

In this section of the paper, therefore, some of these common findings are presented, and in Section 5 the more difficult task is attempted of trying to identify some common remedial actions as enablers to minimize the risk of such events in future.

Common factors can be grouped in a variety of ways, but the analysis presented here has found about eight issues which seem to span nearly all of the events (including those not explicitly presented in the paper). It would be easy to expand the list to try to cover every recognizable factor in the incidents studied, but this would be unhelpful in trying to develop potential priority areas for improvement. Equally, providing a few very general issues would be similarly unhelpful. A compromise has been sought using an element of judgement, and these eight major common factors have been identified and presented broadly in line with the sequence of 'layers' discussed above.

A number of events in the nuclear industry have occurred which are highly relevant to this discussion. Recent examples include the events at Paks and Davis Besse, as well as other events providing learning opportunities. Unlike the Tokaimura JCO accident, these fortunately did not lead to loss of life or disaster but for several of them, issues discussed below also appear to be highly pertinent.

In this study, we note that, in several instances, the organizations involved had generally good safety records (e.g. in industrial safety). This seems to illustrate the fact that, important though it is, dealing with industrial safety alone does not always substantially mitigate the risks of these complex, organizational accidents. The 'Swiss cheese' model allows this at least partly to be understood.

Finally, in drawing out the issues below, it is also important to realize that none of the individuals involved — from people involved in safety policy, to the plant supervisor or operator — had any intention through their actions to be part of a chain of 'failed' judgements which led to disaster. It seems important, therefore, to try to understand better the 'drivers' which condition thinking at all levels. This may involve issues relating to competence, a questioning attitude and a range of other pressures. Understanding these factors better may provide further clues on how to minimize the occurrence of complex, organizational accidents.

4.1. Maintaining competence

It is striking that almost all of the incidents involve a lack of competence on the part of operators and/or supervisors and decision makers. Shortfalls also exist in the systems to recognize the need for training and to check that competence is maintained (particularly during periods of substantial change).

Within organizations, certain activities sometimes become the 'poor relation': unresourced, unskilled and often the 'dumping ground' for those who are not deemed to meet the standards required elsewhere in the company. Such unloved, orphaned parts of the organizations are potential breeding grounds for disaster.

4.2. Application of standards

Inappropriate and poorly applied safety standards — particularly in respect of procedures, risk assessments and safety cases — are very often apparent in the events studied. This appears to arise not only from a lack of training, but also from poor awareness of their importance. A lack of ownership and involvement in the development and application of procedures by those who have the responsibility to use them in practice, not surprisingly, can lead to short cuts and violations.

4.3. Questioning attitude

This is sometimes referred to, or associated with, the term ‘conservative decision making’. It has been widely accepted as one of the prerequisites of a strong safety culture (see, for example, Ref. [10]). The issue highlights the need for those involved in safety related activities at all levels to try to avoid mindsets that justify actions by assuming that what has been apparently safe before will be so again, and the impact of ‘group think’. It emphasizes the fundamental need to ask what if? questions and to encourage minority views. It ties in strongly with some of the issues discussed below relating to the need to enable and respond to the questioning attitude of others.

4.4. Organizational complacency and loss of focus

Organizational complacency and creeping isolation are factors underlying many of the events. Often, organizations appear to ‘rest on their laurels’ following earlier success or strong performance in a particular aspect of safety (e.g. industrial safety) and fail to recognize the early warning signs of deterioration in other vital areas of safety. The overconfidence is sometimes accompanied by a belief that success means that there is little reason to continue to learn from others and share improvement opportunities. The deterioration can be manifested in a variety of forms, including a failure to communicate difficult issues, listen to messages from the workforce (particularly when these are unwelcome), continue to insist on high standards and be prepared to recognize early warning signs, such as the buildup of maintenance backlogs, increases in near hits, etc. [11].

4.5. Poor communication

Poor communication is a factor influencing almost all failures, because it is rare that somebody in an organization does not recognize a shortcoming or an emerging problem. If only they had been heard, the event would not have occurred. It can take many forms, such as:

— A failure of leadership to communicate their standards and expectations (and be seen to act them out personally).
— A failure to welcome 'bad news'. If messengers are shot, or as a minimum ignored, it is unlikely that messages will get through.
— The development of silos or divisions are allowed to develop between teams, between shifts or between staff and contractors such that messages are not transmitted and rarely welcomed and acted upon.

4.6. Loss of oversight

An important element of ensuring safety is the extra defence in depth provided by independent oversight and scrutiny. This can be at several levels. Firstly, within an operating unit, there is a need for managers to ensure that they are getting more than one view of performance. Important inputs to this may be through listening, respecting and acting on the views of the workforce as the people who know best what is actually happening at plant level, welcoming advice through, for example, audits and peer reviews and encouraging reviewers to present things as they are (rather than as the manager would prefer them to be). Particularly important is the need for leaders to be personally visible and available to listen to feedback on safety issues. Secondly, within an organization, there is a need for effective oversight from those outside the line. This may again be informed by the results of audits, monitoring of KPIs and events and scrutiny of safety cases and other similar requirements. Thirdly, oversight is provided by effective external regulation. This requires a difficult balance to be struck between permissioning, the exercise of regulatory authority and the input of advice. It is noticeable that in many of the events discussed, two or more of these 'layers' were either missing or clearly ineffective.

4.7. Management of change

It is perhaps hardly surprising that many of the events occurred after major organizational change or during periods of non-standard activity (e.g. major overhauls of the plant). It has become increasingly recognized that, in addition to controlling engineering change as part of a structured process which assesses the inherent risks, it is vitally important to do so for organizational and structural changes. These can be at the plant level (e.g. the staffing levels for a shift), the company level (e.g. adequate provision of engineering support or safety oversight) or at the industry level where major restructuring can have profound and often unrecognized impacts on accountabilities, resources and the maintenance of skills and effective control.

4.8. External pressures

Nobody knowingly sets up an organization or an industry in such a way that safety is degraded, let alone in a way that enables disasters or other major events to occur. However, the seeds of disasters are often sown through the unrecognized consequences of such top level decisions and the associated lack of control of the changes. In particular, an understandable drive by an organization or government to inject a greater commercial ethos into an industry through privatization and/or 'contractorization' needs to be managed carefully from the point of view of safety. This is particularly true if a climate is created in which safety begins to be perceived by the workforce as a lower priority.

5. WHAT CAN BE DONE?

There are several 'enablers' which may help organizations in minimizing the risks of the type of events which are the subject of this paper. There are, of course, no simple prescriptive or quick fixes, and the detailed requirements will depend on the organization and where it is on its journey towards achieving high levels of safety. In particular, the best way of addressing the deeper cultural and organizational issues discussed above will depend critically on the current culture within the organization. Issues such as leadership style, effectiveness and openness of communication, and willingness and ability to learn, are at the heart of most of the events studied. These cultural issues have been the subject of significant research, including major work by the IAEA (Refs [12–16]), the World Association of Nuclear Operators (WANO) and the Institute of Nuclear Power Operations (INPO). The discussion below also draws on this work. Some conclusions on this subject are summarized in Ref. [17].

We have chosen three fundamental areas which might form the focus for further debate and potential action: leadership, communication and learning, and alertness and effects on change.

5.1. Leadership

This is the most critical area which the events studied suggest should be addressed. Vital aspects include:

— The need for leaders to understand the impact of their actions and behaviours on the workforce. Not only must they express clearly and consistently their standards and expectations, but they must align their own day-to-day actions to them. It is thus important that they make it their business to know what the real issues are in the workplace, by being visible, welcoming feedback and by not accepting compromise with respect to important safety issues. This may mean being prepared occasionally to demonstrate, for example, that safety takes priority over production, and certainly means not turning a blind eye to unacceptable behaviours, such as work-arounds or lack of professionalism.
— The need for leaders to be familiar with some of the events and their root causes discussed here (as well as others relevant to their industry). Open discussion among leadership teams about the factors leading to such events can form an important focus for action. In particular, they may want to ask whether the issues identified are relevant to their business and the extent to which they feel that they have them under control and to promote the same exercise within their management chain. A further useful process is to address some of the practical questions relating to culture which organizations such as the IAEA have identified [10, 12] for discussion at various levels in the organization.
— A difficult but important issue related to this latter point is the need for leaders to be able to recognize the importance of organizational issues — both from within the organization and those arising from outside — which can in some situations adversely impact on safety. It seems important to try to develop mechanisms by which these can be identified and addressed before they are enshrined in the future direction of the organization and are then very difficult to change.

5.2. Communication and learning

Most of the events discussed involved a significant breakdown in communication. Fundamental to this is, again, the role of leaders at all levels in the organization communicating directly to the workforce and being open to messages which are not always welcome. Several events have arisen from the growth of a ‘good news’ culture. However, there are two other vital subsets of the issue:

— The first involves addressing as a priority the way that safety information and learning is discussed and transferred, for example, between shifts, between engineering support and operators and in ensuring that those who are dealing with the risks are informed (in a way which is non-bureaucratic and fit-for-purpose) about relevant learning opportunities. It is taken as self-evident that in any competent company, formal systems will be in place to promote feedback from operational experience, but the key issue is whether this works in practice by meeting the needs of users — the right message to the right people at the right time.

— The second is the need to listen to what those 'at the sharp end' think and really do. It has been said that if you want to know how safe you really are, ask your people, and this seems like good advice. Well constructed surveys [18] or structured discussion and feedback from 'tool-box talks' can provide valuable insights and lead to the identification of priority areas for action.

5.3. Alertness and effects of change

Another fundamental issue which seems to arise from the above analysis is that most of the events crept up on organizations without them realizing the vulnerabilities which had developed. Of the eight factors discussed in Section 4, deterioration in competence, acceptable standards and their application, failure adequately to manage change and the need to maintain oversight are important components of this area for potential improvement.

— Organizational drift is frequently insidious. Thus, alertness to deterioration through a range of inputs is vital [19]. Performance indicators which go deeper than the 'headline' performance (e.g. the buildup of backlogs, the numbers and types of less serious incidents and near misses) are one component of this. There is also the need, however, to encourage internal and external peer review and audit, comparing practice not just with what is acceptable, but with best practice. Again, the work of WANO, INPO and the IAEA has been an important element in promoting this type of awareness and self-critical examination, and this approach involving best practice peer reviews may be useful in other industries.

— Both major changes and an accumulation of apparently minor changes can destabilize a previously safe organization. Not only do the risk factors and potential remedial actions need to be identified before changes are introduced, but some of the events discussed draw out wider impacts relating to what might broadly be referred to as motivation and morale. At a time when leaders and staff potentially are at their busiest in addressing all the organizational issues relating to change, the need for visible, committed leadership to ensure that messages and actions about safety are maintained is all the more necessary. It is at this point, for example, that incentives which seem to be necessary to drive the change (more trains on time or shuttle flights to schedule and budget) can lead to impacts on safety which were unforeseen and unintended.

6. RECOMMENDATIONS AND FURTHER POTENTIAL STEPS (FOR DISCUSSION)

(1) The underlying issue of safety culture is central to the understanding of many of the people related factors discussed in this paper. Historically, the IAEA has played a lead role in this subject and it is recommended that work on this subject should continue to be given high priority.

(2) However, other international organizations have played an important role in developing thinking and reinforcing the key messages. For example, INPO and WANO have played a vital role in raising the profile of cultural and organizational issues through programmes to assist in developing operational excellence. The OECD/NEA has also held workshops and provided a useful stimulus to thinking. Improved focus in addressing the issues discussed here would, we suggest, benefit from a stronger, integrated approach, drawing on the strengths of existing relationships with key stakeholders. The development of common frameworks and a common language in communicating the issues could helpfully underpin future efforts.

(3) Within such a framework, organizations such as the IAEA might consider how they can further reinforce key messages to top leaders in operating organizations, regulatory bodies and others with a vital role to play. This may require presenting issues in a form and context which makes each group realize the importance of their role, allows vulnerabilities to be critically and constructively reviewed and provides guidance on practical actions. A first step may be to provide a set of simple diagnostic questions which can focus thinking and raise the level of debate. An example of the type of questions are to be found in the annexes of the INSAG-4 and INSAG-15 reports (see Refs [15, 16]).

(4) This paper has provided one overview of the relevant issues. While they seem to correspond well with the views and learning emerging from various organizations such as WANO and INPO, we suggest that the specific common issues identified in this paper and (particularly) the proposed ways forward should be the subject of wider debate within the context of point (2). This could lead to joint discussion papers on each topic and opportunities to share and promote ideas and best practice in each identified key area.

(5) There are several aspects in this paper where specific further work might be considered:

— Provision of a set of tools for senior leader discussion and critical examination of the issues in their organization, including recognition of the impact of external and major organizational change and the way in which a good EH&S decision making climate is created.
— Development of a better understanding of whether regional cultural differences require different solutions to the key issues and how organizational subcultures, e.g. those driving towards improvements in overall business performance, quality and security, etc., can best work to reinforce and take account of the factors identified in the paper.
— Given the vital importance of remaining alert to organizational drift, it may be helpful to revisit the question of developing suitable indicators for identifying declining performance, drawing on both nuclear and wider industry experience. How organizational decision making can generally be helped to stay alert to the issues in this paper, particularly during periods of major change, could benefit from guidance. We note here, particularly, the need to ensure that minority views are respected and considered within the organization.
— Promoting a better and deeper understanding of the psychological factors and competence issues which weakened the defensive layers from top to bottom, in the case of many of the accidents examined, may provide an improved understanding as to how the risk of future events can be minimized.
— Any large organizational accident not only brings pain and suffering to individuals, but also produces a direct threat to the survival of an organization and in some cases (particularly nuclear), potentially to an industry. Good learning from experience currently enables plant operators to refine their operations or their equipment. Learning organizational root causes is just as important. Despite the difficulties of this type of learning, we believe that it is essential that such issues are also strongly pursued by an industry which has already made significant strides in safety.

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GLOBAL SAFETY ASSESSMENT AT ELECTRICITÉ DE FRANCE

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Abstract

To assess the management of safety, radiological protection and the environment of the units under its responsibility (nuclear power plants and national units), the management of the Nuclear Power Operations Division has created a Nuclear Inspectorate that is in charge of verification operations. These verifications are carried out as part of overall or specific safety assessments. The aim of this presentation is to demonstrate the originality of the process that has been established to carry out overall safety assessments, to identify the conditions of success, to show how this process has developed over time and how it forms a coherent part of the Division's piloting process. These assessments are based on the safety assessment reference systems validated by the management of the Nuclear Power Operations Division. These reference systems are implemented completely, which represents the assessment of over 400 performances on the basis of on-the-ground observations during operation and outage, discussions with operators from the full range of professions, and a thorough examination of related documentation. The assessment team consists of 14 professional inspectors and around nine peers from different nuclear power plants. The assessment covers eight different areas: safety management, operation and operation training centre, maintenance, technical support (operating experience, engineering, modifications, fuel and core physics), radiological protection, environment, fire protection and housekeeping. Each area is divided into topics, which are then subdivided into objectives. Each topic is assessed according to seven different levels, from 'excellent' down to 'unacceptable'. These subdivisions allow comparison between the various power plants and monitoring of each power plant from one assessment to the next. These assessments provide the managers of the Division and the power plants with elements that will help them to improve the level of safety in the form of recommendations, suggestions and best practices. In addition to the conformity assessment described above, the inspectors provide their view of the socio-organizational aspect of the site and, in particular, the strengths and weaknesses of the organizational structure, accompanied by an assessment of the risks that these weaknesses could develop into. Since early 2004, the management of the Nuclear Power Operations Division has approached WANO for four or five peers from

abroad to be integrated into the team of EDF inspectors to bring a more international and complementary outlook to the global safety assessments.

1. INTRODUCTION

Electricité de France (EDF) operates 58 PWR units (34 900 MW, 20 1300 MW and 4 1500 MW) located on 19 sites in different parts of France.

The general management includes the following levels:

— EDF Chairman;
— Production and Engineering Branch, managed by a Group Executive Vice-President;
— Nuclear Power Operations Division, managed by a Senior Vice-President;
— Station manager in each nuclear power plant.

The responsibility for nuclear safety is delegated by the Group Executive Vice President to each station manager. The Nuclear Power Operations Division is in charge of the general management of all the stations. The nuclear safety objectives are expressed in prescriptions. They constitute or explain the standards of safety requirements. The prescriptions include compliance of the plant (maintenance programme, for instance) and compliance of operations to expectations. The prescriptions are defined through specifications, operating instructions, internal rules, etc.

2. CONTROL BY THE CORPORATE NUCLEAR OPERATIONS DIVISION

The objectives of the control are to check if the prescriptions are well respected and if the problems are detected and corrected.

To practise control at its different stations, the Senior Vice-President uses mainly:

— Reporting from the station managers;
— External control of the plants by the EDF Nuclear Inspectorate Department.

The Senior Vice-President's expectations are the following:

— Checking that the management of safety is well done;
— Benchmarking different plants in order to help the weakest ones;

— Reinforcing the nuclear power plant's management team, when necessary;
— Defining orientations for enhancing nuclear safety.

The plants are regularly inspected by the French Safety Authority, by the IAEA through its Operational Safety Review Team (OSART), and by the World Association of Nuclear Operators (WANO) through peer reviews.

The objective of the following presentation is to explain the organization of a global safety assessment (GSA), which is the main tool used by the corporate NPP Division to practise external checking of the plants. This tool is operated by the Nuclear Inspectorate Department (NID), an organization directly linked to the Senior Vice-President.

3. ORGANIZATION OF A GLOBAL SAFETY ASSESSMENT

3.1. Objectives of a GSA

The objectives of a GSA are to:

— Have a clear and independent assessment of the results of the different plants;
— Compare the plant safety level in each area and also promote benchmarking between the different plants by an appropriate segmentation of the field covered by the assessment;
— Assess the safety level using a comparison between actual plant results and the reference guidelines decided by the Nuclear Power Operations Division;
— Make recommendations to the line management to improve safety levels;
— Assess if plant improvements have been implemented since the last assessment;
— Upgrade the corporate safety policy when necessary.

This allows:

— The progress of the plants to be assessed which have not yet reached the expected results;
— The responsibility of the nuclear operator to be assumed completely, serving the goal to look forward to excellence.

3.2. Interest for the plant of a GSA

The interest for the plant is to:

— Have answers for its particular expectations;
— Have further information about its own control;
— Have exchanges with peer staff of other plants who are members of the evaluation team.

3.3. Responsibility of NID and plant in a GSA

NID guarantees the quality of the assessment results by:

— A homogeneous, reproductive and simple method;
— The inspectors' professionalism acquired by experience and training. They are specialists in their areas and are knowledgeable in NID procedures and methodology for conducting nuclear safety assessments.

The plants have the responsibility to:

— Make easy the success of the assessment by a constructive approach;
— Validate the release, appropriate the analysis and take a position towards recommendations.

3.4. Areas covered by a GSA

The areas covered by a GSA are:

— Housekeeping (implemented on the first day of the assessment of the plant with the participation of the whole team);
— Operation and operation training centre;
— Maintenance;
— Technical support;
— Radiological protection;
— Fire protection;
— Environment;
— Safety management;
— Decommissioning when necessary.

3.5. Method

Each area of the GSA has a reference guideline:

— It expresses nuclear safety objectives (example for 'operation': supervision in the field completes efficiently the supervision in the

control room by operators) and expresses Nuclear Power Operations Division requirements as result-oriented performance criteria;
- It is common for all the plants;
- It is approved by the corporate Nuclear Power Operations Division management.

The safety objectives are grouped inside an area by topics (44) in order to allow benchmarking within the different French EDF nuclear power plants. During a GSA, 134 objectives are systematically assessed through 472 result-oriented performance criteria (standards). That means that a GSA is a complete implementation of all the result-oriented performance criteria. The method is mainly based on observing individuals in their activities (during operation and outage) and on the comparison of these observations to the standards.

3.5.1. Actors in a GSA

Professional inspectors with a background in different areas and peers from different plants are involved in a GSA. The assessment team is made up of around 23 people:

- A team leader who guarantees the quality and the results of the assessment; he manages the team. He is also in charge of safety management assessment.
- Fourteen inspectors from NID. One leader for each area is responsible for the assessment of the area.
- Nine peers from different nuclear power plants participate during one week of preparation and during the two on-site weeks; they bring their experience to the team, work in pairs with NID inspectors and acquire a useful practice of control.

All members of NID guarantee proper application of the method.

On-site, counterparts for each evaluation area are identified. They are the permanent contact for each of the area pilots during all the assessment steps. They particularly validate the observations. The site host is the team manager counterpart. He participates in all the on-site meetings in order to facilitate the evaluation of the conclusions. He has to respect deontology and confidentiality.

3.5.2. Different steps of the GSA process

Through the GSA process, NID cooperates with the station manager in order to make easy the understanding and evaluation of the results.

A preliminary meeting on-site is held around four months before the on-site assessment to present the assessment goals, to collect the expectations of the plant management, to impart knowledge of the context and to define the accurate agendas.

The preparation, during the four weeks prior to the on-site assessment, allows a direction to be given to the evaluation, as it is impossible to evaluate all the activities. The preparation objectives are to:

— Collect and analyse the plant information and data;
— Take into consideration the complementary expectations of the plant management;
— Establish a diagnosis about the strengths and weaknesses;
— Give the direction of the investigations.

This step ends with a work group including peers to allow proper evaluation of the preparation and of the evaluation tools.

The on-site assessment comprises two parts:

— One week during an outage for observations;
— Two non-consecutive weeks during operation, with the middle week in Paris to manage the investigations direction.

Every day a team meeting is held to exchange information. The afternoon of the last day is dedicated to a presentation to the plant staff of the main strengths and weaknesses identified for each area.

During the assessment period there is continuous contact with the plant management:

— The team leader regularly holds meetings with the plant manager to discuss the main deviations;
— The area pilots have regular meetings with their counterparts to validate the deviations, to exchange information, and if necessary to ask for a correction when there is an emergency situation.

The analysis takes about 20 days in Paris. A draft of the report is then sent to the plant for comments.

A first meeting is planned with the plant four weeks after the on-site assessment in order to:

— Present and explain the problems, the recommendations and the suggestions;
— Collect the comments of the plant.

A *second meeting* is planned with corporate Nuclear Power Plant Division top leaders about five weeks after the on-site assessment to present the main conclusions of the GSA and the level of performance.

All the reports and documents are:

— Subject to limited dissemination;
— The property of EDF Nuclear Power Plant Division top managers;
— Not documents for public communication.

3.5.3. Different steps of the method

(1) Collecting the facts at the nearest point of the results:

— The facts which are either deviations or positive points are analysed and sorted. They are all validated by the plant;
— This step ends after two weeks of on-site evaluation by a debriefing to the station management of the preliminary results and impressions.

(2) Analysis of the progress of each objective of the Reference Guidelines:

— Facts (deviation or positive point) are formulated for the different objectives (for instance, the field operator does not examine completely the installation during the round);
— Root causes and consequences of deviations are determined;
— NID performs a marking for each objective with four levels (reached, partially reached, very partially reached, not reached).

(3) Classifications of the facts:

— A synthesis is done to formulate strengths, problems and good practices;
— The consequences for safety define the importance of the problem;
— Suggestions and recommendations are proposed to treat the causes and to help the plant to improve its safety performance level.

(4) Benchmarking:

— A mark (from 1: excellent, to 7: not acceptable) is awarded to the different areas with a comment for each of them. This allows an intercomparison to be performed between all the plants and also a comparison of the performance between two assessments of the same plant.

3.5.4. Reports produced during the GSA

One detailed analysis report is produced for each area (housekeeping, operation and operation training centre, maintenance, technical support, radiological protection, fire protection, environment, safety management and decommissioning when necessary). One report collects the level of performance of the different areas, the comments, recommendations and suggestions. One report of the evaluation is addressed to the corporate Nuclear Power Plant Division top leaders. One specific report about socio-organizational aspects of the station is addressed to the station manager and to the corporate Nuclear Power Plant Division top leaders.

Each year, NID issues a report which presents the good practices and compares the performances of the different plants. This report is addressed to all plants and the results are also available on the NID web site.

3.6. Assessment frequency

The frequency of GSA is about three years for each plant, plus or minus one year according to the plant's safety level. If there is an international assessment, the time between two GSAs may be increased up to a maximum of five years.

The annual assessment programme requires international assessments of the EDF nuclear power plant fleet. For 19 plants (58 units) there are:

— Two peer reviews per year;
— One OSART per year.

4. MEASUREMENT OF THE EFFICIENCY OF A GSA

The measurement of the efficiency of a GSA is performed in different ways:

— By assessing plant progress between two assessments through some follow-up visits;
— By periodic enquiring to the satisfaction of the plant management and of the commendatory (Nuclear Power Plant Division top leaders).

We noticed that after a second assessment of the same plant, the evaluation of the safety requirements is generally improving in every area.

5. OPERATIONAL FEEDBACK

The conditions for the success of a GSA are:

— The reference guidelines updated every two years and an annual assessment programme approved by the Senior Vice-President;
— The involvement of line management;
— Skilled, competent and qualified teams;
— The GSA results integrated into plant business plan;
— A follow-up of action effectiveness.

The plants which carry out voluntary self-assessment using corporate reference guidelines improve their safety results.

Finally, benchmarking of plants carried out by the Senior Vice-President encourages plant managers to rise to excellence.

6. RECENT DEVELOPMENTS

(a) Social-organizational aspects

For a couple of years, NID has produced a report on the social–organizational aspects of the plant thanks to the observations collected from interviews or discussions with workers and from the team’s perception. It helps the plant managers to better understand the social regulations established in the organization and how the different groups and actors adjust their behaviours in order to achieve the collective goal, producing electricity safely.

(b) International vision

During 2004, three GSA were performed with the participation of a WANO team, including six foreign operators. The facts collected by EDF and

WANO inspectors are shared. NID and WANO perform their own independent analysis and produce independent reports. The first assessment performed clearly showed the value added produced by the two different and complementary methods.

7. CONCLUSION

A GSA is a profound and complete assessment which allows the Senior Vice-President to:

— Define orientations for enhancing nuclear safety;
— Benchmark different plants in order to help the weakest plants and to encourage plant managers to rise to excellence;
— Reinforce the plant management team when necessary.

MANAGING OPERATIONAL PERFORMANCE
The Canadian nuclear regulatory perspective

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Abstract

Despite significant advances in nuclear power plant safety, many issues relative to operational performance continue to present challenges. These challenges arise mainly in the areas of management of safety (involving both quality of management and management of quality), maintaining adequate safety levels in ageing plants, obtaining, maintaining and managing knowledge (hence, adequate staff training and information management), and dealing with a changing environment (e.g. organizational changes). The paper describes the perspective of the Canadian Nuclear Safety Commission (CNSC), the nuclear regulatory body in Canada, with respect to the complementary roles played by quality management, training, human factors and safety culture, in managing nuclear power plant (NPP) performance. The Canadian nuclear power industry has identified this broad area as an area of focus for improvement.

1. REGULATION OF THE NUCLEAR INDUSTRY IN CANADA

The Nuclear Safety and Control Act (NSCA) and its regulations came into force in 2000 and modernized the basis for regulation of the nuclear industry in Canada.

The NSCA sets out requirements for protection of health, safety, security and the environment, and the fulfilment of Canada's international obligations in activities in the nuclear industry. It establishes the Canadian Nuclear Safety Commission (CNSC) with the mandate to:

— Regulate the development, production and use of nuclear energy in Canada;
— Regulate the production, possession, use and transport of nuclear substances, and the production, possession and use of prescribed equipment and prescribed information;

- Implement measures respecting international control of the development, production, transport and use of nuclear energy and nuclear substances, including measures respecting the non-proliferation of nuclear weapons and nuclear explosive devices;
- Disseminate scientific, technical and regulatory information concerning the activities of the CNSC and the effects on the environment and on the health and safety of persons, of the development, production, possession, transport and use referred to above.

As such, the mandate of the CNSC is very comprehensive. It is responsible for the regulation of activities that range from the operation of nuclear power plants, to uranium mining, uranium fuel fabrication, nuclear substance processing and use, waste management, and export and import controls.

The approach taken by the CNSC to regulation is based on two fundamental principles. The first is that those persons and organizations that are subject to the NSCA and regulations are directly responsible for managing regulated activities in a manner that protects health, safety, security and the environment, while respecting international obligations. The second principle is that the CNSC is responsible to Canadians, through Parliament, for ensuring that those responsibilities are properly discharged.

2. THE CNSC'S MODUS OPERANDI

The CNSC fulfils its regulatory mandate through three main results-based functions: licensing, assurance of compliance with regulatory requirements, and the development of the regulatory framework. The framework uses risk based approaches to regulatory oversight and resource allocation in ensuring the protection of health, safety, security and the environment, and conformity with international obligations.

In the case of the nuclear power plants (NPPs), the licensing process covers the stages of siting, construction, commissioning, operation, decommissioning and abandonment. The CNSC grants power reactor operating licences based on assurance of safety in the following nine areas:

- Operating performance;
- Performance assurance;
- Design and analysis;
- Equipment fitness for service;
- Emergency preparedness;

— Environmental performance;
— Radiation protection;
— Security;
— Safeguards.

The CNSC compliance programme consists of three elements: promotion, verification and enforcement. Promotion refers to activities related to fostering compliance with the legal requirements, such as consultation, training and participation in seminars and conferences. Verification activities include inspections, audits, reviews of licensee submissions and event reviews aimed at determining and documenting licensees' performance against regulatory requirements. Enforcement encompasses activities required to compel a licensee into compliance, and to deter non-compliance with the legal requirements. It is applied using a graduated approach, where severity of the enforcement measure (e.g. written notices, increased regulatory scrutiny, orders, licensing actions and prosecution) depends on the safety significance and other factors related to the non-compliance.

On the basis of the risk associated with plant operation, the CNSC assesses licensee performance and determines the appropriate verification activities required in each of the nine safety areas. To evaluate licensee programmes and their implementation against regulatory requirements, the CNSC has instituted a five-category rating system. CNSC staff assigns these categories to assessment and inspection results, and uses them to summarize licensees' programmes and performance in the aforementioned safety areas.

In consultation with the public, the licensees and other stakeholders, CNSC staff has developed a regulatory document framework which reflects needs for response to the CNSC's mandate and, more specifically, for regulatory oversight in important safety areas and associated programmes. The regulations and other guidelines form the basis for the framework.

In discharging its statutory obligations, the CNSC's approach is consistent with IAEA Safety Standards Series No. GS-G-1.1 [1]. The guide stipulates that a regulatory body should develop a regulatory management system with the necessary arrangements for achieving and maintaining a high quality of performance in regulating the safety of nuclear facilities under its authority, and that the production of regulations and guides should be undertaken with full consultation both within and outside the regulatory body.

3. CONTROL OF RISKS TO PUBLIC HEALTH, SAFETY, SECURITY AND THE ENVIRONMENT

Risk can be considered as the chance of injury or loss, defined as a measure of the probability and severity of an adverse effect to health, property, the environment, or other things of value. Risk control, therefore, entails reducing the probability of an occurrence (that could have an adverse effect on health, safety or the environment), or mitigating its consequences, or both. Risk control includes:

— Identifying the risk, and identifying those managing and affected by it;
— Communicating the risk and assigning responsibilities and resources;
— Defining the scope of required decisions and risk scenarios;
— Estimating risk frequency and consequence;
— Estimating the extent of risk acceptance by affected parties;
— Estimating the costs and benefits of containing the risks;
— Assessing feasible risk control options and options for dealing with residual risk;
— Developing an implementation plan;
— Monitoring the effectiveness of the risk reduction programme [1].

Taking these elements into consideration, licensees would reduce the overall risk posed by NPP operation through operation within the licensing basis, and adequate management of human and organizational issues (e.g. safety culture, human factors, human performance, training, organizational structure of a facility, and safety/quality management systems applied to operation and maintenance).

The outcome of these activities should result in minimizing system, structure or component failures, improvements in human and organizational performance, and better operational safety.

4. MANAGING OPERATIONAL PERFORMANCE

4.1. Operational performance and performance assurance

Experience in operation over many years has shown that effective management of operational performance presents a continuing challenge for operational NPPs. There are numerous aspects that have to be considered, implemented and controlled to ensure that good safety performance is achieved in a nuclear facility.

The CNSC seeks through its regulatory activities to influence licensee management of operational safety performance so as to obtain timely identification, analysis and control of risks that arise in operation and to influence the minimization and mitigation of the impact of failures that do occur.

The focus on performance assurance includes oversight of the adequacy of safety culture, quality management systems, human factors and human performance programmes, including training programmes as important contributors to safe operation and maintenance at the facility.

4.2. Safety culture

Safety culture can be defined as the characteristics of the work environment, such as the values, rules and common understandings that influence employees' perceptions and attitudes about the importance that the organization places on safety.

Organizational effectiveness is an area of key focus for the CNSC in so far as it affects safety. Assessment of organization and management behaviours that influence safety performance is necessary to understand organizational effectiveness in terms of safety performance. However, these assessments pose some challenges. Behaviours are largely shaped within the context of the organizational and, more particularly, the safety culture that exists at the facility. Cultural assumptions and beliefs which influence behaviour and, therefore, safety performance, are not always clearly observable. However, understanding the basic assumptions that people bring to the organization is the key to understanding the culture operating within the organization.

The CNSC has developed a systematic approach, called the Organization and Management Review Method, to evaluate licensees' organizational influences on safety performance, by assessing the underlying values and attitudes that comprise the basic assumptions [2]. The assessment is based on the characteristics that have been identified to be important for the existence of a positive safety culture within a nuclear facility. Each characteristic has specific and measurable performance objectives that represent the visible signs and claimed values of the organization. The CNSC has employed this approach to conduct baseline measurements of licensees' safety performance. The method allows for the identification of potential areas of concern, which are further evaluated using compliance activities targeted to specific programmes (e.g. quality management, human factors, training, radiation protection). A recent initiative in this area was the development and implementation of a pilot project, which incorporated elements of this method into compliance inspection activities at one NPP. By applying the same measurement tools that are used to evaluate safety culture, the CNSC was able to compare its assessment of the facility to the results of a recent safety culture evaluation. The safety culture characteristics and associated performance objectives provided a useful framework for the consideration and integration of inspection findings across a number of diverse areas and provided a mechanism for discussion and exchange of information among CNSC staff members from different divisions.

In March 2004, the CNSC held a two day symposium on safety culture for the industry, to provide industry with the conceptual framework of safety culture as well as practical examples of its implementation in the field. This is an example of a CNSC compliance promotion activity. Following the symposium, the CNSC hosted a workshop in June 2004 for participants from industry to discuss approaches for licensee self-assessments of safety culture. Another workshop on this subject in November 2004 had the aim of reaching agreement on common strategies for safety culture self-assessments.

4.3. Quality management

The CNSC's expectation is that a strong safety culture will foster effective safety management and hence promote good safety performance. In general practice, safety management is an integral part of an organization's quality management system.

Quality management within the nuclear industry is intimately related to safety. For example, the objective of the IAEA Code on Quality Assurance for Safety in Nuclear Power Plants and other Nuclear Installations [3] is to establish basic requirements for quality assurance in order to enhance nuclear safety by continuously improving the methods employed to achieve quality. In Canada, the Canadian Standards Association (CSA) N-286 series of quality assurance standards have been developed to facilitate, support and ensure safety in all phases of a nuclear power plant life cycle [4].

By the end of 2001, the CNSC introduced licence conditions that specify requirements for quality assurance programmes at all of the operating NPPs. Since then, CNSC staff has been monitoring and ensuring compliance with this condition, to the extent that licensees have made significant progress towards compliance. In addition to being imposed by regulations and specific licence conditions, the quality management models have the advantage of being well developed, widely accepted among business organizations, and are well suited for application at NPPs. Furthermore, they are updated regularly to include the most recent knowledge and 'lessons learned' from the industry. The main tool used by CNSC to assess licensees' progress in the quality management area is the audit process, whereby findings are reported in a structured way that takes safety significance into consideration.

4.4. Human factors: Methods to prevent, detect and correct human errors

A CNSC policy (P-119, Policy on Human Factors) describes how human factors should be taken into account during NPP design and operation. For the CNSC, human factors are factors that influence human performance as it relates to the safety of a nuclear facility throughout its life cycle. Given the number of potential issues for consideration, the CNSC focused on those which would have the greatest impact on nuclear safety. Through a review of historical CNSC regulatory practices, benchmarking against other nuclear regulatory bodies and review of relevant human factors research, CNSC identified five review areas: human factors in design, work organization and job design, human performance in operating experience and root cause analysis, human reliability, and procedures and job aids.

Currently, CNSC is collecting performance data related to licensee human factors programmes through compliance activities and by monitoring performance indicators developed for some of the review areas. It is anticipated that increased regulatory oversight may be required in some areas (e.g. work organization and job design, event investigation and root cause analysis).

Areas of improvement related to human and organizational behaviours, which are identified in station operation and maintenance as a result of assessments (independent and self-assessments), analysis of events, performance indicators and adverse trends, are usually addressed by the licensees as part of their human performance programme.

4.5. Human performance

Industry information indicates that human performance is one of the most important factors in terms of minimizing the risk of plant operation. Analysis of significant event reports from NPPs indicates that human performance is a causal factor in the majority of the reported events, and that there are often multiple causal factors related to human performance.

In light of the importance of human performance, Canadian NPP licensees have recently developed human performance improvement programmes, designed to reduce the risk of human actions. The NPPs' human performance programmes are broader in scope, and more results oriented than previous efforts in this area. The purpose of these programmes is to promote, reward and improve those behaviours that support safe, efficient and reliable operation and maintenance of NPPs. While these programmes were developed on the basis of weaknesses identified in station performance, and best practices in the nuclear industry contain initiatives related to leadership, plant processes, individual behaviours and learning needs.

The CNSC assesses the adequacy of licensees' efforts to address human performance issues by conducting compliance verification activities, and monitoring how effectively the components of human performance programmes are being implemented. Following significant events, the CNSC conducts detailed analysis aimed at assessing root cause analyses done by the licensees, and monitor the adequacy and implementation of the licensee identified corrective action plans.

The CNSC and the licensees are developing performance indicators for each major programme element.

4.6. Training

In order to improve regulatory effectiveness in the area of training and qualification of NPP operation personnel, the CNSC has commenced a staged withdrawal from direct examination of reactor operators and shift supervisors. In due course, there will be reliance on the soundness of the licensee-set training programmes and certification examinations to gain assurance of candidate competence prior to initial certification [2]. The CNSC will continue to certify reactor operators and shift supervisors under the legal authority in the NSCA and the Class 1 Nuclear Facilities Regulations. The integrated regulatory oversight, required for certification, will be obtained from a combination of appropriate regulatory guidance, compliance activities and observations of licensees' personnel performance.

Another major project completed in the area of training and certification involves the establishment and implementation of a Requalification Testing Program for Certified Operating Personnel. Requirements for renewal of certification of personnel came into force with the implementation of the NSCA in 2000. Requalification testing programmes are now being developed and implemented by the licensees in accordance with requirements specified in a draft standard developed by the CNSC in consultation with the industry. The aim of the programme is to demonstrate, in a reasonable way, the continuing competence of certified staff, who include reactor operators and shift supervisors. The implementation of this programme and the subsequent compliance activities that will be conducted in this area will enhance the CNSC's capability for assessment of licensee performance in the training and certification examination programme areas.

5. SUMMARY

The CNSC has, in line with international standards and benchmarking, developed a comprehensive approach to its regulatory activities in the area of operational performance

The CNSC sees the fostering of a strong safety culture supported by sound quality management systems and human factors and performance management programmes as important contributors to operational safety at NPPs.

The management of operational performance remains an area of importance to safety. Risks that arise can be minimized through commitment to sound performance assurance programmes at nuclear facilities and by focused regulatory oversight.

ACKNOWLEDGEMENTS

Special thanks go to A. Nicic, Director, Human Performance Division, Directorate of Assessment and Analysis, and G. Ishack, Director General's Office, Directorate of Power Reactor Regulation, CNSC, for their contributions to this paper.

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UPGRADING THE SAFETY LEVEL OF NUCLEAR FACILITIES THROUGH THE EC ASSISTANCE PROGRAMMES

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Abstract

The European Union's TACIS and PHARE programmes were established in 1991. One priority for TACIS funding is nuclear safety. In nuclear safety, the countries mainly concerned are the Russian Federation, Ukraine, Armenia and Kazakhstan for the TACIS programme; and Bulgaria, Czech Republic, Hungary, Slovakia, Lithuania, Romania and Slovenia for the PHARE programme. The European Commission has made available a total of €944 million for TACIS and €242 million for PHARE nuclear safety programmes covering the period 1991–2003. The TACIS and PHARE nuclear safety programmes are devoted to the improvement of the safety of Soviet designed nuclear installations in providing technology and safety culture transfer. The paper gives an overview of the implementation of the TACIS nuclear safety programme and the planned projects. It also details the scientific and technical support that the Joint Research Centre of the European Commission is providing to the other services of the European Commission in charge of the programming and the implementation of the TACIS and PHARE Nuclear Safety programmes.

1. INTRODUCTION

The TACIS and PHARE nuclear safety programmes are mainly focused on reactor safety issues, contributing to the improvement in the safety of ageing reactors in the Commonwealth of Independent States and in Central and Eastern European countries and providing technology and safety culture transfer. For TACIS, the European Commission Directorate General, External Relations is responsible for the strategy and indicative programmes while the European Commission EuropeAid Co-operation Office (AIDCO) is in charge of identifying and implementing all assistance projects. For PHARE, Directorate General, Enlargement is responsible for the complete project cycle. In these programmes, the European Commission's Joint Research

Centre (JRC) is the technical and scientific adviser of the European Commission Directorates. Figure 1 shows for TACIS the work scheme of these European Commission General Directorates mentioned. The main areas of the TACIS nuclear safety concern On-Site Assistance for CIS Nuclear Power Plants (NPP), Design Safety, Regulatory Assistance, Industrial Waste Management and Nuclear Safeguards, and are dealt with in the annual action programmes, under the responsibility of the European Commission EuropeAid Co-operation Office. Since 2001, each TACIS action programme comprises projects for a global budget of more than 50 million annually. The TACIS Indicative Programme 2004–2006 for nuclear safety, which is under the responsibility of the European Commission Directorate General, External Relations sets out the priority fields of cooperation, in particular, enhancing the safety culture both at regulator and operator level, with design safety considerations, and addressing issues related to nuclear waste and spent fuel, including in the north-west of the Russian Federation.

2. ON-SITE ASSISTANCE

The TACIS on-site assistance to NPPs in Armenia, the Russian Federation, Ukraine and Kazakhstan aims to improve operational safety and includes the conditions of operation and surveillance of the installations, and equipment supplies. Since 1998, the programme focuses on a limited number of

FIG. 1. European Commission General Directorates involved in the TACIS nuclear safety programme.

large-scale projects named plant improvement projects (PIP). PIPs are based on a range of activities from the assessment of the safety relevance to procurement of modernization equipment (about 8–15 million), including licensing, installation and adaptation of operational procedures.

The NPPs concerned by the TACIS nuclear safety programme are in:

— Russian Federation: Balakovo, Beloyarsk, Bilibino, Kalinin, Kola, Leningrad, Novovoronezh, Smolensk;
— Ukraine: Kmelnitsky, Rovno, South Ukraine, Zaporozhie;
— Armenia: Medzamor;
— Kazakhstan: Aktau.

In 2003, nine projects for the Russian Federation were implemented. They concern the assistance to the nuclear power plants of Balakovo, Beloyarsk, Bilibino, Kalinin and Novovoronezh, in particular the large-scale PIPs for the modernization of the reactor control systems for Balakovo and Novovoronezh. In 2004, eight projects are planned to be implemented concerning the nuclear power plants of Balakovo, Bilibino, Kalinin, Kola, Leningrad, Novovoronezh and Smolensk and, in particular, the large-scale PIP for Kalinin dealing with the upgrading of the reactor control system.

The technical expertise of the JRC for on-site assistance to the 14 TACIS nuclear power plants in the Russian Federation, Ukraine, Armenia and Kazakhstan comprises:

— Participation of the JRC experts in all procurement processes for equipment important to safety;
— Expert visits to nuclear power plants to assess and facilitate the implementation of TACIS projects.

Since July 1999, the JRC has carried out technical specifications for about 120 equipment supply projects.

Assessment missions carried out by AIDCO and the JRC are regularly taking place at all TACIS NPP sites, including Chernobyl.

JRC also is participating in the evaluation of tenders for equipment supply projects: 32 evaluations were carried out in 2003. At present, AIDCO and the JRC are embarking on the evaluation of the tenders for large modernization projects. The PIPs for Balakovo, Novovoronezh and Medzamor have already been evaluated and contracted in 2003, and are presently being implemented.

3. DESIGN SAFETY

Supporting design safety activities in the Russian Federation and Ukraine is considered important, notably in relation to the review of the safety and modernization of second and third generation reactors. Specific actions for the TACIS programme include the establishment of detailed safety reports, the validation of computer codes and the plant lifetime management for second generation Russian design reactors, in particular, the ageing aspects affecting nuclear safety.

In 2003, four projects have been contracted by AIDCO. They concern the assistance to diagnostic system use and to maintenance operation for VVER primary loop, the software development and validation for accident analysis for WWER and RBMK reactors in the Russian Federation, and the support for certification of nuclear equipment. In 2004, one project is planned to be implemented concerning the equipment supply according to up to date requirements for the off-site emergency centres of Novovoronezh and Kursk NPPs.

The technical assistance provided by the JRC for AIDCO in TACIS Design Safety includes all aspects of the project life cycle, namely:

— Participation in the programming;
— Drafting or checking project description sheets and terms of reference;
— Participation in evaluation committees;
— Technical follow-up of projects;
— Review and assessment of final reports of projects.

One of the areas of concern in design safety is the structural integrity assessment of the NPP components of the primary circuit, where the JRC is deeply involved through the studies on in-service inspection (ISI) and neutron embrittlement of the reactor pressure vessels (RPV).

3.1. RPV integrity reassessment

Two TACIS regional projects have commenced, which shall be considered twin projects, in the frame of the most recent programme launched by the European Commission on this particularly sensitive safety issue. They will be implemented simultaneously in the Russian Federation and Ukraine and have to be developed in very close cooperation, since the results of the second project shall be integrated in the final assessment done in the frame of the first project.

The first project has the aim to generate the conditions for an extensive understanding of the situation regarding the RPV integrity assessment, with a particular concern about materials embrittlement aspects. This project includes the validation of the global programme on the basis of a consistent state of the art evaluation of current knowledge, including a comprehensive identification of the most critical and urgent remaining open safety issues. This task has been carried out within an international expert group (Senior Advisory Group), specifically set up for the purpose. Furthermore, this project defines the conditions for improving the results of the VVER 1000 and 440/213 RPV surveillance programmes, the corresponding experimental programme being implemented in the twin project and made available later. The evaluation of these results and their consistency with others shall be performed with the aim to conclude on specific aspects, such as validation or re-assessment of the neutron embrittlement prediction laws, the 'quality' of the surveillance programmes, further assessment of spectrum and flux effects on neutron embrittlement, and the direct measurement of fracture toughness in comparison with the application of the codified Charpy V/Ic K correlation. This project also includes the preparation of the technical syntheses needed for performing End of Life RPV integrity assessments, aiming to assess, at least, the most sensitive cases among all. The JRC is the main contractor for this project. A Russian consortium involving the RRC Kurchatov Institute, CRISM Prometey and EDO Gidropress, as well as a Ukrainian one involving the Institutes for Problems of 4/7 Strength and Nuclear Research of the National Academy of Science are involved as local subcontractors.

The second project shall be seen as an experimental 'support project'. It includes the performance of in-depth analyses, as well as complementary investigations and tests, which are being considered as necessary for upgrading the available surveillance results. A significant number of reconstituted standard and pre-cracked Charpy V surveillance specimens will be prepared according to the needs defined in the first project. The impact tests and the fracture toughness measurements, according to the 'Master curve' approach are also being performed in that frame. Specific consideration is given for the implementation of the specimen reconstitution technique in Ukraine and the qualification of Ukrainian specialists for the corresponding techniques. Further tests for underpinning advanced methods for the evaluation of the fracture toughness are also proposed. They are partly dedicated to further validation of the 'local approach', but they also provide for the complementary assessment of the shape of the temperature dependent fracture toughness curve. No additional reference irradiation is proposed at that stage of programming, since it has been considered more efficient to rely on upgraded surveillance results. The detailed programme will not be in force until the Senior Advisory Group will have agreed. The results of this project will later be included in the final stage of the first project. A tender is foreseen for that project, which is intended to identify the most appropriate industrial Western main contractor.

Conclusions on the evidence of acceptable safety margins and the expected remaining reactor lifetime shall be given to the operators. Past experience on the implementation of mitigating measures (thermal annealing of the RPV core zone, heating of the emergency core cooling system water storage tank) shall be taken into account for identifying the relevant mitigation measures to be evaluated. The possible benefit which could be expected from implementation of optimized in-service inspection programmes and/or the impact of further R&D results, should be carefully identified. Recommendations for immediate or later implementation of mitigation measures will be given to the utilities. WWER 1000 RPVs, with particular insights on those having a high nickel content for the core weld, and some sensitive WWER 440/213 RPVs are of most concern.

3.2. 'Leak before break' project

The JRC is ensuring for AIDCO the technical follow-up of TACIS projects. As an example, for the project 'leak before break' (LBB) applicability review and basic implementation for WWER-1000/320, the JRC has evaluated the experimental testing programme performed by the Russian institutes ZNIITMASH, ZKTI and Izorsky factories. LBB calculations performed by the consortium (Ansaldo, Empresarios Agrupados and EDO Gidropress) were also assessed, as well as the in-service inspection programme and leak detection system at Balakovo NPP Unit 2.

In this LBB project, plant-specific data on material properties and manufacturing procedures of the main coolant piping and surge line were collected and 'as-built' layout drawings for the selected reference Balakovo NPP Unit 2 was elaborated. Using these data as input, the first LBB assessment was carried out by the local subcontractor following current Russian guidelines. Then a second LBB assessment was carried out using both Russian and Western fracture mechanics approaches. A materials testing programme was formulated and implemented in order to elaborate more specific material parameters for advanced fracture mechanical LBB studies. Finally, a third LBB assessment was performed by using upgraded material data collection, as well as the more advanced material parameters (fracture toughness) obtained in the completed materials testing programme. Simultaneously, a review and evaluation of the existing leak detection system and in-service inspection systems was carried out at Balakovo NPP Unit 2 and recommendations were made for upgrading the systems accordingly.

It was shown that LBB criteria could be met at Balakovo Unit 2, providing that an adequate leak detection system was installed and the periodic in-service inspection will be upgraded. The LDS should be able to detect and localize a leak of 1.9 l/min in the surge line and 3.8 l/min in the main coolant piping within one hour after occurrence. The leak detection system should be based on, at least, three detection methods based on different principles (acoustic, humidity and radiation). An acceptable leak detection system system has already been planned and created for new WWER 1000 plants under construction, but it needs to be qualified and benchmarked before approval and implementation. Furthermore, the periodic in-service inspection programme must be completed by an automatic inspection method in addition to the manual method presently used. For the surge line, the scope of inspection must also be increased to cover 100% of the piping welds instead of presently 5/7 50%. As a main result and deliverable of this project, the following reference methodology report was elaborated: Description of the Reference Methodology for the LBB Assessment of Main Coolant Piping, Summary of Application to Balakovo NPP Unit 2 and Recommendations for Implementation at Other WWER 1000 NPPs. This report could serve as a handbook for conducting LBB assessments at all WWER 1000 as well as other PWR plants.

3.3. RPV surveillance programme

The JRC is assessing for AIDCO the final technical reports of TACIS projects. In particular, the projects concerning R2.06/96, Surveillance Program for VVER 1000, were assessed. This project was successful, solving some of the main identified problems and shortcomings of the VVER 1000 RPV surveillance programme, as well as identifying important issues which still need to be addressed. As a main result of the project, the irradiation conditions (temperature and neutron flux) of the surveillance capsules could be confirmed. The irradiation temperature of the test specimen is quite close to the temperature of the down-comer water despite its location above the core. Furthermore, the reconstruction technology for broken impact specimens was successfully implemented and adopted in the RRC Kurchatov Institute in Moscow, giving the possibility to remarkably improve the quality of the surveillance test results in all Russian NPPs if needed. The reconstitution technique was adopted in VTT, already 15 years ago, for improving the quality of Finnish surveillance test results with great success.

3.4. Dissemination of TACIS project results

The TACIS and PHARE dissemination projects have the aim of amplifying the effects of the results of safety related projects by wide information dissemination to TACIS and PHARE beneficiaries, and to the Commonwealth of Independent States, Central and Eastern European countries, and European Union organizations.

During these projects, the following tasks have been performed and are being performed by the JRC:

— Drafting and editing the project result summary for about 500 TACIS and PHARE projects.
— Drafting and editing the executive summary reports of about 50 chosen design safety projects, as well as the corresponding workshop papers. The issues concerned wide ranging projects dealing with RPV embrittlement and integrity, application of the LBB concept, accident analysis, simulator training, in-service inspections, maintenance and quality assurance.
— Setting up a web site at JRC/IE (http://sic-www.jrc.nl/tp/nrtp). This site presently includes a TACIS and PHARE welcome page, the TACIS project result summaries and executive reports summaries, press releases and workshop papers for 15 design safety projects (in English and Russian).
— Organizing seminars in Moscow and in Brussels. About 130 specialists mainly from Russian NPPs, design institutes, regulatory authorities and TACIS contractors participated in the first Dissemination Seminar in Moscow in June 2002.

The current dissemination project for the Russian Federation has the objectives of complementing the database of project result summaries and executive summary reports, and to organize a second Dissemination Seminar in Moscow in October 2005. A similar project started early 2004 for the PHARE programme. A PHARE Dissemination Seminar will be held in Brussels in autumn 2005.

A similar dissemination project is being prepared for the Ukrainian TACIS nuclear safety projects, and should be launched by the end of 2004.

4. REGULATORY ASSISTANCE

TACIS regulatory assistance to regulators and their technical safety organizations has the objective of transferring regulatory methodology, including the formulation of legislation and regulatory documents. It provides support in conducting licensing assessments for specific PIPs under the '2+2 approach': European Union and TACIS regulators + European Union and TACIS utilities. Assistance is also provided for the overall safety assessment of specific installations.

In 2003, four projects for the Russian Federation have started, concerning mainly the support of the Russian regulator in the licensing process of PIPs for Balakovo, Kola, Leningrad, Novovoronezh, Smolensk NPPs. In June and July 2004, three projects are planned to be implemented to provide Beloyarsk and Kalinin NPPs with the same support type.

The technical assistance provided by the Joint Research Centre in regulatory assistance for TACIS concerns the implementation and execution of specific projects, by checking the projection description sheets and terms of reference, making the technical follow-up and assessing project results.

5. INDUSTRIAL WASTE MANAGEMENT

The TACIS nuclear safety programme has two main areas of concern for industrial waste management: the storage of spent nuclear fuel and radioactive waste in the north-west of the Russian Federation and the waste management situation at Chernobyl NPP.

The TACIS programme is supporting:

- Projects related to the management of spent nuclear fuel and radioactive waste from the nuclear submarines of the Northern Fleet, such as Lepse defuelling and Gremikha feasibility;
- The installation of new and additional radioactive waste facilities, in order that safety of waste storage and of treatment installations is ensured.

In Kazakhstan, the TACIS programme has been providing on-site assistance to the Aktau fast breeder reactor since 1995. The Aktau decommissioning plan has been submitted to the IAEA for peer review, in which AIDCO and the JRC are contributing.

In 2003, five projects for the Russian Federation have been implemented, concerning mainly safeguards projects. A particular project dealing with the remediation concept for uranium mines in Lermontov has also started. In 2004, 11 projects are planned to be implemented, concerning safeguards, radioactive waste in the Moscow region and in the north-west of the Russian Federation.

The technical assistance provided by the JRC in industrial waste management for TACIS concerns the main aspects of the project life cycle:

checking and drafting projection description sheets and terms of reference, and ensuring the technical follow-up and assessment of projects. In particular, the JRC participated in 2001 in the evaluation of tenders for the Chernobyl Industrial Complex for Radioactive Waste Management, and more recently in the evaluation of the Lermontov project.

6. SENUF: THE JRC NETWORK ON MAINTENANCE ISSUES

While providing scientific and technical support to the TACIS nuclear safety programme, a large amount of knowledge related to Russian design reactor systems has accumulated and led to the creation of a horizontal and integrated project concerning nuclear safety in Central and Eastern Europe. The project is called Safety of Eastern European Type Nuclear Facilities (SENUF) and has linked to the JRC Institute for Energy's existing nuclear safety related SAFELIFE action.

The SENUF objectives are to facilitate:

- The harmonization of safety cultures between the candidate countries, the new European Union member States and the rest of the European Union;
- The understanding of needs to improve the nuclear safety in candidate countries and the new European Union member States;
- The dissemination of the JRC Institute for Energy nuclear safety institutional activities to candidate countries and new member States.

SENUF contributes to bringing together all stakeholders of Russian designed NPPs: the beneficiaries, end users, Eastern and Western nuclear industries, and thus, to favour fruitful technical exchanges and feedback of experience.

At present, the main focus of SENUF is the maintenance of NPPs as a substantial element of plant operational safety. A specific Working Group has been established on NPP maintenance and to date, nine institutions (mainly utilities or NPPs) from Western as well as Central and Eastern Europe have agreed to collaborate with the JRC. Major tasks in 2004 focus on the following topics:

- Analysis of the existing maintenance concepts and practices, as well as optimization strategies, e.g. condition based, reliability centred, risk informed maintenance and, based on this, preparation of a status report on advanced strategies to optimize plant maintenance;

— Setting up and operating a database on advanced and specific equipment, tools, materials and processes to provide maintenance managers and engineers with adequate information in order to help them select the most appropriate and cost efficient solution.

7. CONCLUSIONS

The TACIS and PHARE nuclear safety programmes implemented by the European Commission EuropeAid Cooperation Office and DG Enlargement allow to contribute to the safety improvement of operating Soviet designed NPPs. The JRC technically and scientifically supports this programme by assisting the other concerned European Commission General Directorates during all phases from project preparation until completion.

The JRC network, dealing with the safety of Eastern European nuclear facilities, established in 2003 its Steering Committee made up of nine organizations, seven of which are from the Commonwealth of Independent States and the Central and Eastern European countries, and defined its work programme focused on maintenance issues. The JRC has also launched a new TACIS project that aims to provide the Russian and Ukrainian nuclear power operators with conclusions on demonstrated safety margins and the remaining expected lifetime of RPVs.

All summaries of project results of TACIS and PHARE nuclear safety projects are being made available through a web site operated by the EC-JRC.

ACKNOWLEDGEMENTS

We would like to acknowledge all contributors to the results described, colleagues from the European Commission who were involved in the management and the technical and scientific support of the TACIS nuclear safety programme, as well as all contributors having been active within the teams working for the various projects. Without their contributions the reported results could not have been achieved at all.

OPERATING EXPERIENCE
*OECD/NEA activities and results**

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1. CONTENTS

— Why international exchange of operating experience is needed;
— What international tools are available;
— What activities is the OECD/NEA performing on this topic;
— What have the successes been;
— Where are improvements still needed;
— Concluding remarks.

2. WHY INTERNATIONAL OPERATING EXPERIENCE IS NEEDED

— Three Mile Island (TMI) lesson — share experience in order to learn;
— Few NPP designs, 'standard' problems recur;
— Nuclear strive for excellence, few events at national level;
— National level may be insufficient to grasp the importance of the problems experienced;
— International data collection efforts from plant level events (e.g. IRS) to component data (e.g. ICDE project) have proved to be useful;
— Sharing operating experience internationally has been a success story.

3. TOOLS TO EXCHANGE INTERNATIONAL OPERATING EXPERIENCE

— IRS (technical tool):

*The following outline is drawn from the original slide based presentation.

  - Incident Report System (restricted);
  - Deep analysis of events, including lessons learned;
  - Guidelines approved by IRS National Coordinators;
  - Jointly run by the IAEA and the OECD/NEA Secretariat.
- — FINAS (technical tool):
  - Fuel Incident Notification and Analysis System (restricted);
  - Jointly run by the IAEA and the OECD/NEA Secretariat.
- — INES (communication tool):
  - International Nuclear Event Scale;
  - Severity scale ranging from 0 to 7 (Chernobyl);
  - INES rating should be given normally within 48 hours after an incident.
- — NEWS (communication tool)
  - IAEA, OECD/NEA (CNRA) (Fig. 1), WANO;
  - Nuclear Event Web-Based System;
  - Intention to exchange rapidly information between experts and to communicate with public (media).

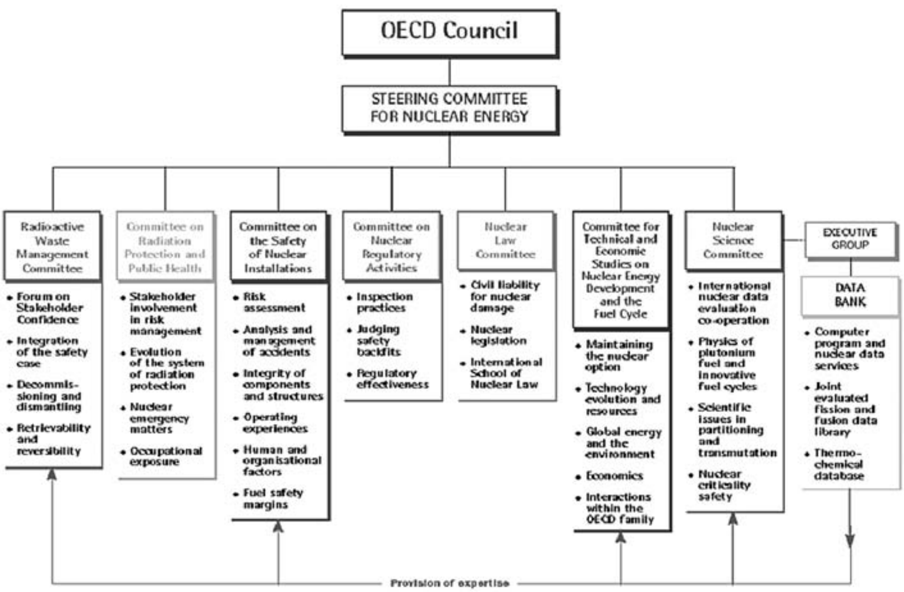

FIG. 1. The OECD Council and associated Committees.

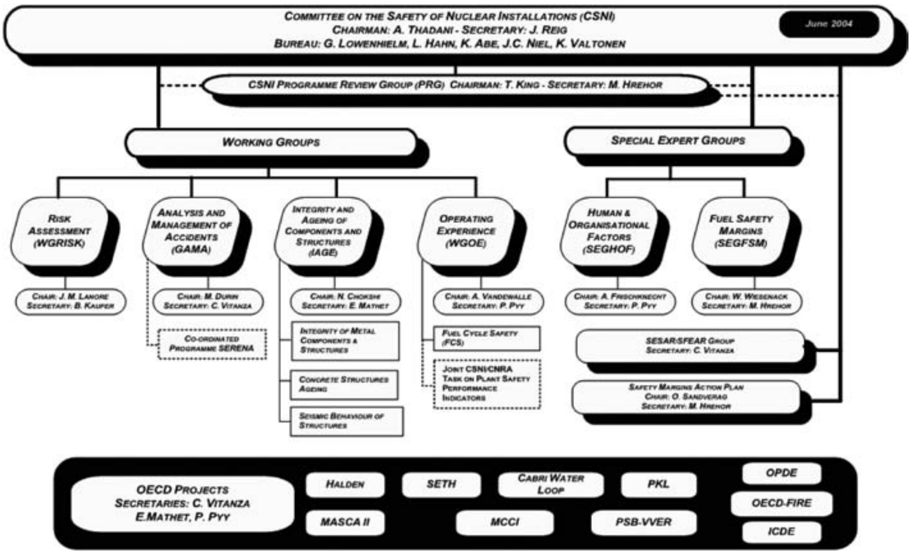

FIG. 2. The OECD/CSNI and associated bodies.

4. CSNI WORKING GROUP ON OPERATING EXPERIENCE (WGOE)

— The main mission is to analyse and develop insights from operating experience, including fuel cycle safety, and give recommendations to CSNI and CNRA. This includes the feedback of lessons learned from operating experience databases such as IRS, FINAS, etc., and the conduct of special studies, workshops and generic assessments in areas of high safety and regulatory significance.

— Some recently issued reports:
  - CSNI Technical Opinion Paper: Recurring Events;
  - Technical Notes: Conclusions Drawn from Recent Events in NPPs;
  - Nuclear Power Plant Operating Experiences from the IAEA and OECD/NEA Incident Reporting System 1999–2002 (IRS Blue Book No. 2).

— Recent workshops:
  - Workshop on Debris Impact on Emergency Coolant Recirculation, Albuquerque, NM, 25–27 February 2004;
  - CSNI/CNRA Workshop on Regulatory Uses of Safety Performance Indicators, Granada, Spain, 12–14 May 2004.

5. OTHER CSNI WORKING GROUPS: WGRISK AND SEGHOF

Risk Assessment (WGRISK): The main mission is to advance the understanding and use of probabilistic safety assessment (PSA) to ensure continued safety of nuclear installations and improve the effectiveness of regulatory practices in member countries.

Recently issued reports:

— CSNI Technical Opinion Paper #4, Human Reliability Analysis in PSA for NPPs.

Human and Organisational Factors (SEGHOF): The main mission is to improve the current understanding and use of methodologies for human and organizational factor assessment, in order to maintain and improve the safety of nuclear installations.

Recently issued reports:

— Proceedings of the Workshop on Scientific Approaches to Safety Management;
— CSNI Technical Opinion Paper No. 5, Managing and Regulating Organizational Change.

6. OECD/NEA INTERNATIONAL PROJECTS AS A MEANS TO EXCHANGE INTERNATIONAL OPERATING EXPERIENCE

Complementary databases to the IRS:

— International Common Cause Data Exchange (ICDE), 11 members;
— OECD Piping Failure Data Exchange (OPDE), 12 members;
— OECD Fire Incident Records Exchange (OECD-FIRE), 8 members;
— Data Exchange about Events in Computer-based (I&C) Systems (COMPSIS), to begin in 2005.

Information is proprietary but lessons drawn are shared.

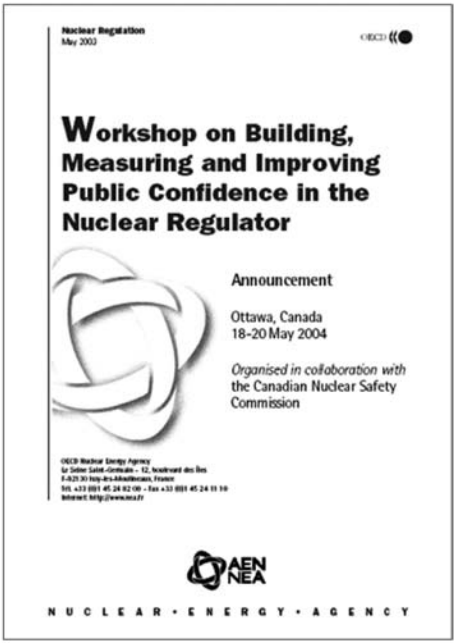

FIG. 3. OECD/NEA initiatives in public communication.

— CNRA Working Group on Public Communication (Fig. 3). Several events assessed from the point of view of public communication (Paks, TEPCO, Power outage North America, heatwave Europe);
— CNRA Working Group on Inspection Practices. Workshop on Regulatory Inspection Activities related to Inspection of Events & Incidents, Inspection of Internal & External Hazards, and Inspection Activities Related to Challenges Arising from Competition in the Electricity Market (2003).

7. INTERNATIONAL OPERATING EXPERIENCE EXCHANGE — SUCCESSES

— Good cooperation between IAEA and OECD/NEA;
— Large event database;
— Network of experts;
— Quality of reports;
— New web based IRS;
— Topical studies;
— Specific databases.

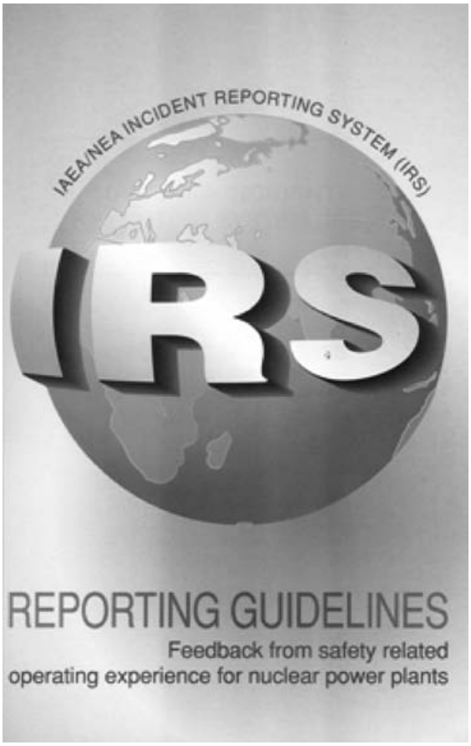

FIG. 4. Operating experience feedback.

8. INTERNATIONAL OPERATING EXPERIENCE EXCHANGE — IMPROVEMENTS NEEDED

— Use each OE tool for the intended purpose and target audience (Fig. 4);
— Low incident reporting rate;
— Recurring events in erosion corrosion of piping, electrical disturbances and foreign material intrusion into the primary system;
— Closing the feedback loop: More attention to assessment;
— Special focus on safety management issues.

9. INTERNATIONAL OPERATING EXPERIENCE EXCHANGE: CONCLUDING REMARKS

— Recurring events underline the need to continue improving the process of learning from experience;
— The OECD/NEA, through the safety committees, is reviewing its expectations and working methods in the field of operating experience. An action plan to focus more on the assessment is being prepared.
— The OECD/NEA continues enhancing cooperation with the IAEA:

- Jointly sponsored workshop on safety management and the effectiveness of inspections, Tokyo, January 2005;
- Jointly sponsored conference in 2006 to identify improvements needed on the feedback from operating experience.

— The OECD/NEA, through the CNRA, is assessing the communication aspects of operating experience.

INTERNATIONAL NUCLEAR SAFETY GROUP ACTIVITIES IN OPERATIONAL EXPERIENCE FEEDBACK*

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1. WHAT IS THE INTERNATIONAL SAFETY GROUP (INSAG)?

— Established in 1985 by the Director General of the IAEA;
— Five previous terms;
— Response to challenges:
  • Chernobyl, Tokai Mura, Davis Besse, Paks;
— Results in INSAG Series:
  • 18 documents;
  • 4 notes.

2. HISTORICAL FOCUS

— Safety culture;
— Safety principles;
— Specific topics:
  • Radiation protection;
  • Radioactive waste;
  • PSA;
  • Old design concerns;
  • Management of change.

3. NEW INSAG

— Authoritative advice and guidance on nuclear safety approaches, policies and principles;
— Identify important current and emerging issues;

*The following outline is drawn from the original slide based presentation.

— Forum for information exchange on generic safety issues;
— Recommend principles for safety standards and measures;
— Address generic safety issues of international importance for the Director General of the IAEA.

4. TOPICS FOR INSAG ACTIONS

— Periodic report on issues and trends in nuclear safety;
— Enhancing the nuclear safety regime;
— Safety principles;
— Operational safety;
— Stakeholder involvement.

5. OPERATIONAL SAFETY TOPICS

— Operational experience feedback and sharing;
— Safety performance evaluation;
— Competitiveness versus safety;
— Ageing and lifetime management;
— Risk informed operation;
— Safety culture.

6. OPERATIONAL EXPERIENCE FEEDBACK (OEF) AND SHARING

— Objectives;
— Features;
— Coordination:
  • National;
  • International;
— Regulator’s role;
— Operator’s role;
— Supporting organization’s role;
— Assessment and evaluation.

6.1. Safety objectives

— Improve performance;
— Share experience and learn from others;

— Recognize generic deficiencies;
— Find and correct root cause;
— Avoid recurrent events;
— Improve safety culture through learning and knowledge management.

6.2. Universal features of OEF 1

— All events should be recognized, categorized, analysed;
— Dig to find the root causes;
— Aware of common cause failures, generic failures, recurrent events;
— Share with partners;
— Look for human factors.

6.3. Universal features of OEF 2

— Reporting and questioning attitude and atmosphere;
— Always ask why;
— Information management:
  • Recording;
  • Retrievable storage;
  • Reporting.
— Lessons learned:
  • Installation specific;
  • General.

6.4. International coordination

— IAEA–OECD/NEA Incident Reporting System;
— WANO/owner's groups;
— Vendor networks;
— Nuclear regulators networks.

Coordination should be organized, integrated and improved! User friendly databases for easy learning.

6.5. Regulator's role

— Policy on requirements and involvement;
— Event notification system;
— Important factor in performance assessment and evaluation;
— Require and inspect the OEF system.

— Disseminate international information;
— Update regulations with lessons learned.

6.6. Operating organization

— Well defined and understood corporate policy;
— Encouraging open and self-critical reporting of any irregularities;
— Roles and responsibilities well defined;
— Upstream and downstream equally important;
— Resources allocated;
— Self-assessment of the effectiveness of OEF.

6.7. Supporting organizations (contractors, TSOs, suppliers)

— Communication lines established;
— Scope and way of information exchange clearly defined;
— Joint commitment in operating experience feedback;
— Advice and support;
— Monitoring the effectiveness.

6.8. Assessments

— Self-assessment;
— Process indicators;
— Performance indicators;
— Regulatory assessment;
— Peer review.

7. CONCLUSIONS

— ‘My event is your event’ (Mihama event as nuclear accident in the media);
— Guidance for uniform practice in all levels;
— Ideal field of cooperation;
— Harmonization of international cooperation;
— An INSAG document is planned, contributions are warmly welcome.

THE EUROPEAN PRESSURIZED WATER REACTOR
An advanced evolutionary design

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On 18 December 2004, Teollisuuden Voima Oy (TVO) and the consortium led by Framatome ANP signed the contract for the turnkey supply of a nuclear power plant equipped with a European Pressurized Water Reactor (EPR) nuclear island. The manufacturing of the main primary components was immediately started. The first concrete pouring is planned early 2005 on the Olkiluoto site.

Following the positive conclusion of the political debate in France with regard to nuclear energy, it is anticipated that EDF will also decide to build an EPR unit. These two independent decisions make the EPR the first generation 3+ design under construction. However, no major risk due to the transition from the previous designs is anticipated for the customer, thanks to the evolutionary nature of the improvements on which the EPR technology is based.

At the origin of this project was the common decision in 1989 of Framatome and Siemens to cooperate in the design of the nuclear island to meet the future needs of utilities. EDF and a group of the main German utilities joined this cooperation in 1991 and from that point have been completely involved in the progress of the work. The compliance of the EPR to the European Utility Requirements was verified to ensure acceptability of the design by other participating utilities. In addition, the entire process was backed up to the end of 1998 by the French and the German safety authorities which have a long lasting cooperation to define common requirements applicable to future nuclear power plants. Upon the signature of the Olkiluoto 3 contract, STUK, the Finnish safety and radiation authority, began reviewing the design of the EPR.

Taking into account the feedback from the experience of the utilities participating in the project, ambitious objectives were defined to meet the global requirements of the operators. In line with the will to achieve the minimum possible production cost, the choice of the promoters of the EPR has been to select the power level in the highest possible range. This decision plays a major role in the global competitiveness of the unit, in addition to other specific design features going in the same direction.

Important safety functions are ensured by separate systems in a straightforward operating mode.

Redundant trains of all safety systems are installed in four separate layout divisions for which a strict separation is ensured so that common mode failure, for example, due to internal hazards, can be ruled out. A reduction in common mode failure potential is also obtained by design rules, ensuring the systematic application of functional diversity.

A four train redundancy for the major safety systems provides flexibility in adapting the design to maintenance requirements, thus contributing to reduce the outage duration.

Additional features are implemented to satisfy the following safety objectives adopted by the French and German safety authorities:

— Achieve a significantly lower core melt probability by appropriate prevention means;
— Achieve the ‘preclusion’ of accidents liable to cause early containment failure, such as core melt under high pressure conditions;
— Achieve a major reduction in radioactive releases which could result from low pressure core melt accidents.

The EPR is characterized by a robust containment not only with respect to hypothetical loads resulting from a core melt accident but also from external hazards resulting from extreme situations, such as an aeroplane crash directly on the nuclear island buildings.

The EPR is an advanced reactor with outstanding performance qualities in terms of competitiveness, outage duration, operator dose and safety. Thanks to its evolutionary nature, it brings peace of mind to the investors and reliability to the operators who will benefit from a unique experience feedback.

SIZEWELL B MAINTENANCE AND REFUELLING PROJECT
A case study in globalization issues

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Abstract

In 2000, British Energy (BE), owner of the Sizewell B PWR in eastern England, went out for tender in accordance with European Union rules for the contracted portion of the maintenance and refuelling work performed at the plant. In early 2001, BE announced that they had selected a new consortium (FMA) consisting of two companies from the United Kingdom: Alstec and Mitsui Babcock; and a French multinational company, Framatome ANP. An unexpected forced shutdown in May 2001 revealed some of the globalization issues that the new consortium and BE would face during the lifetime of the contract. In the first refuelling outage under the contract, RFO 5, further issues were identified. The way the issues were identified and the way they were addressed by FMA and BE are reviewed in order to gain insights into what are typical problems associated with globalization of the commercial nuclear industry (see Topical Issue 1 of this conference).

1. INTRODUCTION

Sizewell B is a nominal 1200 MW(e) PWR of the four loop Westinghouse design. It was intended to be the first of a British fleet of such reactors and, as such, incorporates significant design enhancements over the standard Westinghouse 1200 MW(e) plant, including a secondary containment with filtration, as well as four independent safety trains — including four emergency diesels.

Subsequent to the construction start on Sizewell B, the CEGB decided to cancel the fleet programme, thereby leaving Sizewell B as the only PWR in the United Kingdom. Its unique design and the fact that it is the lone PWR in the United Kingdom combine to make Sizewell B dependent on strong support from its vendors. Following the completion of construction in 1995, Sizewell B retained the team lead by Westinghouse to provide its initial maintenance and refuelling services.

In the summer of 2000, British Energy (BE) decided to go out for a tender for the provision of maintenance and refuelling outage services in accordance with European Union rules. In early 2001, BE announced that a consortium, FMA, consisting of two companies from the United Kingdom — Alstec and Mitsui Babcock — and a French multinational company — Framatome ANP — had been awarded the contract. This paper explores the globalization issues raised by this change of vendors, and the solutions devised to meet them by BE and FMA as seen from the FMA perspective — the author was the first FMA site manager.

2. 2. FORCED OUTAGE No. 28 (FO 28)

Shortly after startup from the refuelling outage No. 4 (RFO 4) in November 2000, Sizewell B detected indications of reactor coolant system (RCS) leakage into the containment. The leakage was less than that allowed by the plant's technical specifications, and plant operation was continued while attempts were made to find and isolate the leak. In May 2001, the staff concluded that the leak was bypassing both reactor vessel head O-rings and the decision was made to shut the plant down, inspect and make the necessary repairs.

This forced outage was unusual in that it is not typical for a plant to have to disassemble the reactor during a forced outage (except in the case of leaking fuel forcing a shutdown). Since the contract had only just been announced, and not even signed, Framatome ANP (F-ANP) had not begun any preparations for reactor vessel (RV) work at Sizewell B. The incumbent vendor, Westinghouse, had provided reactor disassembly/reassembly services in the first four outages. Thus BE and FMA faced a *management of change* issue even before the formal contract was signed: should they use crews who had no Sizewell B specific experience and no time to make preparations to disassemble the RV head? FMA and BE discussed the matter and both concluded that prudence demanded using the experienced Westinghouse crew to do the reactor disassembly/reassembly on such short notice. Westinghouse agreed to support Sizewell B and FMA was asked to prepare the repair contingencies, which included potential removal of a stuck RV stud and potential weld repairs to the RV sealing surfaces. Due to the behaviour of the two vendors in this instance (competitive issues were put aside to help Sizewell B), a potentially difficult situation did not develop. Nuclear plant operators cannot rely solely on goodwill when making large changes, the *transition period* needs to be adequately addressed.

FMA decided to use F-ANP to staff and lead the two repair contingency crews since it had in its French region the procedures, tooling and experienced personnel to do this work. These people were immediately identified and deployed to the site. In support of the French crews, Mitsui Babcock supplied some grinders and labourers from the United Kingdom. The site manager arrived from the United States of America a few days after the forced shutdown began and it became immediately apparent that significant language and cultural issues existed in the FMA team. A French QA person, a French engineer, as well as a secretary from the United Kingdom, were the only bilingual members of the team.

The most significant problems caused by this sudden mixing of three cultures, two companies and two languages are listed below:

— The ability to communicate between the monolingual French speakers and the monolingual English speakers was very limited. This raised a significant *industrial safety concern* relative to the French speakers' response to evacuation alarms and public address system announcements. This also presented operational challenges to the management of the project, as well as making it very difficult to create an 'FMA team' environment which would enhance worker job satisfaction.
— The French speakers had a very difficult time ascertaining outage status (and, hence, when they could expect to finish and go home), thus increasing their frustration.
— Expectations with respect to working hours among the people of different nationalities varied widely. The nature of the outage exacerbated the situation as the schedule, and thus work start and stop times were highly variable.
— The QA programmes of the two companies, while both meeting ISO 9001 – 2000, implemented these requirements in different ways, causing some confusion among the staff, as they were all familiar only with their own programmes.
— This was the first time that most of the Mitsui Babcock personnel had worked on a PWR, and the repair that they supported was on the RV itself in a high radiation, airborne contamination area. These conditions are not usual in advanced gas reactors (AGRs), where these members of staff had gained their nuclear experience, and there was some reluctance to enter the more radiologically challenging environment of the PWR.

To address these issues in the short term, the following action was immediately initiated:

— An ‘all hands’ meeting was called wherein the site manager conveyed his expectations relative to safety (nuclear, industrial and radiological), problem reporting and respect for the cultures of others. Current outage status and best estimate of what to expect and when were covered. This discussion was translated simultaneously by the bilingual French QA engineer. Daily FMA team status meetings were established, also with simultaneous translation, where FMA work status as well as overall outage status and other issues were covered.
— Some crews were sent home for a few days with a short turnaround return agreement so they could be rested.
— BE supplied qualified personnel to receive all plant safety documents and work start permissions, since the FMA personnel were not familiar with the site specific procedures.
— At least one English speaking Mitsui Babcock person was assigned to each all-French speaking crew as a ‘safety man’. Both he and his French colleagues were briefed (in both languages) that in the event of an alarm or public address announcement with safety implications, the ‘safety man’ would make the French field supervisor aware (through prearranged hand signals) and the ‘safety man’ would lead the French speakers in carrying out the actions required by the situation.
— The F-ANP QA programme was adopted for use on all work. The Mitsui Babcock personnel were briefed in their responsibilities under the programme and were shown how to properly complete the associated paperwork. A 100% QA review of all FMA paperwork was specified to ensure no errors had been made by persons unfamiliar with the system. A 100% inspection of all fieldwork was performed by the F-ANP QA person and/or the F-ANP engineer to ensure that quality standards were maintained for all work.
— The Mitsui Babcock crew was given a short introduction to PWR technology, including a discussion of the generation, transport and radioactive nature of the material typically found in a PWR. Also covered were the health physics techniques used to keep exposures ALARA in this environment. This technical discussion allowed the personnel to understand the risk at the PWR in the context of their experience at AGRs.

2.1. FO 28 results

Reactor disassembly/reassembly was performed by the Westinghouse team without incident. Similarly, repairs to the RV flange and bolting ring, and a stuck RV stud removal were performed by FMA without incident, and the equipment was returned to original specifications. The interim management actions to address the various language and cultural issues were deemed adequate for a small scope (20 personnel, 5 work orders) forced outage, but impractical for the large scope (539 personnel, 1600 work orders) refuelling outage, RFO 5 planned for a year hence. In retrospect, FO 28 presented FMA with a valuable opportunity to learn some valuable lessons prior to the deployment of a large workforce for a planned refuelling and maintenance outage.

3. REFUELLING OUTAGE No. 5 (RFO 5)

In response to the lessons learned from FO 28, the following actions were taken during the preparation and execution phases of RFO 5:

— A comprehensive FMA induction programme was developed and delivered to all FMA personnel. In addition to normal administrative topics, topics relevant to the lessons learned from FO 28 were delivered. These included PWR technology overview, PWR shutdown safety, PWR radiation protection and elements of ALARA, respect for other cultures, ensuring effective communication, and problem reporting. Also a full QA and industrial safety induction were included.

— BE and FMA concluded that all FMA personnel who did not speak English were required to be accompanied by at least one bilingual person per team. This person was, in most circumstances, the team leader and they provided communication in the native tongue: in the event of a safety incident, to ensure that job scope and requirements were clearly understood, to provide interface with support groups and to ensure administrative requirements were adhered to.

— For work where communication had safety implications, most notably fuel handling operations, FMA and BE specified that only native English-speaking personnel would engage in these activities. In all other work, mixed crews were allowed, subject to the requirement of at least one bilingual person as described above.

— RFO 5 working hours were set to accommodate both operational requirements and the ‘cultural norms’ of the work groups executing the work. Specifically, for those work groups who typically worked shorter hours, crew sizes were increased to gain the production rates required. In some cases of mixed crews, the ideal was not achievable.

— FMA developed a Consortium Quality Plan for the Sizewell B project. It is an umbrella document which recognizes the conformance of all member companies to ISO 9001 – 2000, and thereby allows the use of individual company QA processes and procedures in their own scope of work. Some common processes were developed for Sizewell, such as non-conformity reporting and work order processing, but generally speaking, the goal was for people to be using systems with which they were already familiar.
— FMA built into its organization 24 hours per day, 7 days per week, field safety engineer support. Given the large workforce, the diverse cultures and experience, and the newness of some of the work to some members of the workforce, this action was considered essential. The position was staffed by nationals of the United Kingdom who were certified safety professionals, knowledgeable in safety practices and laws of the United Kingdom.
— The QA portion of the FMA site refuelling organization was led by the QA engineer (F-ANP France) with the most Sizewell B experience. His team was supplied with members from all three companies in order to ensure that good knowledge of each company's QA programme was available on-site. In addition, the QA staff were given introductions to each other's programmes. A routine QA surveillance programme was featured during the outage execution, to verify adequate field performance, and a 100% QA review of work orders prior to and upon completion was specified in order to ensure good quality documentation of the work performed.
— FMA senior management spent at least three hours per day in the field, observing performance of the work. Feedback was given at the shift turnover meetings which were conducted every 12 hours. Safety, ALARA and production were reviewed every 12 hours at these meetings, which were attended by the leadership of each FMA work group (seven groups in total), FMA QA, planning and health physics.

3.1. RFO 5 results

Collective dose: 251.2 man·mSv;
Highest individual radiation dose: 2.52 mSv;
Lost time accidents: 0;
Accident book entries: 32;
Accident incident rate: 2.55;

Off-site reportable events: 0;
Volume unsorted radwaste: 57 m^3.

These were best ever performances for the plant except for lost time accidents and volume of unsorted radwaste.

4. CONCLUSIONS

In RFO 5, despite the extensive inductions and other measures taken, problems arose. In particular, it proved very difficult to engender in the mixed teams (France/USA, United Kingdom/France, United Kingdom/USA) a sense of teamwork and esprit de corps. While rare, there were incidents of friction between groups, which had to be resolved. These conflicts appeared to be as much a product of the differences in company culture as of differences in national culture. This issue was never satisfactorily resolved and had to be managed throughout the outage. Thus, the FMA organization had to operate at somewhat of a handicap as it did not benefit from the level of teamwork usually achieved in a monolithic organization.

Finally, while there were many problems encountered and lessons learned relative to the process of assembling a multicompany, multinational workforce to plan and execute outage work at a standalone PWR, the results of both FO 28 and RFO 5 were very good from a safety and operational point of view.

COMMUNICATION PLAN PROPOSAL

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My topic this afternoon is “Achieving Successful Communication”. My purpose is two fold. First, I would like to discuss some thoughts on why communication is so important to the nuclear industry, and this conference. Second, I would like to provide you certain key thoughts of how to achieve successful communications.

As we talk about communications, I would like you to think about the communication challenges faced by the industry and government as a result of events such as Three Mile Island. This was one of the most significant challenges the industry has faced from a communications standpoint, separate from the technical aspects of the accident. We should ask ourselves, are we better off today — more than twenty years later — in our relations with the public?

Is there more public acceptance and understanding of our technology since the Three Mile Island event? I think the answer varies from country to country. Three Mile Island was the first time the industry and regulator had to really face the necessity of communicating accurately and rapidly to the public, and to address fears and criticism. Now, many years later, have we in the industry learned how to achieve successful communication with the public? Clearly, in the USA, we are doing better. Is it good enough? It has to be good enough. Because the time is now to meet the challenges of the industry and technology.

I would like to share with you some comments from two presentations that were made at recent international conferences. These statements are significant to this conference and my topic. They are perceptive comments about how essential communication with the public is to the nuclear industry. First, let me give you a brief overview of the specific points made in these insightful statements: (1) The nuclear industry can no longer escape *not* communicating with the public. (2) The future of nuclear power depends on achieving successful communications with those *outside* the industry. (3) Finally, public confidence and their perceptions of nuclear energy *have the power* to influence a country’s choice of energy.

I will go directly to the comments made by two distinguished individuals. In June of this year, in the Russian Federation, at an international conference on fifty years of nuclear power, the IAEA Director General, Dr. ElBaradei, discussed that public perceptions are a crucial factor in shaping the future of nuclear power. He said: “The failure of the nuclear community — both scientists and technical experts, operators and regulators — to effectively “market” their strengths in comparison with other sources, has contributed to a lack of public understanding regarding the basics of radiation science and the characteristics of nuclear power…." I recommend that you read all of Dr. ElBaradei's comments under "Public Perceptions and Misconceptions: Shaping National Choices" of his speech "Nuclear Power: A Look At the Future."

The second person who I would like to reference is the President and CEO of the Canadian Nuclear Safety Commission (CNSC), Linda J. Keen, who is with us here at the conference and spoke earlier today. Five months ago, Ms. Keen made three key points during an international conference on public confidence that I think are equally pertinent to *this* conference. The first was: "…policies that lack public support are policies that risk failure….". Secondly, "…perhaps once considered a 'nice to have', public confidence is now a 'need to have'…". The final comment was: "…Our ability to meet the challenges of the future will depend on our ability to assure citizens that they can have confidence in regulatory regimes that are clear, open and accessible." This last line does not apply to just nuclear regulators. It applies to all in the industry.

If the public — politicians, journalists — do not have faith that the nuclear utilities or companies are keeping them safe, if they think you are hiding something from them…it is an almost lost battle. In this day and age of instantaneous communications, a rumor or inaccurate information that gets spread into the public domain is almost a lost battle. If the crowd you are facing at a public meeting is a hostile crowd rather than a neutral one, it is almost a lost battle. If the anti-nuclear activists get to the politicians before you do, it is almost a lost battle. A month ago, the newspaper USA Today wrote: "…with record energy costs and global electricity consumption expected to double by 2020…the future of nuclear power is popping up on political agendas around the world...".

While the need for nuclear power clearly exists, you know the arguments against it and what confronts it better than I do. Utilities and regulators alike — all in the nuclear industry — will be forced to at one time or another to "sell", "justify", "explain", the complex issues of nuclear power to the public, politicians and journalists. And how well you do this — how well you communicate — will impact your success or failure as an industry or as an effective regulator.

At the international conference in Canada, some successful communication practices by nuclear regulators were cited in countries including Finland, the United Kingdom and Sweden. For example: the United Kingdom is beginning a programme to engage the public and become more transparent. In Sweden, employees are trained to speak to the media, and are expected to do so. Internationally, there are successes in achieving communication with the public — journalists and politicians included. I would encourage you go to the CNSC's web site (www.nuclearsafety.gc.ca) and read the 18 May speech.

Achieving successful communication is hard work, and it takes time. Communication is a skill that can be learned. Speaking of skill, let me share a current example to make this point. I am sure everyone in the audience from China is familiar with this scene from the recent Olympics. Who could not be in awe of the grace and strength of Mr. Teng of China, who received the gold medal in the pommel horse event. The movements of the Olympic athletes seem so simple, so graceful and so easily performed, to our eyes, yet we all know that there is tremendous power in what they accomplish. How do we translate the thought and view of the pride and accomplishment of the Olympic athletes into the business of good communication practices?

There is nothing simple about what Mr. Teng or the other great athletes do. It is from the hours of hard work and the commitment, that their strength and energy impacts us. It is from superb preparation that these complex movements appear to be simple. This is what successful communication is: a simple message — clear and true — that reaches the heart and mind of your audience. It took countless hours to succeed in their sport and to achieve the gold medal. To succeed in good communication, you must prepare and practice and train over and over again, to achieve that "simple message — clear and true — that reaches the heart and mind of your audience.

What is the "heart" of your audience? It can be the emotional, or the *central core* of what is important to them. The "mind" is where your communication message is processed and understood. It is the crisp sound bite, or the (the simplicity) which allows your message to be what is focused on — to be strong. A 'sound bite', for those of you not familiar with this term, is a short, concise, crisp and easily understandable sentence. In the media — television and radio — your sentences most of the time need to be limited to 30 seconds or you will get cut off. The content of your message can be complex. But the structure needs to be crisp and clear in order to allow the audience's mind to focus on the message freely.

For example, a tunnel visually is a simple structure. A tunnel is also a complex engineering task to design and then to construct. Vehicles are able to enter and exit a tunnel easily, without obstacles to distract them or hinder them from safe movement. Visually, good communications might be viewed as something like these fast moving cars in the tunnel. With successful communication, the messages will be quickly understood. The process of communication will be dynamic. And the mental images will grow immediately in someone's mind. Because the sentence structure is not complex,— nothing is blocking the flow of communication and the message imagery.

In order to illustrate this point further, I would like to share with you three famous quotes that are outstanding for their simplicity yet powerful content: Gandhi's "My Life Is My Message"; Tolstoy's "All, everything that I understand, I understand only because I love"; and Truman's "The will for peace without the strength for peace is of no avail".

Why are these successful? They are powerful quotes that have stood the test of time. When the authors spoke these lines, they were probably not aware how effective and powerful these statements were. These three quotes have all the attributes of good communication. They are crisp and good sound bites. Also, people can immediately create imagery within their mind with these statements. An imagery that they individually can relate to, and thus be able to "bond"/ connect to the message. Also, these messages create both an intellectual and emotional response. With Gandhi, the man himself comes to mind and what he represented in his life — a history of a country. With Tolstoy, love — whatever it is to you and has been within your experience to this point — touches you. With Truman, the meaning of war or conflict, and unity within a country is aroused.

In the book You Are The Message by Roger Ailes — who worked for US President Ronald Reagan and has been involved in television for most of his life and now runs the 24 Hour Fox News cable show — writes: "Unless you are being interviewed for highly technical journals, avoid jargon." "Speak plainly." "Use examples and illustrations that enable the average person to understand you." "If you are talking about imported oil, for example, instead of just quoting how many tons of oil comes into a country every day or every year, you might say that's enough to fill every football stadium in this country ten times over."

While I don't believe successful communication requires a complex message development system, it does require preparation— 'knowing your audience' and a commitment to the message, which means 'knowledge of your topic and a belief in it'. Good communication is a skill that can be learned.

I'd like to briefly mention the television advertisements that one industrial group in France, launched in 2002 and 2004; , you will be able to view them their web site (www.areva.com). The 2002 television campaign was aimed at introducing the company to the public. The 2004 campaign discusses the company's electrical transmission and distribution capabilities and its expertise in the energy field. At the end, there is one line, that I think is an excellent sound bite and a line that stays with you: "Areva: Solutions for producing, transmitting and distributing the energy the world needs". It is an action statement. It is positive. It reaches into the heart of human needs

In summary, part of being successful communicators, is reaching the heart of the people — be a "people's expert", another quote I have taken from the Head Regulator of Canada. Focusing *on the key issues of concern to your audience — by being prepared, and explaining the truth of the technology in strong, clear sound bites.* There are many other techniques that you can also use to make you a successful nuclear communicator. I have touched on a few of them today.

You are here this week to do important work in identifying changing trends in the nuclear world. What you identify at this conference cannot and should not exist in a vacuum. Without good communications and techniques the nuclear industry has the potential to fail. This is a challenge that faces you. Without excellence in communications, there will be no support in your country, no progress in the arena of public acceptance, no real development of media education on this technology. In large part, the success of the nuclear industry will depend not only on the utilities' ability to address safety issues, but also on your ability as communicators to present the issues the public wants and needs. In closing, I would like to leave with you this one final thought that is especially pertinent to my topic: "Only a human communicator can become a master communicator" (Roger Ailes).

OPERATING EXPERIENCE
Getting the most out of industry trends information

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Abstract

The United States Nuclear Regulatory Commission (NRC) systematically assesses and screens all nuclear power reactor related events, reports and data to determine their significance and need for additional evaluation. This operating experience information is collected, evaluated, communicated and applied to support the NRC's goal of ensuring safety; to improve the effectiveness, efficiency and realism of NRC decisions; and to provide the public, Congress and other external stakeholders with accurate, timely and balanced information regarding operating experience, including actual or potential hazards to health and safety. The industry trends programme monitors trends in indicators of industry performance as a means to confirm that the safety of operating power plants is being maintained. The NRC assesses the safety significance and causes of any statistically significant adverse industry trends, determines if the trends represent an actual degradation in overall industry safety performance, and responds appropriately to any safety issues that may be identified.

1. BACKGROUND

The mission of the United States Nuclear Regulatory Commission (NRC), in part, is to ensure that commercial nuclear power plants are operated in a manner that provides adequate protection of public health and safety and the environment. The NRC fulfils this mission by establishing regulatory requirements for the design, construction and operation of plants, performing licensing reviews and overseeing plant activities. Within this framework, the primary responsibility for operating plants safely rests with the NRC licensees. Therefore, they have the primary responsibility to review operating experience (OE) to identify safety concerns and take action to address these concerns. However, it has long been recognized that the NRC's systematic collection and evaluation of OE is also an important element of its mission. Both the industry and the NRC's programmes should work towards the common objective of ensuring that plants are operated safely.

OE in this context involves a broad range of information regarding events and conditions at nuclear power plants. OE includes, but is not limited to, safety system failures, safety system actuations, emergency notifications, component failure data and inspection reports, as well as industry reports and foreign OE reports. The lessons learned from a thorough evaluation of OE provide a unique and valuable tool to prevent recurrence of past safety significant events and to identify and resolve new safety issues and thereby avoid even more serious events in the future. The evaluation of OE can also provide information important to assessing the effectiveness of the NRC's regulatory programmes and to informing the public about the performance of licensed plants. To be effective, an agency OE programme needs to support and work in concert with agency programmes involved in the licensing and oversight of nuclear power plants. For any OE programme to be effective, it also must have clearly defined objectives that are consistent with and support the agency's overall goals.

2. OBJECTIVES OF AN OE PROGRAMME

2.1. Ensuring safety

OE is collected, evaluated, communicated and applied to support the agency goal of ensuring safety. This objective is the primary focus of the agency's reactor OE programme. To accomplish this objective, the agency will have an effective, coordinated programme to systematically collect and evaluate OE, identify and resolve safety issues in a timely manner, and apply lessons learned from OE to support the agency goal of ensuring safety. The agency will share OE information with the nuclear industry in a timely manner so the industry can ensure safety.

2.2. Improving the effectiveness, efficiency and realism of NRC decisions

OE is used to improve the effectiveness, efficiency and realism of NRC decisions. Evaluations of OE provide fundamental information necessary to improve safety assessments and the realism of NRC decisions. Lessons learned from OE evaluations will be used to improve NRC regulatory programmes, including licensing and inspection.

2.3. Providing accurate, timely and balanced information regarding OE

The public, Congress and other external stakeholders are provided with accurate, timely and balanced information regarding operating experience, including actual or potential hazards to health and safety. Timely sharing of OE information with the public, Congress and other external stakeholders will enhance their understanding of the performance of licensed plants.

3. OE INPUTS

The inputs to the OE programme are largely event or condition driven. These inputs include licensee event reports, NRC generated data from inspections, foreign events, vendor and INPO generated information, and other sources, such as the press, industry journals and allegations.

The NRC has reporting criteria for operating reactors which were designed to provide risk significant issues that may need to be addressed in the short term, as well as providing data for long term analysis and trending. Licensees are responsible for reporting information that meets the criteria.

NRC generated data include information gathered from planned calls with our regional offices who are getting up to date information directly from their on-site resident inspectors. While there is overlap between these first two sources of information, the information gathered in the daily calls has substantial value based on the ability to distribute the information in a timely manner.

The NRC learns of foreign events through the International Reporting System (IRS) and the International Nuclear Event Scale (INES) web postings of the IAEA. It also learns of foreign events through the press and direct contacts individual staff may have in other countries.

4. OE OUTPUTS

The NRC primarily uses risk informed decision making in formulating an agency response. If warranted, a generic communication may be issued to the operating reactors. Not all events result in a generic communication, often times issues are entered into the events database solely to capture for future reference. Concurrent with the need for generic communication is the assessment of the need for agency response in the form of additional inspection.

The OE data obtained from licensee event reports can also be used to assess whether the nuclear industry is maintaining the safety performance of operating plants and to provide feedback on the Reactor Oversight Process (ROP). The ITP monitors trends in indicators of industry performance as a means to confirm that the safety of operating power plants is being maintained. This programme is described in more detail below.

5. USING INFORMATION ON INDUSTRY TRENDS

5.1. Objectives of the industry trends programme

The NRC provides oversight of plant safety performance on a plant specific basis using both inspection findings and plant level performance indicators as part of its Reactor Oversight Process (ROP). Individual issues that are identified as having generic safety significance are addressed using other NRC processes, including the generic communications process and the generic safety issue process. The ITP was implemented to complement these processes by monitoring and assessing industry level trends in safety performance.

The purposes of the ITP are to provide a means to confirm that the nuclear industry is maintaining the safety performance of operating reactors and, by clearly demonstrating that performance, to enhance stakeholder confidence in the efficacy of the NRC's processes. The objectives of the ITP are as follows:

— Collect and monitor industry-wide data that can be used to assess whether the nuclear industry is maintaining the safety performance of operating plants and to provide feedback on the ROP.
— Assess the safety significance and causes of any statistically significant adverse industry trends, determine if the trends represent an actual degradation in overall industry safety performance, and respond appropriately to any safety issues that may be identified.
— Communicate industry level information to Congress and other stakeholders in an effective and timely manner.

5.2. Identify short term issues

The NRC adopted a statistical approach using 'prediction limits' to provide a consistent method to identify potential short term emergent issues before they manifest themselves as long term trends. The prediction limits are values that set an upper bound on expected performance for that year for each indicator. The NRC investigates indicators that cross the prediction limits to determine the contributing factors. These factors are assessed for their safety significance and used to determine an appropriate agency response.

5.3. Identify adverse trends

For purposes of assessing whether there are any statistically significant adverse industry trends, only long term data are used. The trending of long term data minimizes reacting to potential 'false positive' indications that may emerge in short term data. 'Short term' was defined to be less than four years to ensure that sufficient data (i.e. data for at least two typical nuclear plant operating cycles) are available so that valid trends can be distinguished from operating cycle effects, such as refuelling outages and from random fluctuations in the data and to allow sufficient data for the use of statistical methods.

The staff applies common statistical techniques to the long term indicator data to identify trends. In general terms, a trendline is fitted to each indicator using regression techniques. Once a statistically significant fit of a trendline is made to each indicator, the slope of the trendlines is examined. Improving or flat trendlines are not considered adverse and need not be investigated further.

5.4. Analyses of issues

Once an adverse trend is identified, the staff conducts an initial analysis of information readily available in the databases used to compile the indicator data to determine whether the trend is unduly influenced by a small number of outliers and to identify any contributing factors. If the trend is the result of outliers, then it is not considered a trend requiring generic actions, and the agency will consider any appropriate plant specific actions using the ROP. For example, the affected plants unduly influencing the adverse trend may have already exceeded plant level thresholds under the ROP, and the NRC regional offices would conduct supplemental inspections at these plants to ensure the appropriate corrective actions have been taken. If the plants did not exceed any thresholds, while the NRC would not take regulatory actions beyond the ROP, the NRC would gather additional information on the issue within the scope of the ROP using risk informed baseline inspections. The results of these inspections would be examined to determine if a generic issue existed and required additional NRC review or generic inspections.

If no outliers are identified, the staff conducts a broader review to assess whether larger groups of facilities are contributing to the decline and to assess any contributing factors and causes. The staff will also conduct a more detailed review of applicable licensee event reports. Should a group of plants be identified, the staff will examine the results of previously conducted inspections at these plants, including any root causes and the extent of the conditions.

Once this information is reviewed, the staff assesses the safety significance of the underlying issues. The staff is mindful that trends in individual indicators must be considered in the larger context of their overall risk significance. For example, a hypothetical increase in automatic scrams from 0.4 to 0.7 per plant per year over several years may be a statistically significant trend in an adverse direction. However, it may not represent a significant increase in overall risk since the contribution of a small number of scrams is relatively low, and it is possible that overall risk may actually have declined if there were reductions in the frequency of more risk significant initiating events or the reliability and availability of safety systems had improved.

5.5. Agency response

Should a statistically significant adverse trend in safety performance be identified or an indicator cross a prediction limit, the staff will determine the appropriate response using the NRC's established processes for addressing and communicating generic issues.

In general, the issues will be assigned to the appropriate technical branch for initial review. The branch will engage NRC senior management and initiate early interaction with the nuclear power industry. Depending on the issue, the process could include requesting industry groups, such as NEI or various owners' groups, to provide utility information. Industry initiatives, such as the formation of specialized working groups to address technical issues, may be used in lieu of, or to complement, regulatory actions. This can benefit both the NRC and the industry by identifying mutually satisfactory resolution approaches and reducing resource burdens.

Depending on the issues, the NRC may consider generic safety inspections at plants. In addition, the issues underlying the adverse trend may also be addressed as part of the generic safety issue process. After this interaction, the NRC may consider additional regulatory actions as appropriate, such as issuing generic correspondence to disseminate or gather information, or conducting special inspections for generic issues. The process also includes consideration of whether any actions proposed by the NRC to address the issues constitute a backfit. NRC senior managers review the industry trends information and, if appropriate, recommend any additional actions beyond those implemented by the staff.

5.6. Communications with stakeholders

The NRC communicates overall industry performance to stakeholders by publishing the ITP indicators on the nuclear reactors portion of the agency's public web site http://www.nrc.gov/reactors/operating/oversight/industry-trends.html). The staff believes that communication of the industry level indicators, when added to the information on individual plants from the ROP, enhances stakeholder confidence in the efficacy of the NRC's oversight of the nuclear industry.

The staff informs the commission of the results of the ITP in an annual report that is publicly available. In addition, NRC managers have historically presented industry indicators and trends at major conferences with industry.

Session Summary

OPERATING EXPERIENCE: MANAGING CHANGES EFFECTIVELY

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1. CURRENT STATUS

Recurrent events continue to take place. Since the previous Topical Issues Conference held in Vienna in 2001, significant events have occurred at some of the more mature nuclear facilities and utilities. During this conference, there was general consensus that although similar events had taken place in the past, nothing really new had been determined as the root causes of these recurring events. Discussions raised the question of how the international nuclear community could better share and promote the feedback of the international experience and lessons learned while protecting sensitive proprietary information.

Due to a heightened security awareness, especially after the attacks of 11 September 2001, some barriers have been imposed on the information sharing mechanism. Although the reasons behind those protective measures are understandable, there was consensus that these barriers should be minimized when nuclear safety related information related to enhancing safety performance has been clearly identified. While the information should be shared in an effective and timely manner, the proprietary rights of confidentiality should be protected.

The members of the nuclear industry are hostages of each other and as such, an accident anywhere is an accident everywhere. To be more proactive in the management of safety, we must ensure that lessons learned somewhere should be lessons learned everywhere. The nuclear industry should ensure that lessons learned in the past are not forgotten in the present and also not lost in the future. These lessons learned are not unique to any specific period in the life cycle of a nuclear installation or any particular type of nuclear installation; likewise, lessons learned are not unique to any particular industry. All sources of lessons learned regarding material, process and knowledge management insights, etc., must be pursued. Information technology networks could be developed and comprehensively used, to ensure that information and resources are utilized to the maximum degree possible. Such self-sustaining networks within and between Member States, based on strategic knowledge management, could be a key vehicle to achieve the adequate level of information sharing. IAEA review services, such as OSART with enhanced operating experience reviews, IRRT and Reviews of Operating Experience Programmes (PROSPER), are an effective means to promote the sharing of the lessons learned from national and international experience feedback programmes.

A further aspect discussed was the effect on operational and nuclear safety of organizational changes that the nuclear industry has been undergoing, caused by such programmes as the deregulation of the electricity market and openness to international competition. A question often asked is to what extent should the regulatory organization intervene in the utilities process for the implementation of such organizational changes? — and, if necessary, how should they intervene?. Here, there is room for cooperation between the industry support organizations such as WANO, OECD/NEA and the IAEA in developing strategic guidance to assist in resolving these uncertainties. There was also consensus that specific regulatory mandatory policy could be applied everywhere, due to several factors, such as the independence and credibility of the regulator, together with cultural and political factors. However, during routine inspections and a review of operational performance indicators, the consequences of those changes could be assessed and, if applicable, related enforcements applied. Some established examples of a few Member States could be used. For example, the United Kingdom has internal procedures that require regulatory approval for any significant organizational changes, this includes a review of the safety consequences of such changes.

A factor related to organizational change that received great attention was the example of organizations that change their chief executive officers, some of whom have hardly any knowledge of how some business related decisions could cause operational safety implications for an operating nuclear power plant. Many of these executives look for short term results, quarterly or in the next 12 months. It is important that the nuclear industry is able to demonstrate the need for maintaining long term investment in nuclear safety to their own exceutives and the financial community. Here again, the nuclear industry and the IAEA could develop strategic guidance to assist in managing this important safety related organizational issue.

With regard to the use of low level events and near miss information, the discussions highlighted several important issues. There was overall recognition of the importance of detecting and reporting low level events and near miss information because valuable lessons can be derived from their analysis.

However, in order to have an adequate process in place, the existence of a questioning attitude is necessary. This attitude of mutual confidence and blame tolerant policies is dependent on several factors, such as the existing country culture, social values and underlying safety culture. These factors are the main reason that the reporting and utilization of minor event information is so diverse, ranging from almost none at some nuclear power plants to several thousands at others. Opinions on the responsibility of the regulator in this regard are also very diverse and no consensus was reached. The conclusion was that information contained in such events could be of fundamental importance in detecting precursors of more significant events; and a process to stimulate their detection and analysis should be in place in every operational nuclear power plant. However, care should be taken in developing and managing the programme adequately to ensure that the information is used effectively in enhancing safety performance. If not, important information could be lost and it could be difficult to utilize so much information. Failure to rectify reported issues could lead to a loss of credibility of the process in the workplace, that could then lead to the wrong message being perceived by the operating floor.

2. FINDINGS AND CONCLUSIONS

Significant recurring events continue to occur. Strong efforts should be made to share operating experience more effectively, comprehensively and in a timely manner. International organizations, such as the IAEA, WANO, the OECD/NEA and the various owners groups, should coordinate their efforts in this direction, to improve or revise their actual programmes. Artificial barriers imposed for security reasons should be minimized, while ensuring that the proprietary rights of the organizations involved continue to be protected. The conclusion is not to create a new system to collect and disseminate international experience, but instead to maintain and enhance the effectiveness of existing systems.

The process of identifying minor and low level events, together with near misses, is valuable in identifying lessons to be learned, and their use should be encouraged by the IAEA. However, care should be taken to avoid creating an extensive databank of information that may be difficult to use. Regulators should encourage licensees to develop and implement programmes to capture and analyse information about those low level events.

Self-assessments are excellent tools for managers and senior executives to verify the actual operational safety performance of their facilities. The international organizations should effectively promote the use of the self-assessment process by utilities and regulators. International peer reviews, such as OSART, IRRT, PROSPER and the WANO peer review programme, could help the industry in this direction.

The IAEA is also encouraged to promote workshops, seminars and information exchanges on the results of safety reviews and operating experience, especially when significant recurring events have occurred, in a timely manner and with the open participation of all organizations involved.

In order to address the actual situation of chief executive officers of many nuclear utilities lacking acumen in nuclear safety matters, the IAEA together with the other nuclear industry representatives such as WANO and the OECD/NEA should develop a strategic plan to correct this issue. How regulatory authorities should be informed and/or responsible for approving significant organizational change in utilities should be considered by the IAEA and other nuclear organizations to provide consensus guidance in this area.

REGULATORY MANAGEMENT SYSTEMS: ADAPTING TO CHANGES IN THE ENVIRONMENT

(Topical Issue 3)

Chairpersons

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CHANGING ENVIRONMENTS: COPING WITH DIVERSITY AND GLOBALIZATION

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1. RATIONALE/BACKGROUND

A major mission for the IAEA is to establish an international safety regime, including developing safety standards and mechanisms for applying those standards. With regard to the regulatory activities, this includes the publication of a collection of safety standards on the legal and governmental infrastructure for nuclear, radiation, radioactive waste and transport safety (one Safety Requirements and four Safety Guides) and the establishment of the International Regulatory Review Team service (IRRT), set up in 1989 to provide advice and assistance to Member States who wished to strengthen and enhance the effectiveness of their nuclear regulatory body.

The IAEA publication on Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety [1] establishes requirements for legal and governmental responsibilities in respect of the safety of nuclear facilities, the safe use of sources of ionizing radiation, radiation protection, the safe management of radioactive waste and the safe transport of radioactive material. Thus, it covers development of the legal framework for establishing a regulatory body and other actions to achieve effective regulatory control of facilities and activities. The requirements are implemented through four Safety Guides:

— The Safety Guide on Organization and Staffing of the Regulatory Body for Nuclear Facilities [2] provides recommendations on the organization and staffing of a regulatory body for nuclear facilities: its structure and organization; its interaction with other organizations; the appropriate qualifications required of the staff of the regulatory body; and the training to be provided for those staff;
— The Safety Guide on Review and Assessment of Nuclear Facilities by the Regulatory Body [3] provides recommendations on reviewing and assessing the various safety related submissions made by the operator of a

nuclear facility at different stages (siting, design, construction, commissioning, operation and decommissioning or closure) in the facility's lifetime to determine whether the facility complies with the applicable safety objectives and requirements;

— The Safety Guide on Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body [4] provides recommendations on the inspection of nuclear facilities, regulatory enforcement and related matters with a view to providing the regulatory body with a high level of confidence that operators have the processes in place to ensure compliance and that they do comply with legal requirements, including meeting the safety objectives and requirements of the regulatory body;
— The Safety Guide on Documentation for Use in Regulating Nuclear Facilities [5] provides recommendations for the regulatory bodies and operators on the documentation to be prepared for the regulatory processes for nuclear facilities.

The purpose of the IRRT service is to provide the host country (the regulatory body and any relevant governmental authorities) with an objective peer review of its nuclear regulatory practices against current international best practice. The IAEA Safety Standards are used as the benchmark for this review. The outcome of the review takes the form of a report that includes recommendations and suggestions for improvement if the regulatory body or its performance is considered to fall short of internationally accepted practices. Furthermore, the IRRT missions also provide the opportunity to identify any good practices adopted by the regulatory body that are worthy of wider dissemination to other Member States.

The IAEA safety standards and the IRRT service focus primarily on the recommendations for the establishment of a regulatory system and the peer review on how the regulatory body is established and performs its main functions. These were considered to be very useful and efficient, in particular for those countries were establishing their regulatory system.

Considering that most of the regulatory bodies have already reached a high level of performance and are implementing a continuous improvement strategy based on feedback of experience and self-assessment, future IAEA activities are expected to accompany regulatory development through international cooperation on how to deal with the new regulatory challenges, through the promotion of self-assessment methodologies and tools, and through a future IRRT service, which should focus less on the way the regulatory body performs its function and more on the benefits from exchanges among international experts on the efficiency of the continuous improvement process based on self-assessment.

The purpose of this paper is to identify the main current regulatory challenges resulting from changes in the environment, describe the present status of these issues, considering the results from recent OECD/NEA and IAEA activities, propose areas for future international cooperation and future IAEA activities complementary to OECD/NEA activities, in support of regulatory bodies in the Member States. The discussion on future IRRT services aims at adapting this service to changes in the environment while also taking into account changes within the regulatory bodies.

2. PRESENT STATUS OF THE ISSUE

2.1. Regulatory staffing issues

One of the most common challenges among the regulatory bodies is related to staffing issues. The regulatory body staff is ageing and in some cases a significant proportion of the technically experienced staff will retire soon. This has led the management of the regulatory bodies to establish a recruitment and training plan but again in this area, the regulatory bodies face difficulties in the recruitment of new staff. This is partly due to the differences between the industry and the governmental organization in terms of salary. It is then particularly difficult to recruit experienced staff members from the industry and the regulatory body needs to recruit young staff members that it should train itself. Since also we observe limited interest in universities in nuclear technologies, it appears that in some countries there are limited — or nonexistent — educational infrastructures for nuclear technology and nuclear safety matters, resulting in the regulatory bodies also including in their training courses basic education on nuclear technology and safety. Once more, experience has shown that some of the staff members trained by the regulators have moved to the industry after a rather short time, thus limiting the benefit resulting from the training effort. As a result of this situation, and in addition to the need for self-training, it is crucial that the regulators establish or maintain a sustainable knowledge management system.

2.2. New technical competences and regulatory approaches needed

The regulatory bodies should not only maintain their technical competence in addressing staffing and knowledge retention issues, but should also be able to improve them in order to be prepared to deal with new technical issues. At the same time facing ageing of existing nuclear power plants, the construction or the planning for the construction of new nuclear power plants involving new design features and, in some cases, the early closure of nuclear power plants, the regulatory bodies need to be particularly prepared to address a number a new technical issues and develop new regulatory approaches and requirements. This includes the establishment of licensing approaches and regulatory requirements for the lifetime extension of nuclear power plants, the establishment of regulatory approaches to safety upgrading and nuclear power plant modification, review of ageing management programmes, the establishment of integrated regulatory decision making, considering both deterministic and risk informed regulation and criteria, the establishment of licensing approaches for the decommissioning and waste management activities following the early closure of nuclear power plants, the establishment of regulatory requirements for new plants, including the regulatory review of new design features, the establishment of processes between the regulatory bodies of importing countries and exporting countries.

2.3. Need for harmonization of regulatory requirements

Another challenge that the regulatory bodies will have to face is the increasing need for harmonization of regulatory requirements from different countries applying to the same type of nuclear power plants. Regulatory approaches vary from country to country and result in different regulatory requirements. With the globalization of the energy market, these differences will be challenged. Efforts in term of harmonization are currently being made in some countries, on a regional basis, but this should be followed up by an international effort on a worldwide basis. As such, this is not a challenge to each individual regulator but for the entire regulatory community, and for the IAEA for the next revision cycle of the safety standards for nuclear facilities. In this effort, the recommendation of the Workshop on Nuclear Safety Management and Safety Culture, held in June 2003, to ensure that clear and unambiguous regulations are in place, should be taken into account.

2.4. Effectiveness of the operational experience feedback mechanisms

The international exchange of operating experience of nuclear power plants and, in particular, the promotion of the broad dissemination of lessons learned is one of the important activities for keeping and improving the safe operation of plants. Thus, collecting, sharing and analysing operating experience are vital elements of the safety management of nuclear power plants. There is concrete evidence that learning from plant operating experience is leading to improvements in plant safety. Parties to the Convention on Nuclear Safety have thus made a commitment to establish programmes to collect and analyse operating experience, as indicated in Article 19, para. vii.

In the new environment of a deregulated energy market and privatization, when effective power production is a prerequisite of competitiveness, decision makers in the industry, regulatory bodies and nuclear organizations have to face many challenges, such as maintaining operational safety at the highest level, cost effectiveness expressed through high availability to the grid, steady operation, and good public acceptance. In managing risk and resources, decision makers need credible and reliable information, in particular, about areas of high risk, in order to prioritize their programmes accordingly. They need to get early warning of deteriorating safety performance to address and maintain the level of safety. They also need to share experience and lessons learned with others, thus building and making efficient use of their resources and common knowledge through networking. The importance of an effective operational experience feedback process, both nationally and internationally, has been especially emphasized since the Three Mile Island accident in 1979. Since then, many countries have established specific groups for operating experience feedback at the national level. At the international level, in 1983, the Incident Reporting System (IRS) that is operated jointly with the OECD/NEA, was set up to exchange information on unusual events at nuclear power plants and increase awareness of actual and potential safety problems. Later on, the same tool developed for nuclear power plants was extended for research reactors and recently, for fuel cycle facilities.

The IRS is a system based on the voluntary commitment of the participating countries. The events reported to the IRS should be of safety significance for the international community in terms of causes and lessons learned. For example, events may present potentially serious consequences in terms of safety as precursors for more serious events.

The IRS has proved its usefulness as a comprehensive source of information for worldwide operating experience and lessons learned from that experience. Being a knowledge-based system substantiates its role in the enhancement of the safety of nuclear installations and prevention of occurrence or recurrence of events. It ensures proper reporting and feedback of safety significant events in the nuclear power plants for the international community, so that the causes and lessons learned can be disseminated widely. The information provided through IRS is also useful for making improvements in design, operational procedures, organizational aspects and human factors in nuclear power plants.

The safe operation and performance of nuclear power plants has steadily improved in the last decades with the consequent reduction in the number of significant events, as well as the possibility to learn from those events.

Nevertheless, recent experience has shown that the nuclear regulatory organizations still have to face some specific challenges: (1) a number of recurrence events challenged the operational experience feedback systems at both the national and the international level; (2) the discovery through nuclear events of unexpected phenomena; and (3) the difficulty for the regulatory body to deal with organizational and management factors, and with factors of individual and collective human behaviour. These issues were addressed in several meetings in 2003, including the IAEA Senior Regulator's meeting and the OECD/NEA–CNRA and WGOE meetings.

A number of recurrence events of minor significance continue to challenge the operating experience feedback systems and more attention should be dedicated to the collection and analysis of such events. The IAEA Safety Guide on A System for Feedback of Experience from Events in Nuclear Installations [6] provides guidance for the establishment of an operational experience feedback system to manage operational experience on a national level and encourages reporting of even near miss (or minor) events. Thus, addressing the issue first at national to be then extended, if required, to international systems, such as the IRS, is required to avoid the occurrence or recurrence of events.

Another issue is to better address the root causes of human and organizational factors that contribute to the events and the decision process that follow the analysis.

Therefore, future initiatives should promote: (1) an increasing sharing of lessons learned into international databases (such as the IRS); (2) the sharing of good practices and how they were achieved; and (3) address human and organizational factors.

2.5. Use of safety performance indicators and regulatory performance indicators

The use of safety performance indicators was addressed during the international conference on topical issues in nuclear safety organized in 2001. It was concluded that the framework proposed in IAEA-TECDOC-1141 [7] provides a good approach for establishing a comprehensive operational safety performance indicator (SPI) programme for nuclear power plants. However, it must be used in combination with other insights, such as safety culture and human performance evaluations, inspections and audits, risk analysis, feedback of experience and other external review and self-assessment tools. It was further recommended to develop a set of SPIs, which could be used by regulatory bodies and more generally to identify and test indicators, which can have international relevance for use by all stakeholders. There is international consensus that regulatory bodies should use SPIs as a part of the evidence they gather in judging a licensee's safety performance, and that it is desirable that the regulatory body's indicators mirror (or, if possible, are the same as) some of the licensee's SPIs. However, each regulatory body needs to use its licensees' SPIs in a way that is consistent with their own regulatory processes. The IAEA is developing for the selection of nuclear power plant SPIs for use by regulatory bodies.

With regard to regulatory performance indicators, the issue was particularly addressed during the OECD/NEA Forum on Measuring, Assessing and Communicating Regulatory Effectiveness held in June 2003. The starting point for this forum was a set of indicators developed to measure regulatory performance in five key areas: (1) safety promotion; (2) continuous improvement; (3) internal processes; (4) competence; and (5) stakeholder confidence. A one year pilot project that has been undertaken in ten OECD/NEA countries provided the technical basis for the discussions. Participants debated the appropriateness of the chosen indicators, whether others should be applied and what the most essential measures are of efficiency and effectiveness. Views on these issues from the regulatory bodies vary considerably from country to country, considering that incorrect indicators can lead to inaccurate decision making, that misinterpretations can lead to misunderstandings by stakeholders, that the information provided by indicators is only part of the assessment picture; qualitative data being essential to an accurate assessment of performance. It was recommended that Member States utilize direct performance indicators to the extent possible to assess and improve their regulatory efficiency and effectiveness, considering that maximum benefit can be derived from the use of performance indicators if they are part of an established quality management system. The OECD/NEA continues its efforts, in cooperation with the IAEA, with a view to developing an integrated framework for regulatory efficiency and effectiveness, paying particular attention to qualitative aspects of regulatory performance and the value-added by the regulatory body to nuclear safety.

3. PRIORITIES FOR FUTURE WORK

Considering the challenges identified in Section 2, the priorities in terms of regulatory activities for the future should include:

— The establishment of a sustainable training capability for new staff and the establishment of a sustainable knowledge management system to

facilitate the maintenance of knowledge within the regulatory bodies and their TSOs;
- The development of licensing approaches and regulatory requirements for the lifetime extension of nuclear power plantss, the establishment of regulatory approaches to safety upgrading and plant modification, the review of ageing management programmes, the establishment of integrated regulatory decision making, considering both deterministic and risk informed regulation and criteria, the establishment of licensing approaches for the decommissioning and waste management activities following the early closure of nuclear power plants, the establishment of regulatory requirements for new plants, including the regulatory review of new design features, the establishment of processes between the regulatory bodies of importing countries and exporting countries;
- The improvement on the national operational experience feedback exchange mechanisms.

4. NEED FOR STRENGTHENING INTERNATIONAL COOPERATION/GLOBAL SAFETY REGIME

In addition to the future revision of the safety standards, which will contribute to the enhancement of a global safety regime, it can be concluded from the issues and developments addressed in Sections 2 and 3, that there is a need to strengthen international cooperation in the following three areas:

- International exchange on regulatory self-assessment practices;
- International exchange on, and development of, regulatory performance indicators;
- Review and improve the current IRS to promote an increasing exchange of lessons learned from nuclear events through international mechanisms, an increasing efficiency in the use of the information exchanged, the sharing of good practices, and better address human and organizational factors.

5. POTENTIAL AREAS FOR FUTURE ACTIVITIES

5.1. Safety standards

A major mission for the IAEA is to establish an international safety regime, including developing safety standards and mechanisms for applying those standards. This fits well in one of the IAEA's functions, as given in its Statute:

> To establish or adopt standards of safety for protection of health and minimization of danger to lifeand to provide for the application of these standards, at the request of the parties or, at the request of a State (Article 3.A.6).

The IAEA Medium Term Strategy for 2001–2005 reinforces this function, noting that a principal objective is to achieve more effective application of safety standards in the Member States.

Thus, one of the first priorities for the future activities should be to revise the set of safety standards for the safety of nuclear installations, taking into account the feedback from the use of the existing set, and in particular the feedback from the regional groups, such as Western Europe Nuclear Regulators Association (WENRA), which works towards harmonization of regulatory requirements. The objective of the new set of safety standards should be to reply to this need for harmonization of the regulatory requirements among the Member States. The new set of safety standards should also be established in such a way that the publication could more easily be used when establishing national regulation. For the safety standards on regulatory activities, this includes issuance of guidelines on quality management of the regulatory bodies and guidelines on regulatory body self-assessment.

5.2. Future IRRT service

One of the important mechanisms for applying safety standards is to provide a wide range of safety review services to meet the demands of the Member States. To date, the IAEA has developed a variety of safety review services in the area of nuclear installation safety, and continues to improve the services to reflect experience gained from previous reviews, changing demands on governments and industry, and international best practices.

The IRRT service was set up in 1989 to provide advice and assistance to Member States who wished to strengthen and enhance the effectiveness of their nuclear regulatory body. Although this service was primarily developed to serve all our Member States, considerable interest in the IRRT service was shown by Eastern European countries considering, or in the process of reviewing, whether to develop and introduce 'Western' regulatory methodologies and practices into their regulatory bodies' structure. The service has been improved since its inception, and now also is being used by a number of developed countries with well established regulatory bodies.

Most of the regulatory bodies have reached already a high level of performance and are implementing a continuous improvement strategy based on experience feedback and self-assessment. Moreover, the IAEA promotes appropriate approaches for self-assessment of regulatory performance and quality management in regulatory organizations. Regulatory guidance will have been developed to foster effective management of safety and a safety culture in operating organizations under their jurisdiction. Improvements in regulatory performance also benefit from the use of direct regulatory performance indicators and the monitoring of facility safety performance indicators. Therefore, another priority for future activities is the establishment of an advanced IRRT service, which should review not so much the way the regulatory body performs its functions but review more the efficiency of the continuous improvement process based on self-assessment.

The degree of involvement of the IRRT in self-assessment may vary depending on the need for international exchange. An IRRT may be organized as part of the self-assessment process to benefit from external views. It would use as a basis the current IRRT questionnaire and be complemented by the use of other tools, such as the review of the self-assessment of the technical competence available within the regulatory body (see an example in the annex, prepared within the WWER forum), the independent review of the quality management systems, the review of the use of regulatory performance indicators, the review of the feedback from the stakeholders, etc. In this case, the IRRT will support and complement the self-assessment process. If requested, a workshop on self-assessment methodologies may be organized as a first step before the IRRT review mission.

The IRRT may otherwise be organized after the self-assessment is carried out by the host regulatory body and review the action plan and success indicators being established to implement the conclusions of the self-assessment exercise. In this case, the IRRT will support and complement the development of the action plan and the related indicators.

In both cases, a follow-up mission would be organized after the implementation of the action plan and after a new self-assessment exercise. The follow-up review will then review the overall efficiency of the whole continuous improvement process, from the self-assessment, the identification of strengths and weaknesses, the establishment of an action plan with the identification of the related indicators, the implementation of this action plan and the assessment of its results through a new self-assessment.

Annex

SELF-ASSESSMENT OF COMPETENCE AVAILABLE WITHIN THE REGULATORY BODY AND ITS TSO

TABLE A–1. EXAMPLE BASED ON THE ACTIVITIES OF THE WWER FORUM

Areas of competence or activity	Number of staff in the regulatory body actual/optimum	Age profile	Qualification profile	Availability of independent expertise in TS/ availability of funding to establish contracts	Rather strong	Rather weak
Basic knowledge of:						
— Radiation and industrial safety						
— Relevant legislation						
— Principles of nuclear, radiation, waste and transport safety						
— Human factors						
— Safety culture						
— Site characterization						
— Seismology						
— Environmental issues						
— Facility and system knowledge (design, operation and maintenance, including surveillance methods) for WWER 440						

TABLE A–1. EXAMPLE BASED ON THE ACTIVITIES OF THE WWER FORUM (cont.)

Areas of competence or activity	Number of staff in the regulatory body actual/optimum	Age profile	Qualification profile	Availability of independent expertise in TS/ availability of funding to establish contracts	Rather strong	Rather weak
— Facility and system knowledge (design, operation and maintenance, including surveillance methods) for WWER 1000						
— Facility and system knowledge (design, operation and maintenance, including surveillance methods) for fuel storage						
— Facility and system knowledge (design, operation and maintenance, including surveillance methods) for next generation nuclear power plants technology						
— Bubble condenser						
— Fuel behaviour and fuel management						
— Software, I&C						
— Component life management, ageing						
— Fracture mechanics, structural mechanics						
— Process simulation						
— Non-destructive testing						
— Pressure vessels, metallurgy						
— Fluid mechanics and heat transfer						

TABLE A–1. EXAMPLE BASED ON THE ACTIVITIES OF THE WWER FORUM (cont.)

Areas of competence or activity	Number of staff in the regulatory body actual/optimum	Age profile	Qualification profile	Availability of independent expertise in TS/ availability of funding to establish contracts	Rather strong	Rather weak
— Water chemistry						
— Fire technology						
— Radiation embrittlement						
— Accident analysis						
— Severe accident evaluation						
— Emergency planning						
— Safety assessment						
— Decommissioning						
— Waste management and disposal						
— QA and organizational matters						
Knowledge of regulatory policies and processes :						
— EU and international safety standards						
— Legislative aspects						
— Regulatory policy and its objectives						
— Regulation and use of regulatory guides						

TABLE A–1. EXAMPLE BASED ON THE ACTIVITIES OF THE WWER FORUM (cont.)

Areas of competence or activity	Number of staff in the regulatory body actual/optimum	Age profile	Qualification profile	Availability of independent expertise in TS/ availability of funding to establish contracts	Rather strong	Rather weak
— Authorization stages and procedures, including the purpose and content of supporting documents						
— Internal guidance and procedures of the regulatory body						
— Methods of review and assessment						
— Inspection techniques						
— Enforcement procedures						
— Event evaluation						
— Review of experience feedback						
Communication and management skills, such as skills in respect of:						
— Oral communication						
— Effective writing						
— Interviewing						
— Negotiation						
— Leadership						
— Project management						

TABLE A–1. EXAMPLE BASED ON THE ACTIVITIES OF THE WWER FORUM (cont.)

Areas of competence or activity	Number of staff in the regulatory body actual/optimum	Age profile	Qualification profile	Availability of independent expertise in TS/ availability of funding to establish contracts	Rather strong	Rather weak
— Teamwork						
— Decision making						
— Languages						
— Computer use						
— Public communication						
Information exchange and international cooperation						

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HOW CHANGES IN THE ENVIRONMENT OF THE NUCLEAR COMMUNITY ARE CHALLENGING THE REGULATORS OF NUCLEAR SAFETY

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Abstract

A country introducing nuclear power in its energy strategy has a lifelong obligation. The obligation is not mainly a question of energy production. It is an obligation to maintain safety during the phase of construction, energy production and decommissioning, as well as to take care of all the waste streams from nuclear installations. In addition, a country introducing nuclear power has an obligation that nuclear sources, material and equipment is used solely for peaceful purposes. In order to protect individuals and the environment, society has decided on legal requirements for the operation of nuclear facilities and established national safety authorities to oversee that the licensees fulfil their obligation and responsibility for safety. The changing environment related to nuclear will most certainly challenge the regulator, thus influencing oversight strategies and inspection practices — change which has started already. The paper addresses some of the changes and regulatory challenges related to this changing environment.

1. CHANGES IN THE ECONOMIC CONDITIONS TO PRODUCE ELECTRICITY

Several countries or regions are in the process of deregulating their electricity market. This development is a result of economic as well as political interests. In some countries, such as Sweden, we can observe a changed behaviour of the nuclear industry to meet the new market demands. Structural and organizational changes in the companies and optimization of the operation, such as thermal power uprating and higher fuel burnup, are examples of such changes. Another example is the tendency of increased international ownership of the power plants and with that the merging of different cultural influences on how the power plants are managed.

I would not say that these changes have a negative impact on safety per se. It is, however, necessary for the regulator to have the capability to analyse the safety implications. The regulator will be facing new areas for inspections and with that, introduce new competence in the regulatory body.

2. AGEING REACTORS — MATERIAL DEGRADATION

We can expect that many reactors will be operated beyond their ‘technical lifetime’. Worldwide, there are about 30 reactors operating with an age above 30 years. In five years we might have an additional 80 reactors with an age above 30 years. This implies that age related degradation could be expected to occur in many reactors in the future. Damages like intergranular stress corrosion cracks in certain material are known phenomena. Other age related damages are less well known or perhaps not known at all. For example, we know only little about the ageing phenomena of the containment and the reactor tank.

The regulator has to adapt its oversight strategy to make sure that licensees have a preventive approach in their work with respect to ageing related phenomena. This means that we have to be sure that licensees have a comprehensive maintenance and intensive in-house inspection programme in place to detect ageing related phenomena before any severe damage appears. Licensees have to develop new analytical tools and test methods, capable of identifying early indications of damage and of estimating safety margins. These tools and methods have to be evaluated and approved by the regulators. There is certainly room for improvements and additional developments with respect to existing analytical tools and test methods.

3. AGEING REACTORS — MODERNIZATION

There are several reasons behind licensees’ modernization projects. Safety issues have become known during the operation of the reactor which were not considered when the nuclear facilities originally were constructed. Economic considerations related to increased demands for control and test of ageing parts of the facility is another reason for modernization. Thus, modernization can be initiated by the licence holder or be required by the regulator. Introducing new digital techniques in instrumentation and control, including control rooms, is one example of modernization carried out in facilities.

The challenge for the licence holder related to the modernization programme is to have knowledge about the original design and the rationale behind it, the changes made during the period of operation, as well as knowledge about new technical developments, e.g. in the area of software. In addition, the licence holder must have the capacity and competence to assess the safety of the plant, as well as to feed into this process all the experience gained worldwide on safety issues.

Here again the regulator has to adapt its oversight strategy to make sure that the licensee has the capacity to perform safety analyses with respect to the changes introduced in the plant. Several modernization projects will also require new competences for proper judgement of the impact on safety.

4. WASTE STREAMS AND SPENT NUCLEAR FUEL FROM NUCLEAR ACTIVITIES

Facilities have to be established to take care of all arising waste categories and spent nuclear fuel. The challenges comprise research activities, costs, construction, decommissioning, as well as public involvement in the siting process. It is important that all these issues are clarified in good time before decommissioning starts.

5. TERMINATION OF OPERATION

In general, there is a time span between the decision to close a reactor, the actual closure and the decommissioning of the plant, irrespective of the reason behind the closure. One of the challenges for the regulator is to have a strategy and the competence to oversee that the operator is maintaining a high safety performance in the time span between the decision and the actual closure. The operator has to ensure that safety culture, competence and capacity are maintained for several years in a plant not to be used in the future. This might be one of the most difficult areas to handle for the licensee as well as for the regulator. Internationally, there is only limited experience in this area so far.

6. HUMAN ASSETS

The nuclear industry has developed from a time when design and construction were the main tasks into today's production phase. In this period, the competence and resources available in the nuclear industry and at the regulatory bodies have changed. Even if we are no longer in the design and construction phase today, I believe that the nuclear discipline still is an intellectual challenge for students who have a technical interest. We also have to recognize that people working in the nuclear field are well educated and trained, enabling them to be employed also outside the nuclear field. Therefore, we have to attract and be able to keep skilled co-workers.

The challenge for society is to evaluate the competence needed now and in the future, and to ensure that education and professorships at universities are available in specific critical areas. But this is not enough. It is also essential that universities find the means to attract students and for licensees and regulators to be attractive employers. We have to compete with other technology industries in recruiting, as there is a decreasing tendency for students to engage in technical studies.

7. NEW REACTORS

The changing environment related to nuclear will involve licensing of new reactors and development of new reactor concepts, such as Generation IV and the INPRO programmes. This will involve and challenge regulators and with that, influence safety, security and non-proliferation in the new designs. The question of the licensing procedure for new designs has to be addressed in the national as well as international arena.

8. SECURITY

Questions related to security in nuclear installations have increased in importance in the past years in many countries. It has to be recognized that security is needed for safe operation but also that enhanced security in an installation may have a negative impact on safety. This implies an enhanced interaction by national regulators with respect to safety and security measures.

9. INTERNATIONAL COOPERATION

The challenges in the future for the regulators are, in many cases, addressed by international cooperation. I believe that the IAEA as well as the OECD/NEA play important roles for the development of safety, security and non-proliferation areas to address these challenges.

10. OVERSIGHT STRATEGIES AND INSPECTION PROCEDURES

I have mentioned several changes in the environment which will imply new tasks and competences for the regulator. Most of us cannot expand our organizations. We have to cope with the new situations by adapting our oversight strategies and inspection procedures without losing in effectiveness.

The nuclear industry has developed from a time when design and construction were the main tasks of today's production phase. In this period, regulatory practices have changed. In the construction phase, the approach was descriptive, and due to lack of knowledge and experience, there was conservatism in several judgements. The benefit was significantly large margins of safety. Today, several of the deterministic requirements are discussed and, in some countries, a more risk informed approach is used by the regulator. In addition, several regulators are overviewing more and more the management of the facilities. The tendency is also, to a greater extent, to rely on the self-assessment of the licensee. Many regulators are using a mixture of these and several other oversight methods in the overall strategy. It is a challenge for us to obtain the mixture which gives the best regulatory effect. Only a few studies have been carried out with respect to oversight strategies and I have seen none with respect to regulatory effectiveness.

However, it is important to realize that the choice of oversight strategy and inspection practice cannot automatically be transferred from one country to another. The strategy you choose will depend, for instance, on the legal framework in the country, the trust you have in the operator, and on the experience and knowledge in nuclear safety that exist in a country.

11. INTERNATIONAL COOPERATION

Essential input towards maintaining and enhancing a high level of safety derives from information and experience that is exchanged from research activities, from events and from day-to-day operation at international, regional, as well as national levels. Here, of course, the IAEA plays a central role.

Several countries use the IAEA safety standards as a basis for formulating national regulations. These standards have to be seen as good practices or tools for benchmarking. They cannot be used as national legal requirements without appropriate adaptation.

The IAEA safety standards are the result of international experience in nuclear safety since the first nuclear power reactor was constructed and taken into operation.

It is important that the ongoing work on safety standards, also in the future, will be one of the IAEA's main tasks.

In addition, it is important to evaluate the effectiveness of our regulatory approaches. This can be done in several ways. Using the IAEA's services, such as the IRRT, is one of them. It has most efficiently been used in the past. I believe that the IAEA's ongoing work to make these services more efficient is important, enabling the self-assessment of our regulatory performance.

Indicators are mentioned as a tool for evaluating both the licensee and the regulator. I believe that indicators may be used but only as a supplement to other measures. However, I believe that indicators can be used to promote a change in behaviour in an organization.

Many of the challenges we, as safety regulators, can see in front of us can be addressed by international cooperation. I, therefore, believe that this conference is timely to identify issues for international cooperation on emerging safety topics resulting from a changing environment. I look forward to the outcome of the discussions at the end of this week.

FINNISH APPROACH TO THE ASSESSMENT AND LICENSING OF A NEW NUCLEAR POWER PLANT

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1. PROGRESS OF THE LICENSING PROCESS

1.1. Government decision on the nuclear option

The Finnish Government made in January 2002 a Decision in Principle (DiP) which concludes that constructing a new nuclear power plant (NPP) in Finland is in line with the overall good of society. The Finnish Parliament ratified the decision in May 2002 with votes of 107 for and 92 against. That was the first step of the NPP licensing, which according to the Nuclear Energy Act has to be taken before a utility is allowed to make significant investments in a new nuclear power plant project. The purpose of making the political decision first is to ensure that the politicians are not under pressure or having to worry about the loss of large investments if they decide not to approve a proposed new project.

DiP was also the final step of the political decision making process. It authorized the electricity generating company, TVO, to continue preparations at the commercial and technical level for the construction of a new NPP unit.

1.2. Licensing process of Olkiluoto 3

The first step of Olkiluoto 3 licensing was the Environmental Impact Assessment (EIA). It was started in May 1998 and finished in January 2000. The EIA is not included in the Nuclear Energy Act from the year 1987, but it is based on environmental legislation issued in the early 1990s. However, the EIA fits very well into the licensing process because it provides useful input for the DiP.

It is important to note that the EIA does not require specific information on plant type and technology. The environmental impacts are in any case well known on the bases of operation from NPPs and on the basis of safety requirements for a new plant. This approach is necessary for the logical progress of the licensing process and for avoiding unnecessary early investments.

An EIA was done separately by two utilities for two alternative sites, Loviisa and Olkiluoto. Both of these sites already have NPPs in operation.

The DiP application was made in November 2000, listing seven NPPs as possible alternatives for the new plant. The main criterion of DiP approval is that a new NPP is in line with the overall good of society. This decision has to be made by the Government, and after the decision, it has to ask for ratification by the Parliament. There are two mandatory conditions that have to be met before a decision can be made. First, the regulatory body STUK has to state that no safety issues can be foreseen that would prevent the proposed plant(s) from meeting Finnish nuclear safety regulations. And second, the proposed host municipality has to agree to provide the site.

Two other licensing steps after the DiP are similar to a common worldwide practice: construction permit and operating licence. These are intended to be left in the hands of technical experts, and at least so far this seems to come true as planned.

1.3. Conclusions in STUK's statement on the DiP

STUK had for many years reviewed informally most of the alternative plants presented in the DiP application, and it was able to make its statement on short notice when the process became formal. It concluded that all alternative NPPs mentioned in the application could probably be made to fulfil Finnish safety requirements. On the other hand, none of the plants seemed acceptable as presented and some modifications would be needed in all designs. Some plants would need more changes than others, and specific safety issues were identified for each alternative plant type.

STUK concluded also that the utility TVO needs to develop the competence of its own organization during the contracting and construction phase, taking into account the planned lifetime of 60 years.

After the statement had been issued, the terrorist act of 11 September 2001 took place, and the Ministry preparing licensing documents asked whether it was possible to provide necessary protection even against the worst plane crashes. STUK issued new safety requirements on external impacts, and concluded that it was feasible to meet them.

1.4. Political decision on the DiP

Government made its positive decision in January 2002. It did not discuss the issue extensively at this stage because the aim was to send it to Parliament for discussion and possible ratification. Without a positive Government decision, the issue would not have gone to Parliament and the process would have stopped. All parties were split in this matter (except the Green Party), and thus the Government wanted to have all Parliament involved in the decision making.

The following supporting arguments were given by the Government:

— Importance for electric power supply;
— Together with energy savings and increased use of renewable power sources, a new NPP can keep greenhouse gas releases within the agreed target;
— STUK's positive statement on nuclear safety;
— Site suitability and acceptable environmental impact;
— Adequate arrangements for supply of nuclear fuel and management of nuclear waste;
— Full private funding;
— Ability of the applicant to implement the construction project.

In Parliament, the new nuclear plant was the most discussed topic in the spring of 2002. The parliamentarians made a thorough assessment in eight standing committees (there are 15 committees in total) before voting in the plenary session. Of the 200 Members of Parliament, 115 attended the work during spring 2002 in one or more committees. Each committee heard a very large number of experts they had invited for interviews (up to 85 in one committee). Experts representing a full spectrum of views on nuclear energy gave a variety of different viewpoints.

Arguments listed for the Parliament's plenary session in favour of a new NPP were as follows:

— A new plant helps to maintain multiple sources for power production, thus increasing self-sufficiency and improving preparedness for crisis;
— Production costs of nuclear power are smaller than costs of other alternatives;
— Accident risks are small;
— There are no releases to the atmosphere or otherwise, so the environmental impact is small;
— From the national economics point of view, nuclear power is the best way to reduce carbon dioxide releases;
— Nuclear fuel supply and nuclear waste management can be arranged using the existing infrastructure;
— The only realistic alternative to a new NPP would be increased use of gas for power production, but this would strongly increase the dependence on

import from the Russian Federation and increase the power price and the need for State support to the energy section.

Public opinion that had been about fifty-fifty for and against a new NPP changed dramatically after the DiP ratification. A poll conducted among the general public immediately after the Parliament ratification indicated that a clear majority of those questioned approved the decision: 55% were for, 31 against and 13 undecided. Main editorials in all larger newspapers welcomed the decision in a positive spirit. According to a study done for the Ministry for Trade and Industry, not a single main editorial took a negative position on the decision.

Political discussion stopped very quickly, and also the opposition concluded that the final decision had been made. Nuclear power was not an issue in Parliament election in spring 2003.

1.5. Milestones of the contracting stage

TVO started preparation of tender documents after the DiP in May 2002, and the call for tenders went out at the end of September 2002. The technical requirements in the tender documents were specified by using the European Utility Requirements (EUR) document as a reference. The application of the EUR document, compiled in cooperation with utilities from many European countries, represented a new approach that had not yet been used earlier. TVO's specifications complemented the EUR mainly in those points where Finnish requirements are more stringent.

Four tenders were submitted at the end of March 2003.

Vendor and site were decided in October 2003, but two different plant types by the vendor were still considered at that stage. Selection of the site was announced. It is Olkiluoto, where the same utility already has two NPP units in operation since 1978 and 1980. The contract was signed on 19 December 2003. The plant vendor is Consortium Framatome ANP–Siemens, led by FANP. Delivery is of the turnkey type, and the plant type is EPR, which is a 1600 MW(e) PWR.

1.6. Construction permit process

Processing of the construction permit (CP) application, in consultation with the stakeholders, is the task of the Ministry of Trade and Industry. The construction permit is to be granted by the Government. The Government has publicly committed to take fast action after the Ministry has received STUK's statement on adequate safety.

The construction permit application was submitted to the Ministry of Trade and Industry on 8 January 2004. All stakeholders except STUK have already made their statements, as requested by the Ministry. No significant objections have been expressed against the CP.

The Ministry asked STUK to give its statement on the safety of the plant by the end of 2004, if possible. Gradually improving revisions of CP documents have been submitted to STUK between January and September 2004.

A number of preparatory works have been started by the utility and the vendor before receiving the CP. Site works started immediately after signing the contract, including excavation and removal of 500 000 m^3 of soil and rock by the end of 2004. Also, the bottom of excavations is planned to be levelled with concrete before formal CP. In addition, construction of site infrastructure goes on at full speed, including construction of roads, temporary office and maintenance buildings, fences, and power and water supply to the construction site. It is still open whether the utility is to be permitted to install without a formal CP the anchors for prestressing cables of the reactor building and to install reinforcing steels for the first concrete. If everything goes as the utility has planned, the CP is issued as needed to permit pouring first concrete to the building bottom plates on 1 May 2005.

The reactor pressure vessel and SGs were purchased already at the risk of the vendor in early summer 2003, and manufacturing started in the fall of 2003.

STUK has a number of activities during the CP stage, including:

— Review of submitted CP documentation: PSAR, PSA, safety classification, QM of applicant and vendor, emergency plan, security plan, safeguards plan and applicant's own assessment of fulfilment of safety criteria;
— Auditing of plant vendor's design process and project management;
— Independent calculations to validate accident analysis, both in-house at STUK and in cooperation with expert organizations;
— Several meetings every week with the licence applicant and vendor on technical and management issues involved in the CP review;
— Inspections on design and manufacturing of the reactor vessel and steam generators, starting already in October 2003 before the main contract had been signed;
— Other component specific inspections starting in parallel with the CP application review.

In support for its CP review, STUK has contracted specific analysis and assessment tasks to the Finnish organizations VTT and Lappeenranta Technical University, and to the German organizations GRS and ISaR. In addition, information has been exchanged with French regulators and IRSN on the assessment of several design topics, in specific I&C systems.

2. SAFETY REQUIREMENTS IN FINLAND: DEVELOPMENT AND SELECTED EXAMPLES

2.1. Development of regulations in Finland

The need for Finnish nuclear safety regulations arose in 1970 when a decision to buy a Soviet designed NPP had been made (Loviisa, two WWER-440 units). STUK has since then developed and updated national safety regulations.

Safety requirements are based on well established national and international practices. IAEA safety standards are becoming increasingly important. The leading principle has been to incorporate the state of the art in the nuclear safety technology into the safety requirements. This implies alertness to operating experience, research, and development of science and technology.

Mandatory safety requirements are presented in Government Decisions that were drafted and proposed for the Government by STUK. As part of the preparation process, views of stakeholders were requested and taken into account. These mandatory requirements are of the type of general safety principles.

Detailed regulations called YVL Guides are issued by STUK, but the preparation involves thorough discussion with stakeholders and in the national Nuclear Safety Advisory Committee. YVL guides are rules that shall be complied with unless some other acceptable procedure or solution is presented to STUK by which the safety level laid down in an YVL guide is achieved.

Currently there are 73 YVL Guides in force. The Guides are up to date, as needed for licensing of the new plant. Finnish nuclear and radiation legislation, as well as Goverment Decisions and YVL Guides are available on the Internet at www.stuk.fi.

2.2. General principles used in Finnish safety requirements for design

The nuclear safety philosophy applied worldwide since the late 1960s has been 100 per cent successful at commercial nuclear power plants, and there has never been a large radioactive off-site release at plants which apply this philosophy. It is, therefore, well founded to keep safety requirements based on this successful philosophy. The core of the safety philosophy is the defence in depth principle.

Accidents forming an envelope for the potential spectrum of accidents are postulated as the design basis of the reactor core, the release barriers and the safety systems. The traditional deterministic approach to safety is thus followed. This provides clearly specified safety limits and safety margins, and also protection against less specific and unforeseen accidents. This approach has successfully terminated all accidents that had occurred at the current generation of plants.

As a necessary complement to the deterministic safety design, a probabilistic risk analysis (PRA) is required to verify the reliability of all vital safety functions. PRA results indicate the balance of the design features from the safety point of view, and the weakest points that possibly need to be strengthened. Experience from the current generation of plants has shown that insights from the PRA have helped to eliminate risks that had gone unnoticed in the original design. A risk informed approach to safety thus strengthens the traditional design practice.

All calculations in the safety analysis have to be made with models that simulate the physical reality in the best possible manner. Safety margins must be used in the model parameters to account for estimated inaccuracies in simulation of the real situation, and failures in the safety systems have to be postulated as specified in detail in the YVL Guides. Conservative 'unphysical' assumptions should be avoided in order not to give a distorted picture of the course of accidents.

Acceptance criteria for the safety analysis are connected with the actual estimated probability of each accident category. Acceptance criteria take into account what might actually be tolerable consequences for society (releases, doses) and to avoid accident escalation (physical 'cliff-edge' limits). No physically meaningless limits are used, such as the traditional acceptance criteria for LOCA analysis: maximum fuel temperature of 1204°C and maximum cladding oxidation of 17%.

2.3. Example of defence in depth based deterministic approach: Loss of coolant accidents

Postulated loss of coolant accidents are important for defining the design targets for fuel, reactor core, mechanical structures and safety systems, as well as for setting respective operational limits for them. They also give a basis for assessing the consequences and acceptability of design modifications.

Design basis requirements based on postulated LOCAs take into account the experience from the safety systems at the existing plants. It is STUK's position that it is not wise to remove the protective features that are proven to be feasible. Among these are the fuel and core design limits, the ECCS and the containment. Besides, it is well founded to utilize the development of technology by making safety improvements that are reasonably achievable. This approach provides good protection against unforeseen events and events left outside the design basis.

Key points of the defence in depth in this connection are:

(1) Eliminate the possibility of sudden large breaks of the reactor coolant circuit by applying the break preclusion (BP) principle.
(2) Postulate a sudden guillotine break of the largest pipeline, but limit the physically possible maximum break flow areas (and consequent fluid transients in the reactor coolant circuit) by means of pipe whip restraints. Use the maximum estimated break flow as the design basis for specific mechanical structures.
(3) Postulate a loss of coolant accident that is equal to a free flow from both ends of the broken pipe. Use the large break LOCA as the design basis for safety systems, thus providing protection also for unforeseen events. Study the actual strength of mechanical structures under the influence of dynamic forces, by using best estimate assumptions for physical phenomena.

The BP principle used to eliminate the possibility of sudden large breaks of the reactor coolant circuit must involve:

— Qualified construction (materials, fabrication, QA), operation (loadings, chemistry) and surveillance to prevent major cracking throughout plant life;
— Strength analysis to demonstrate adequate safety margins in all design basis load conditions;
— Effective in-service inspections of welds and other stressed areas;
— Effective leak detection and verification of the leak-before-break principle.

Limitation of the break flow area after a potential guillotine break by restricting the pipe motion is required in order to limit dynamic forces on mechanical structures. Vital structures that need to preserve their integrity after a sudden (1 ms) limited break with adequate margin are among others:

— Support and anchoring structures of the main components;
— Reactor pressure vessel internals, including fuel (mechanical strength) and control rod drive systems;
— Steam generator tubes and other internals;

— Main coolant pump flywheels;
— Reactor containment internals.

The requirement to use a double ended leak as the design basis ensures that safety margins remain at the level achieved in the current PWRs. Large break LOCA must be taken into account as the design basis for:

— Nuclear fuel (thermal and hydraulic design);
— Reactor core (thermal and hydraulic design);
— Emergency core cooling systems;
— Containment, including penetrations;
— Environmental qualification of equipment inside the containment.

Furthermore, beyond design studies are made to demonstrate the actual mechanical strength under the influence of dynamic forces that would result from the maximum free leak from both ends of the broken main coolant pipe. In those studies, best estimate assumptions are used for physical phenomena such as break opening time. Items to be looked at are the fuel, reactor vessel internals, steam generator tube bundle and its supports, steam generator primary side manhole, and main coolant pump flywheel.

2.4. Design basis for containment

The design of containment must consider a double ended large break LOCA, loads caused by phenomena expected after a severe core damage, and external events. Adequate capacity to carry pressure loads and to limit radioactive releases must be shown in conditions expected after a large break LOCA. This gives a sound basis to manage also severe accidents.

All foreseeable loads threatening the containment integrity in connection with severe core damage must be identified, and necessary protection (prevention or mitigation) must be provided against each load. At least the following issues have to be considered in severe accident management strategy:

— High pressure failure of reactor vessel prevented by dedicated depressurization system;
— Hydrogen management with autocatalytic recombiners to prevent detonation;
— Low pressure melt arrested in a core catcher, with passive long term cooling;
— Containment integrity against dynamic loads;

— Containment pressure management in the long term;
— Containment leaktightness criteria from release limits.

AC power supply systems and I&C systems dedicated to supporting severe accident management are required. For systems dedicated to protection against severe accidents, the single failure criterion applies.

Potential external events must be identified and protected against. As concerns an aircraft crash, the design basis must include large passenger and military aircrafts. After a crash, no immediate release of any significant amount of radioactive substances must take place. Key safety functions must be initiated and maintained in spite of the direct consequences of the event (penetration of structures by impacting parts, vibration, explosion, fire).

Other external impacts to be considered are microwave weapons and biological weapons.

2.5. System design requirements

The safety classification must take into account the lessons learned from PSA.

N+2 failure criterion is required for systems that deal with design basis events. In addition to redundancy, diversity has to be provided where feasible. Segregation of subsystems has to be based on systematic layout, with physical separation by distance or reliable barriers.

Proven technology is required and this can be demonstrated with properly evaluated operating experience. For novelties, such as ‘passive’ systems, experimental demonstration and analysis are necessary.

Adequate reliability of systems performance and safety margins are assessed based on results of deterministic and PSA studies.

2.6. Classification of design basis events and acceptance criteria

Design basis events are classified in order to set fuel damage and radioactive release criteria. Event categories include anticipated transients, design basis ‘minor and major’ accidents, and severe accidents.

As a deviation from standard practice, it is worth noting that:

— Single SG tube rupture is considered an anticipated transient;
— Large primary-to-secondary leak and ATWS are considered as design basis accidents.

Acceptance criteria for preventing or limiting fuel damage are the following:

— Anticipated events, f > 10–2/a: 95/95 confidence with respect to no DNB or dry-out, no (internal) fuel melting, nor damage due to pellet–cladding mechanical interaction;
— ‘Minor’ design basis accidents, 10–2/a > f > 10–3/a: number of rods in heat transfer crisis < 1%, PCT < 650° C, and extremely low probability of fuel damage by the mechanical interaction between fuel and cladding;
— ‘Major’ design basis accidents, f < 10–3/a: the higher the frequency of a postulated accident, the smaller the number of damaged fuel rods; number of damaged fuel rods < 10%; enthalpy limit 140 cal/g for failure (230 cal/g not to be exceeded); no danger to long term coolability.

Acceptance criteria for radioactive releases and maximum doses to the general public are the following:

— Normal operation: radiation dose limit 0.1 mSv/a for the entire site;
— Anticipated events: radiation dose limit 0.1 mSv;
— Design basis accidents: radiation dose limit 5 mSv;
— Severe accidents: release < 100 TBq ^{137}Cs equivalent, no acute health effects (this can be fulfilled only if containment integrity is guaranteed).

2.7. Fire protection

For adequate fire protection, high importance needs to be given to plant layout. Systematic and complete division of the whole plant into fire areas housing separate redundancies is necessary.

Separation with structures having adequate fire resistance and reliable fire suppression within fire zones is emphasized. Spaces in need of special attention are cable channels, cable spreading areas and the reactor building.

2.8. Fuel burnup

In the YVL Guide a limit of 40 MW·d/kg U is given for fuel assembly average burnup. This is used if higher burnup cannot be supported with adequate experimental evidence. For the operating plants in Finland, a maximum fuel assembly burnup of 45 MW·d/kg U has been approved, based on experimental evidence. The licence applicant has indicated a target value of 50 MW·d/kg U for burnup, but no regulatory position has been taken at this stage.

OUTLOOK OF RISK INFORMED REGULATION IN JAPAN

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Abstract

In Japan, safety goals are proposed and risk informed regulation (RIR) is being introduced. The safety goals will be utilized to improve the current regulatory system and, after experiences of their usage are compiled, to judge the safety of individual facilities. The RIR concept is being applied to all stages (i.e. siting, design, construction, operation, inspection and decommissioning, etc.) of every type of nuclear facility and the activities aiming at more effective and efficient regulation. The current emphasis is placed on improvement of regulatory inspection of nuclear power plants, but other types of applications are anticipated, for example, in the rule making for seismic issues.

1. INTRODUCTION: HISTORY AND THE PROGRESS OF PSA USAGE IN JAPAN

The reflection of risk information, which is obtained by a probabilistic safety assessment (PSA), is essential to establish an effective and efficient regulatory system. Based on this internationally common understanding, PSA methods have been developed and utilized in many countries.

In Japan, the Japan Atomic Energy Research Institute (JAERI) first developed a series of methods for PSAs for light water reactors. Then the Nuclear Power Engineering Corporation (NUPEC) and industry established their own PSA methods. NUPEC's activities were succeeded by the Japan Nuclear Energy Safety Organization (JNES) when it was established in 2003. Aiming at using PSA results in 'formal' processes, such as regulation, the Nuclear Safety Research Association (NSRA) and the Atomic Energy Society of Japan (AESJ) developed manuals and standards to conduct PSAs. In addition, the former Power Reactor and Nuclear Fuel Development Corporation (PNC) developed PSA methods for fast breeder reactors and the Japan Nuclear Fuel Limited (JNFL) developed ones for reprocessing plants.

The PSA results have been applied to many safety related issues by industry and the regulatory body. For example, the safety design of ABWRs was determined to effectively reduce the possibility of severe accidents reflecting PSA results. Accident management (AM) measures were proposed by the industries against the weak points identified by plant specific PSAs and the effectiveness of such measures was examined by PSAs which took such measures into account. The safety of aged nuclear power plants was assessed by PSAs which were carried out in a process of periodic safety reviews (PSRs). Adequacy of test intervals, inspection intervals, allowed outage times, etc., were also discussed based on PSA results.

In 2003, there were some areas of remarkable progress in Japan:

(1) The Nuclear Safety Commission (NSC) proposed Safety Goals [1];
(2) The NSC stated a policy to introduce risk informed regulation (RIR) [2];
(3) The Nuclear and Industrial Safety Agency (NISA) started discussions to embody RIR [3] reflecting the NSC policy statement.

The present paper describes outlines of the proposed safety goals and the NISA's policy to embody RIR, as well as the author's personal views on these matters extending to ongoing issues.

2. SAFETY GOALS PROPOSED BY THE NUCLEAR SAFETY COMMISSION

In 2003, NSC published the proposed safety goals [1]. The objective of the safety goals is to reasonably limit the public risk posed by nuclear accidents. The proposed safety goals are common to all the nuclear facilities and activities and consist of one qualitative goal and two quantitative goals:

— Qualitative goal: The possibility of health effects to the public caused by utilization of nuclear energy should be limited to the level not to cause a meaningful increase in the public risk.
— Quantitative goals:
- The averaged risk of early fatality due to nuclear accidents, which is posed to individuals of the public who live in the 'vicinity of the site boundary', should be less than the probability of approximately 10^{-6} per year.
- The averaged risk of latent fatality by cancer due to nuclear accidents, which is posed to individuals of the public who live 'within a certain distance from the facility', should be less than the probability of approximately 10^{-6} per year.

Here the 'nuclear accidents' include those not only caused by internal events but also caused by external events except for intentional human-made events. The precise definitions of 'vicinity of the site boundary' and 'within a certain distance from the facility' are not made yet. These goals will be applied to various safety issues as trial usage and will be finalized when their applicability is ensured.

Figure 1 shows a comparison between quantitative goals and health risks already existing. According to Japan's statistics in 2001, the death rate by cancer is 2.4×10^{-3}. Comparing with this number, the safety goal for latent fatality is more than three orders of magnitude lower. The total death rate due to all the accidents is 3.1×10^{-4}. The safety goal for early fatality is more than two orders of magnitude lower than this number.

Of course, compared with the quantitative goals are always risks evaluated for individual facilities. At present, however, the goals will not be

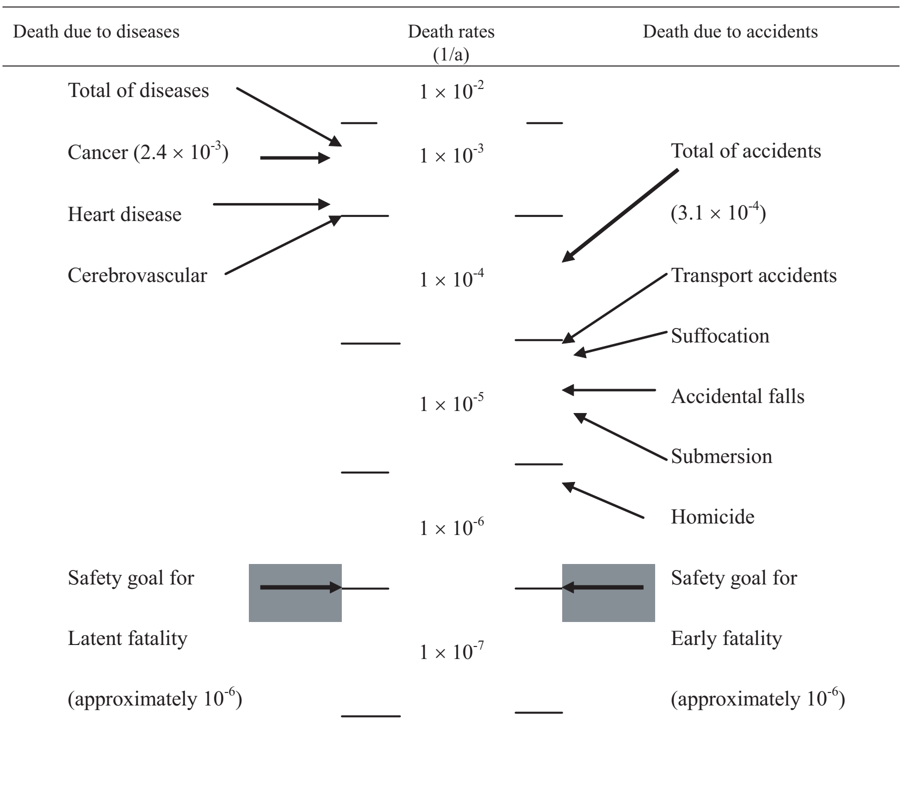

FIG. 1. Comparison of quantitative goals and existing risks. (Source: Vital Statistics 2001, Labour and Welfare Ministry, Japan.)

used for a direct judgement of whether individual facilities are safe enough but they will be used to judge the adequacy of the regulation referring to the risk numbers of these facilities. When risks of some facilities exceed the goals and those of other facilities do not, NSC and NISA will analyse and identify the reasons which resulted in such a difference. Then these organizations will consider a possible rationalization and revision of the regulatory rules so that all such facilities will satisfy properly the quantitative goals. In this sense, the quantitative goals are reference levels with which adequate regulatory policies are discussed.

The reason why the quantitative goals are expressed by the 'approximate' numbers is to take into account the uncertainties in PSA results. Even in the case where risks evaluated for some facilities are slightly larger (Factor 2 will be used in the trial usage period) than the quantitative goals, it does not automatically mean that the regulatory rules applied to those facilities are inadequate but can be adequate provided that reasonable safety measures are taken in those facilities.

Safety performance objectives, which are compatible with the quantitative goals, are sought for every type of nuclear facility and activities, e.g. nuclear power plants, reprocessing plants, high level radioactive waste disposal, etc., since a direct application of health effect goals is not always easy.

In parallel, efforts of upgrading of PSA methods, provision of PSA manuals and standards, establishment of decision making methods taking account of large uncertainties in PSA results, communication on the usefulness of the safety goals with public, etc., are undertaken.

3. POLICY TO EMBODY RISK INFORMED REGULATION BY NISA

In 2003, NSC also decided the basic policy to introduce the RIR concept in nuclear regulation in Japan [2], aiming at: (1) enhancement of the rationality, consistency and transparency of safety regulation and proper allocation of resources for activities of safety regulation; and (2) improvement of regulation, which is currently based on conventional engineering judgement and deterministic safety assessment, by utilizing PSA results, while maintaining the defence in depth concept.

In response to the above NSC basic policy, NISA started discussion to embody RIR [3]. The NISA's policy is summarized as follows:

— The RIR concept will be applied to all stages (i.e. siting, design, construction, operation, inspection, decommissioning, etc.) of every type of nuclear facility and activities.

- All the regulatory issues are targets of the RIR policy to realize more effective and efficient safety regulations, although priorities will be given to the respective issues taking account of, firstly, safety significance and urgency of the issues and, secondly, maturity of PSA methods to resolve the issues.
- With these considerations, the most urgent issue to be studied now is improvement of inspection of nuclear power plants.
- The way to utilize PSA results in regulatory processes will be finally established after sufficient experiences are compiled in a trial usage period.
- Academic and industrial societies are expected to provide standards on the PSA methods.

At present, NISA is going to establish the concrete approach to utilize PSA results in nuclear regulation, especially for inspections at nuclear power plants.

Regulatory bodies have a responsibility to explain their policy on how they are acting to effectively reduce nuclear risks. The NISA is to make efforts to promote the understanding of the general public, asking for their comments to its policy on RIR.

4. AUTHORS' VIEW

PSA is a method to estimate a safety level of a system in the future by integrating existing and past data (e.g. system configuration and component reliability), as well as expert judgement (e.g. estimation of future earthquake occurrence), on all the elements which affect the system's safety. Due to this nature, PSA results always include uncertainties. Care must be taken in using PSA results, especially in a formal usage, such as nuclear regulation.

The authors' image of RIR under the current situation in Japan is illustrated in Fig. 2, which is slightly modified from a figure in Ref. [4].

Regulatory rules, which are based on a defence in depth concept and utilize a deterministic safety assessment, were developed based on expert judgements (in other words, probabilistic consideration) even when the PSA technique was not established yet. Nuclear facilities were designed, constructed and operated according to these regulatory rules. Now the safety of these facilities is examined with PSA, which is a systematic structure of probabilistic consideration. The results of PSAs can be reflected in decision making on the modification of design and the operation of facilities by NSSS vendors and operators and in revision of regulatory rules by regulators.

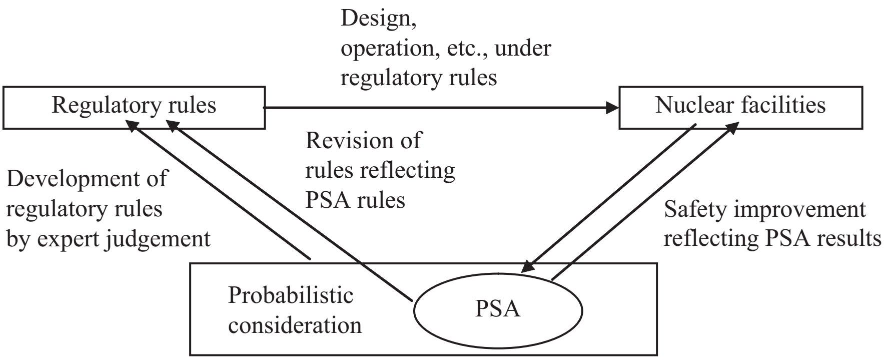

FIG. 2. Relationship between probabilistic consideration and regulatory rules.

If the PSA methods and the PSA utilization techniques are fully matured, PSA results will be directly utilized for regulatory judgement of individual facilities. In this case, PSA is a decision making tool to complement deterministic regulatory rules. In the premature stage, however, PSA results should be utilized mainly for rationalizing and revising the existing regulatory rules.

An example of the author's proposal to utilize PSA results is illustrated in Fig. 3 [5].

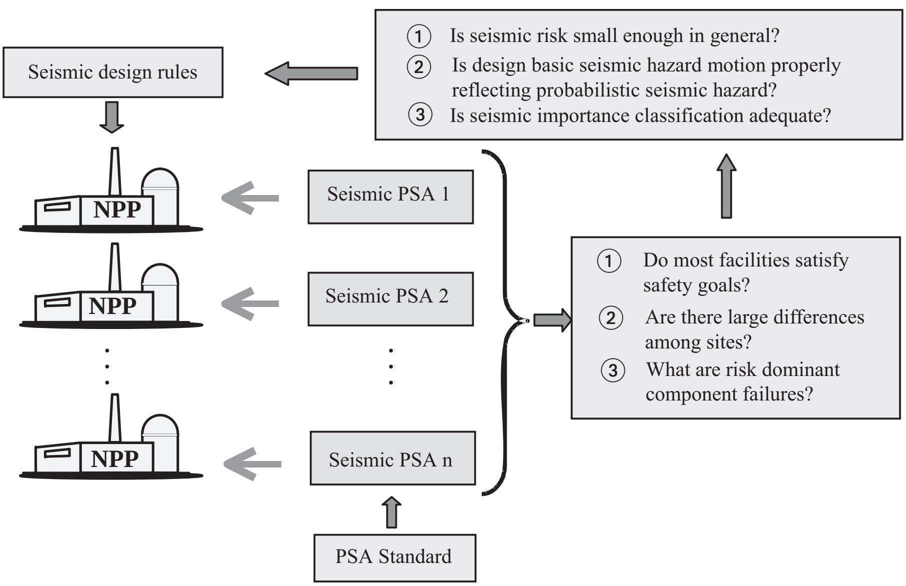

FIG. 3. Proposed application of safety goals to revising seismic design rules [5].

One of the most important and urgent regulatory issues in Japan is the revision of seismic design rules for nuclear facilities. Regarding this issue, the first step should be to evaluate seismic risks of existing facilities using a seismic PSA method (preferably according to a PSA standard provided by an academic society). Some results may satisfy the proposed safety goals and others may not. These results should be used to identify weaknesses in the current seismic design rules and to improve them.

The authors believe that such a usage of safety goals is similar to the early usage of safety goals from the United States of America. After sufficient experiences of the utilization of PSA results and safety goals are accumulated, PSA results will be utilized more widely, including the judgement on whether individual facilities are safe enough.

5. SUMMARY AND FUTURE ISSUES

Usage of PSA results in safety improvement and the regulation of nuclear facilities and activities is becoming popular in Japan. The safety goals are proposed and the RIR concept is to be adopted, aiming at more effective and efficient regulation.

From now on, efforts will be made to:

(1) Develop safety performance objectives (e.g. core melt frequency target for power reactors) compatible with quantitative goals;
(2) Establish effective and efficient rules for regulatory inspection;
(3) Seek approaches to revise existing regulatory rules reflecting the results of PSAs which are carried out for individual facilities;
(4) Seek approaches to directly assess the safety of individual facilities using the results of facility specific PSAs;
(5) Resolve technical issues still remaining (e.g. decision making under uncertainties) in utilizing PSA results in regulatory decision making;
(6) Provide PSA methods and data which are suitable for resolving specific safety issues;
(7) Train staff of the regulatory body on PSA technique so that they will understand well the implications of PSA results;
(8) Especially, keep good communication with stakeholders on such new regulatory policies.

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COMMUNICATION WITH THE PUBLIC
An approach to building public confidence in nuclear regulation in the Republic of Korea

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Abstract

The Republic of Korea is undergoing a dramatic change in every sector of society, including nuclear safety and regulation. The public demands more information on nuclear safety and regulatory issues, and local residents require more involvement in the regulatory process. Such changes are attributable to the recent expansion of communication, to which nuclear regulators should pay keen attention in order to build public confidence in nuclear regulation. The regulatory body in the Republic of Korea experienced the hardship of public distrust early this year when its decisions on nuclear safety matters were rejected and reinvestigation was required by local residents. Lessons learned were that the regulatory body is accountable for its duties and also is responsible for satisfying the public through adequate communication. Acting on the experience, the Republic of Korea has formulated strategies for more effective communication: planning to identify public needs, using an easily accessible and understandable mode, providing information in an open and transparent manner, and attempting new approaches, such as role playing. International cooperation between technical support organizations (TSOs) was suggested to enhance their credibility. And the development of a communication review service was proposed as a future IAEA activity.

1. INTRODUCTION

The importance of communication with the public and other stakeholders on safety and regulatory issues has been recognized by many national regulatory bodies and intergovernmental organizations, i.e. the IAEA and the OECD/NEA. Some regulatory bodies are already set up and are operating an office dedicated to public communication. The IAEA established communication requirements with such standards as GS-R-1 [1] and the Basic Safety Standards [2], and presented relevant guidelines and recommendations in Safety Reports Series No. 24 [3] and IAEA-TECDOC-1076 [4]. The OECD/NEA held a workshop, Investing in Trust: Nuclear Regulators and the Public, in 2000 [5] and established a special Working Group on Public Communication of Nuclear Regulatory Organizations.

The Republic of Korea is undergoing a dramatic change in every sector of its society these days. Once highly centralized Government has now become decentralized, transferring more power to local governments. Diverse citizen groups with different causes and goals started to take the centre stage, pushing the social transformation ahead to a more democratic society and demanding more individual citizen's rights. Unfortunately, however, the vast majority of these groups looks at nuclear technologies with scepticism. Citizens in the communities surrounding nuclear power plants continue to raise concerns about the safety of the plants. They consistently demand their direct involvement in the decision making process, exercising their social and political influence, in light of the growing interest in the safety of nuclear facilities.

Such proactive demand for public involvement is attributable to the widespread availability of electronic communications and information technology, which has made a major impact on public awareness of nuclear safety issues. Conversely, the nuclear regulatory body and the operating organization are constantly under pressure to communicate more actively with the public to satisfy their demand for knowing about the safety of the nuclear facility and for participation in the decision making process.

The means of communication employed by nuclear licensees and regulators may include such mechanisms as collecting the opinions of interested parties, providing information and ensuring public involvement in the decision making process. The ultimate goal of such communication is to make the public assured of nuclear safety, and thus to earn the trust of the public regarding nuclear safety. Based on this, licensees will be able to realize their business objectives through the smooth operation of their business while regulators may achieve the regulatory objectives regarding public satisfaction (Fig. 1).

In order to promote public confidence in nuclear regulations, it is a requisite for the regulatory body to fully demonstrate its compliance with global standards in establishing a national regulatory infrastructure and its competences to perform regulatory activities according to the standards. In this context, it is also important to set up an efficient and effective system for communication with the public. Without such regulatory infrastructures and adequate communication capability, the regulatory body would confront difficulties conducting its regulatory activities.

In this paper, I would like to explain why communication has become a major issue in the Republic of Korea, what events have happened to challenge the regulatory body, what actions have been taken, and future directions to build public confidence in nuclear regulation.

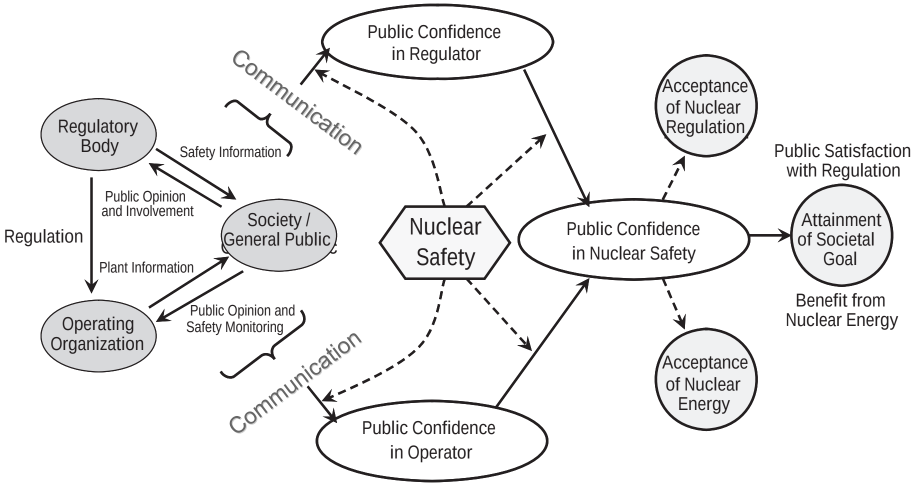

FIG. 1. Relations between public communication, confidence and satisfaction with respect to nuclear safety.

2. CHANGES IN THE SOCIAL ENVIRONMENT

Unlike in the 1970s and 1980s, when the Republic of Korea placed the foremost national priority on economic development, public perception and values concerning safety and the environment have changed significantly. Now, I would like to reflect on several changes with regard to nuclear energy in our society.

2.1. Social acceptance of nuclear energy

Firstly, social acceptance of nuclear energy has emerged as a national issue. Many countries around the globe have experienced difficulties due to the negative perception towards nuclear energy by the general public and their objections, in various forms, to nuclear energy. It is impossible to carry out a nuclear programme without getting public understanding and acceptance, no matter how much its safety is ensured in technical terms. This is a global trend and Korea is no exception.

For example, in the Republic of Korea the storage capacity for radioactive wastes and spent fuels at nuclear plant sites has almost reached its limits. However, a site for radioactive waste management facilities has not been selected yet in the face of local residents' resistance. Nuclear licensee and related organizations have made constant efforts to persuade the public concerning the safety and necessity of radioactive waste management facilities by communicating with the public. However, it has been a hard sell because of the social bias and negative perception towards radioactive wastes and related facilities.

Despite strenuous efforts, the prospect for the resolution of the site selection issue still remains dim due to strong and persistent protests by local residents and NGOs. The Government regards this situation as very serious. Now, the social acceptance of nuclear energy is no longer an issue reserved exclusively for nuclear licensees. It has become one of the items waiting for urgent resolution on the major national agenda.

2.2. Public demand for information on safety and regulatory activities

Secondly, the public continues to ask for more information on safety and regulatory activities. Nuclear energy related communication with the public has been considered an integral part of licensee activity. However, the roles and activities by the regulator in the area of public communication are increasingly required as the public becomes more interested in and concerned about safety issues. Therefore, the regulatory body must take into account how to incorporate public communication matters into its decision making process and how to communicate with the public in a manner of achieving effectiveness, efficiency and transparency. It is recognized that the regulatory body would have the obligation to communicate with the public regarding their activities, as well as the accountability for conducting their regulatory duties to ensure nuclear safety.

2.3. Public confidence in safety regulation

Thirdly, public confidence in nuclear safety regulation has become a pressing issue. So far, no major manifestation of public distrust in nuclear safety regulations has surfaced in the country. However, significant changes are now emerging. People tend to react sensitively to any small incidents, such as trivial component failures or system malfunctions at a nuclear power plant that have no safety impact. And the public would not give full trust to the official announcements regarding the investigation results.

For example, there recently were some events that involved dislocation of thermal sleeves at Yonggwang Units 5 and 6 and Ulchin Unit 5, and a small radioactivity leak at Yonggwang Unit 5. In the initial phase of the incidents, the regulatory body made a decision according to its rules and regulations applicable to safety related issues, as it usually does. A series of investigations was conducted, as thoroughly as required by the established regulatory procedures, by a team of in-house inspectors and several outside experts who were invited to reinforce the team as the incidents warranted. Root causes were established and the impact on plant safety and on the environment was analysed. Necessary corrective measures and follow-up actions were developed. All these were reported to the Nuclear Safety Commission for further consideration. Then the regulatory body hosted a town meeting at the Yonggwang site to present the investigation results, opinions by the experts and its final decisions.

Then local residents and some NGOs launched a protest. Flatly rejecting all regulatory measures and actions, they demanded to set up a joint investigation committee composed of the representatives from all stakeholder groups, i.e. local community and NGOs, responsible government ministries, manufacturer, operator and regulatory body to look into every aspect of the issue. And they also demanded a reinvestigation by independent expert organizations in other countries that they selected.

Finally, the Prime Minister's Office stepped in for intervention. The joint investigation committee agreed to accept their demand and decided to launch a reinvestigation by foreign expert organizations that they selected, such as TV and KO-Institut of Germany. When their investigation results came out a few months later, they were found basically identical to those previously presented by a team of Korean experts.

The dispute and controversy over these incidents settled down quickly and a normal atmosphere was restored for everybody. However, these incidents will be remembered for a long time and recorded as an example of public distrust of the regulatory body and particularly a serious challenge to regulatory decisions in the Republic of Korea. We learned hard lessons that the regulatory decisions cannot stand and the regulatory body cannot keep its authority without gaining the confidence of the public.

2.4. Increasing the participation of local communities in nuclear safety matters

Fourth, there is a growing sense of more active participation in community matters among local communities, together with the movement to directly monitor the safety issues development in their community and take necessary actions for themselves. The development of information technologies and transportation means, along with democratization and a maturing civil mindset has encouraged local residents to involve themselves more aggressively in nuclear safety issues. They are demanding safety measures, improvement and their participation in the process to nuclear licensee and regulatory body by independently collecting and analysing safety information.

In the Republic of Korea, the Civilian Environmental Monitoring Group started to operate at nuclear power plant sites since the late 1990s so that the local community may directly and independently check the safety of nuclear power plant operation in their community. Primarily, they were monitoring the environmental radiations in the surrounding areas outside the nuclear plant. However, in the aftermath of the incidents at Yonggwang as mentioned earlier, the local community stepped up their demand to expand the scope and functions of the monitoring group and strengthen their independent safety monitoring activities. Accordingly, the Civilian Environmental Monitoring Group has attained what it demanded from the Government as of 1 October 2004. Now, they can attend the maintenance and inspection activities being conducted inside the plant and collect necessary samples from inside and outside the plant at any time they wish.

This can be regarded as an opening of a new era for direct public involvement and participation in monitoring and overseeing the safety of nuclear power plant operation, which have been exclusively the realm of regulatory activities. We are looking forward to a general debate, in the near future, to draw a clear line between the regulatory oversight by the government and independent civilian monitoring activities, and also to figure out a complementary role in achieving safety of nuclear power plant operation.

3. A KOREAN APPROACH TO PUBLIC COMMUNICATION

3.1. Experience and lessons learned regarding communication with the public

The events of thermal sleeve dislocation and radioactivity leak at Yonggwang posed a landmark challenge to the independence and technical competence of the regulatory body, as already mentioned. The reaction shown by the public to reject the regulatory judgement and decisions, and to demand a reinvestigation by foreign expert organizations should be viewed as an act of denying the existence of a qualified and competent regulatory authority. We consider this is a prime example of public distrust of the regulatory authority taken to the extreme.

Going through all this agonizing process, we learned some valuable lessons:

(1) The mission that should be carried out by the regulatory body does not end with the ensurance of safety of nuclear facilities, but should be extended to build public confidence in regulatory actions to ensure safety. The regulatory body should be accountable for conducting its duties in

good faith and at the same time be responsible for satisfying the public through adequate communication about the results of its performance of duties — let the public know we ensure the safety of the nuclear power plant in due process.

(2) The basis of public trust and confidence in the regulatory body lies in its professionalism and technical competence which must be up to international standards. Through communication with the public, the regulatory body should demonstrate its full compliance with international standards in its daily operation with established technical competence.

(3) The regulatory body should be independent from the operator of nuclear facilities. The public and the local community are always suspicious of the relationship between the regulator and the operator. They do not trust what the regulator says, as long as this suspicion remains. We would not forget why they demanded an investigation by independent expert organizations in another country.

We have learned that public confidence in nuclear regulation grows with the belief that the regulator is indeed independent from the operator and works in good faith to achieve the safety of nuclear facilities for the public.

3.2. Strategies for communication regarding safety regulations and the status of their implementation

On the basis of its experiences and lessons learned from the communication with the public with regard to safety regulation, the Republic of Korea has formulated strategies for more effective communication, which feature the planning, methods, details and new approaches of such communications.

3.2.1. Planning of communication: Identification of public needs

The starting point of communication by a regulatory body is to identify what the public wants. This can be achieved through opinion polls concerning safety and regulations. Opinion polls would reveal how much the public is satisfied with the outcome of the regulatory body's performance of duties and what reasons could be behind public satisfaction or dissatisfaction. Based on this, the regulatory body could adjust its programmes and activities, and develop communication programmes to meet public needs.

Starting in 1995, KINS conducted public awareness surveys in 2000, 2002, 2003 and 2004. Based on these surveys, KINS has checked the level of public awareness and satisfaction concerning nuclear safety and regulations, and identified the areas that need more communication.

3.2.2. Methods of communication: Easily accessible and understandable

Communication must be carried out in an easily accessible and understandable manner. In our society, equipped with a strong IT environment, the web based information system could serve as a convenient communication method. The risks of providing information to the public through the Internet include that it may end up as a mere one way delivery of information, however, it is important to provide relevant information by studying what type of information the public and local residents want.

KINS has developed and operates a cyber information system. First of all, KINS operates its main home page, which is a designated portal site to provide all information about KINS, together with the Nuclear Safety Information Center. It also runs individual home pages reserved for specific safety information as requested by the public. At those home pages, KINS has set up a question and answer board in an effort to swiftly respond to safety related enquiries and civil petitions. Table 1 and Fig. 2 present the results of a survey on safety information requested by the public which was conducted earlier this year, as well as related home pages providing specialized safety information.

In addition to on-line communication with the public through the Internet, off-line communication based on face to face meetings are of great significance. KINS hosts nuclear safety symposia on an annual basis by inviting residents near nuclear facilities, NGO members and the general public, and holds on-site presentation meetings with local residents about site specific outstanding safety issues. And KINS provides the public with increasing opportunities for off-line, face to face meetings, such as various workshops targeting a wide array of interested stakeholders.

In addition, KINS has been developing a safety indicator system that is easily understood by the public. The safety indicator system is designed to have three components: safety performance indicators, safety culture indicators and safety perception indicators. Safety performance indicators display the safety status of each nuclear power plant in an easily understandable manner by using a scheme of different colours. Safety culture indicators are under development based on the classification into tangible and quantifiable aspects of framework and management, and subjective and psychological aspects of employee attitude. Safety perception indicators are being developed as a yardstick to identify the level of public satisfaction with nuclear safety and regulations. Upon completion of the development of these three indicators, they will serve as a good vehicle to provide the public with information related to safety status of nuclear plants in a comprehensive and visual manner, and also to measure the level of public satisfaction. We hope that the IAEA will take an interest in this three-pronged indicator system.

TABLE 1. PUBLIC REQUESTS FOR NUCLEAR SAFETY INFORMATION AND CORRESPONDING INFORMATION SYSTEMS DEVELOPED BY KINS

Requested information	Response rate (multiple choice)	Information system/contents	Home page
Status of radioactive waste management	50.9%	Waste Comprehensive Information Database (WACID)	wacid.kins.re.kr
Status of NPP	41.8%	Operational Performance Information System for Nuclear Power Plant — Safety Performance Indicator (SPI) module	opis.kins.re.kr
Details of accidents/ failures	40.8%	Operational Performance Information System for Nuclear Power Plant — Nuclear Event Evaluation Database (NEED) module	opis.kins.re.kr
Radiation dose in areas surrounding NPP	35.9%	Integrated Environmental Radiation Monitoring Network (IERNet)	iernet.kins.re.kr
Safety awareness and compliance with rules by radiation workers	14.8%	Safety Culture Indicator	(under development)
Radiation dose inside NPP	14.1%	Korea Information System of Occupational Exposure (KISOE)	kisoe.kins.re.kr

3.2.3. Details of communication: Openness and transparency

One of the difficulties that communication poses is to determine the level of detail of the information to be provided. Most people want data in the form of indicator or figure that encapsulates safety information. However, others would seek a more detailed and full account of nuclear safety issues. For the former type of people, it is enough to provide information on the overall level of nuclear safety processed in an easily perceivable and understandable manner. In the case of the latter, it is necessary to supply more specialized material that includes analyses and descriptions of major outstanding issues, root causes of incidents/accidents and so forth. Since they take more interest in

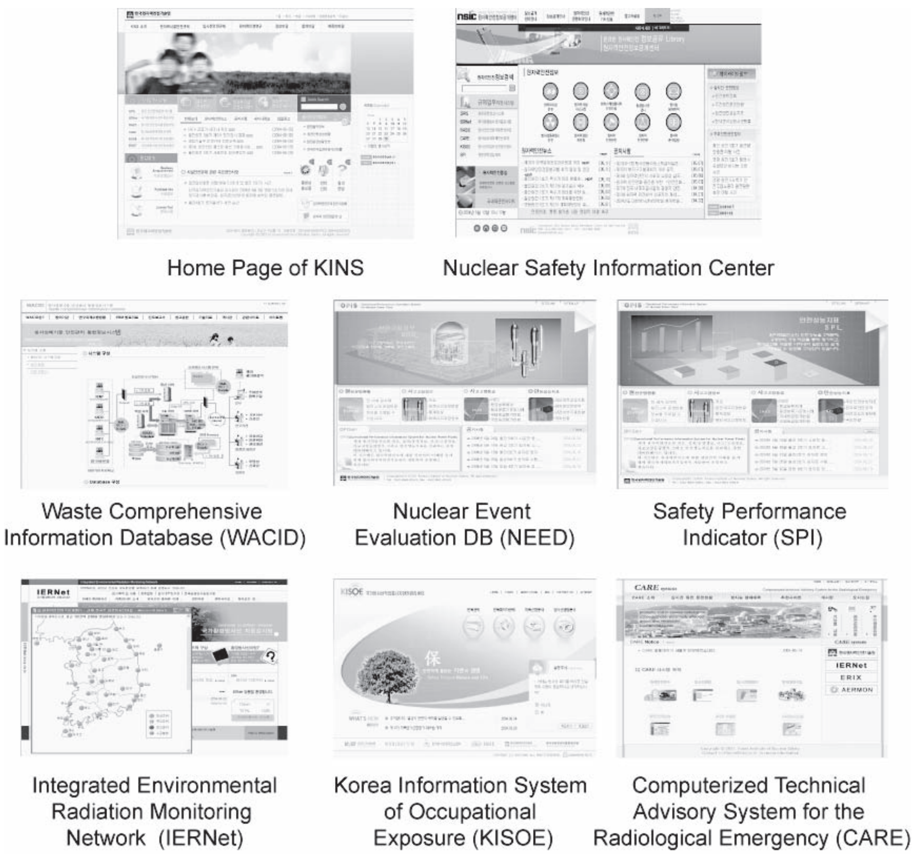

FIG. 2. Internet home pages providing nuclear safety information.

nuclear safety, relevant information should be provided to them in an open and transparent manner.

In the Republic of Korea, most reports generated by the regulatory body are made available on the Internet for the benefit of interested parties seeking more detailed information. It is possible to download, at the individual home pages, the entire texts of reports on current safety issues reviewed and analysed by related committees and experts, reports on investigation of incidents/ accidents and reports on various safety inspections and reviews regarding nuclear facilities, as well as laws, government announcements and technical standards related to nuclear safety.

3.2.4. Expansion of communication: New attempts

Communication is not a mere theoretical concept, but an act materialized through actual activities. Therefore, there exists a wide range of methods to conduct communication and it is necessary to explore more effective ways of communication based on fresh attempts. New approaches to communication adopted by KINS are described.

KINS hosted the world's first role playing session regarding nuclear safety. Role playing is a kind of sociodrama with strong persuasive power that effectively works to coordinate and resolve conflicting interests and broaden the scope of mutual understanding among different groups. The role playing was performed on an impromptu basis, based on a change of roles between KINS personnel and local residents under voluntary participation, after the participants' performance according to a set script with various safety related situations as the subject matter. After the role playing session, local residents expressed their opinions that role playing convincingly put across the message that KINS and the public should forge a partnership to promote the common cause of ensuring nuclear safety.

The divergent views of experts and the public regarding nuclear safety are attributable to many reasons. One of the reasons could be the varying levels of knowledge and experience with regard to how safety is ensured and confirmed through regulatory activities. Under the circumstances, KINS provides training and an education programme in the area of safety and regulation to local residents interested in nuclear safety in order not only to enable the residents to acquire the knowledge and techniques necessary for safety monitoring activities in their community but also to allow the regulatory body to expect an informed judgement by the local residents.

4. FUTURE ACTIVITIES

4.1. Consolidation of international cooperation

One of the major functions of communication is to deliver objective and reliable information in a fast and accurate manner. Since nuclear safety transcends borders, safety information needs regional and international communication beyond the national boundaries. Especially, it is imperative for neighbouring nations to set up a communications network enabling accurate and rapid sharing of information regarding nuclear incidents and accidents, as well as good practices. Such networking among neighbouring countries may expand to regional networking and ultimately to international networking. In this respect, the Republic of Korea has been actively participating in the global safety networking project being implemented by the IAEA.

In the meantime, such information needs to be timely and should also contain objective and professional judgments and analyses. The general public would accept and trust only objective and expertise information, and the same goes for the sources of such information. In this sense, the emphasis should be placed on the role of TSOs (technical support organizations, as mentioned previously) as these information sources that support regulatory authority. Cooperation among TSOs would lead to global improvement and networking of objectivity and professionalism, which would contribute to the credibility of TSOs and ultimately to public confidence in nuclear safety. Therefore, the top priority should be placed on the establishment of a cooperative network among TSOs around the world.

4.2. IAEA activities

A high level of safety ensured by strenuous efforts of nuclear licensees and regulatory bodies and their continuous communication with the public, press and NGOs is the key to earning public trust in nuclear safety in this changing environment. Each country may employ different communication strategies due to different structures and operating policies of nuclear institutions, the varying status of nuclear industries and divergent social and cultural backgrounds. However, each strategy should be based on basic communication principles and systems. In this respect, it would be helpful for Member States to enhance communication capability if the IAEA develops and provides communication review services. Moreover, various communication approaches in different countries may be worthwhile to be shared as useful information. The development of such a service as a module of IRRT service could be a possibility.

Communication starts with confirming whether the public is satisfied with what regulators do. For this purpose, opinion polls are conducted to analyse the level of public satisfaction with nuclear safety and regulations, factors affecting such a level of satisfaction, information sought by the public, etc. An opinion survey is a process of working out scientific and objective methodology based on such procedures as design, implementation, analysis and feedback. Considering the growing public interest in nuclear safety, it would be required to develop methodologies of opinion survey on nuclear safety and regulation.

Indicators that provide comprehensive safety information could play an important role in public communication. So far, the IAEA has developed safety performance indicators. If it takes a step forward to complete safety culture indicators and to develop perceived safety indicators, it would contribute to gaining public trust and facilitating more effective communication.

5. CONCLUSION

I have presented several outstanding issues facing the nuclear regulator in the Republic of Korea, explored some communication approaches to enhance public trust, and attempted to find a solution that could satisfy the high level of diverse social and public needs concerning nuclear safety.

The nuclear industry should carry out a serious study as to what measures should be taken to make the public feel safe, rather than merely delving into how safe is safe enough?, so as to improve social acceptance of nuclear safety. Safety sought by the public is safety that makes people feel secure, not just safety in technical terms. This means that regulatory bodies should pay attention and take necessary measures to *public concerns* as well as to *safety concerns*.

The world is witnessing a trend where the general public is taking more of an interest in nuclear safety. Under the circumstances, the regulatory body would be required to understand public sentiments concerning nuclear safety, handle issues from the perspectives of the public, and pursue proactive communications with the public to arrive at satisfactory solutions.

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CHINA'S SAFETY REGULATORY INSPECTION OF OPERATING NUCLEAR POWER PLANTS

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Abstract

Since the Guangdong Regional Office was set up in 1987, it has performed its safety surveillances for more than ten years and formed a surveillance system with its characteristics. The paper presents the experience over its history, especially in a five year period from 1999 to 2003. In the paper, the inspection method of the specific topic inspection was discussed. At the conclusion of the paper, several suggestions are made.

1. INTRODUCTION

Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China (promulgated by the State Council on 29 October 1986) specified that the National Nuclear Safety Administration (NNSA) is charged with unified surveillance, and exercises its surveillance power over the safety of civilian nuclear installations throughout the country, and that the NNSA may set up regional offices with certain resident inspectors in regions where the nuclear installations are concentrated to exercise safety surveillance. In August 1987, the NNSA set up its Guangdong Regional Office (GRO) at Shenzhen city, Guangdong Province, where the Daya Bay Nuclear Power Plant (GNPS) is located, to perform surveillance of nuclear installations in the Guangdong area. Since then, GRO has been performing four site level surveillances, such as civil work, site construction, commissioning and the operation step of GNPS, which was started in 1987, and the Ling'ao Nuclear Power Plant (LNPS), which started in 1997. During these, GRO exercised site safety surveillances based on the regulations on the four nuclear power units of the two plants mentioned. Under the supervision of the NNSA, and referring to other offices' experiences in safety surveillance, GRO has formed, step by step, a specific safety surveillance system with its characteristics and experiences.

Regarding the normal operation stage of nuclear power plants, and considering safety related problems that happened in a certain period on-site, and systematic considerations of safety systems and components, GRO had planned periodically its own annual inspection plans. In these plans, daily safety inspection, several routine inspections and non-routine inspections, and specific topic inspections (STIs) had been included. Otherwise, one month before an outage, GRO will submit to NNSA and inspected plant an inspection plan, named the Outage Inspection Plan, in which several outage activities, which will be selected to be inspected as subject inspections.

Although the term 'subject inspection' (SI) performed during outages is not defined in our national regulations, the approach of SI has been used frequently during outages and recognized in the nuclear safety area of China. In an article, Nuclear safety surveillance of operation NPPs, by Wang Zhongtang, the Director of the Shanghai Regional Office of the NNSA, a general description presented methods and approaches of offices in China, and especially introduced SI.[1]

Generally speaking, GRO will select inspection items for the annual inspection plan of the coming year surveillance. The plan shall be submitted to NNSA for review and approval, and then implemented by the Office. The sampling principle is based firstly on those requirements specified in the Code on the Safety of Nuclear Power Plant Operation (HAF 103, authorized by the State Council and promulgated by the NNSA on 27 July 1991), such as operational limits and conditions, operation specification, maintenance, core and fuel management, modification, radiological protection, fire protection, effluent and waste management, quality assurance programme, physical protection, operation review and experience feedback, etc., and secondly, on unit situations, frequency of problems occurred, and operating experience feedback. The sampling cycle is around four years, that is, these items will be inspected once every three to five years, depending on the importance or questions about the item. Such items, as periodic testing, emergency preparedness, and surveillance of examinations of operators and senior operators, are regular yearly items, so they were not in the sampling cycle.

When any abnormality, incident or accident happens during unit operation or outage, GRO would arrange some STIs as reactive action.

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[1] WANG ZHONGTANG, Nuclear safety surveillance of operation NPPs, Operation Research of Nuclear Power Installations **4**, (2003).

All in all, up to now five inspection methods used in GRO are daily nuclear safety inspections, routine and non-routine nuclear safety inspections, STIs and SIs. The last two methods are not specified in the regulations.

2. SPECIFIC TOPIC INSPECTION

Article 15 of the Safety Surveillance of Nuclear Installations (HAF 001/02, Part Two of Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China, promulgated by the NNSA on 14 June 1995) specifies that nuclear safety inspection may be classified into daily inspection, routine inspection and non-routine inspection (or special inspection). The non-routine inspection can be announced or unannounced. The announced inspection shall be notified one month before to the operating organizations and/or the units concerned for preparation and arrangement.

Article 19 specifies that: The non-routine nuclear safety inspection is the inspection made in case of need of the NNSA or the regional office, and is in response to the accidental, non-scheduled or abnormal cases or events. The non-routine nuclear safety inspection shall be executed according to the practical conditions of the items, referring to the routine nuclear safety inspection procedure.

Among GRO's five inspection methods, the STI is a special one.

For the implementation time, the STI can be performed both during normal operation stage or outage stage. Different from subject inspections (SI) during outage, STI generally is an inspection reactive to safety important issues, whether in the outage or operation stage; the previous one is arranged in the outage inspection plans, and especially for certain safety important outage activities.

For example, during the normal operation of Unit 2 of GNPS in 2003, the corrosion of some bolts of a safety important container was found and impacted safety function under certain conditions. For the problem, GRO sent a group immediately to check the real situation on-site, pointed out the issue to the owner, and reported to NNSA. The inspection called NNSA's and the owner's attention, and effectively resulted in safety reviews by NNSA and improvements by the owner.

For the approach, the STI is similar to routine inspection, combined with the entrance meeting, implementation of inspection and the meeting after Inspection. After an inspection, a report will be submitted to NNSA for review and approval, and the results of the inspection will be sent to the owner with certain regulatory requirements for correction and follow-up actions.

For the scheme, some STIs may be arranged in a GRO annual inspection plan. They will be announced to inspected operating organizations or departments one month before. From this view, the inspection belongs to routine inspection mentioned in the regulations.

However, there were some STIs which were performed on some abnormalities, incidents or other safety related issues as reactive actions. Because these inspections shall be performed in time, they could not be notified one month before. So they belong to non-routine inspections.

For the content, the STI focuses on the specific topic, differing from routine inspections organized by NNSA or GRO, which are all-round. For example, the routine inspection on re-critical activity after refuelling is an all-round inspection, when the inspection will cover all areas related to the activity.

STI uses relatively few resources, few inspectors, shorter inspection time and is professional, with a special emphasis on deep search and flexibility. So, the inspection method is suitable for the Office on-site surveillance.

On the other hand, because of its professional and special emphasis, the inspectors in GRO pay more attention before the inspections. It is necessary to prepare carefully before and to devote all energies to the process, to succeed in the inspection. Generally, efforts taken per inspector in an STI are similar to or more than those in a routine inspection organized by the NNSA or GRO.

Because of focused emphasis, the findings of the inspection were concentrated correspondingly, so the results of the inspection may be noticed over all related organizations or departments. During the spring of 2003, the SARS epidemic impacted the whole of the country, even menaced the normal operation of units of the plants. Late in May, as the number of SARS patients decreased, GRO arranged an STI to avoid some people in the plants relaxing their protection from SARS. The result was satisfactory.

3. OUTCOME OF STI

Taking a five year period from 1999 to 2003 as an example, in the period two units of GNPS were in normal operation stage, and two units of the LNPS were mainly in construction and commissioning stage. On 28 May 2002, Unit 1 of LNPS started its normal operation, and on 8 January 2003, Unit 2 started normal operation. During this, GRO had performed 38 inspection items, if regarding operation stage of units only. From Table 1, we can find these figures as the following:

(1) In five years, all requirements specified in the regulations mentioned were checked at least once. So we can say, GRO's annual inspection plans

satisfied the regulations. Of the items, fire protection inspection has been performed three times. The first reason emphasized on the area is for fire protection is more important to operation, and the second reason is that GRO focused on the precautions of fire problems, that is the inspections stressed the weakness in original design, modification and fire control.

(2) In Table 1, there are 24 routine or non-routine inspection items that are included in annual inspection plans, and 16 items are STIs as reactive action to unit situations. The rate for planned to reactive items is 6 : 4. Generally speaking, we can say that planned items are more than reactive items. However, from 1999 to 2002, there were only four reactive or non-planned items, that is once a year around; for 2003 reactive or non-planned items are 12 more! It is two times the planned items in the yearly inspection plan.

Generally, for an STI two or three inspectors are needed. The time from preparation to the final report is about 20 days. So we can see, in 2003 for four operation units GRO staff has taken a half year more for reviewing of refuelling reports, in-service inspection programme, precaution maintenance programme and modification items in outages. The resources GRO can use are limited, so GRO would face difficulties when some inspection items were not planned in the annual plan but needed in the year, even though reducing inspection items in the yearly plan.

How to deal with the situation with limited resources? How to use the limited resources in best possible way? This question is still being discussed. GRO keeps thinking of and practices how to use the resources reasonably on more safety important issues and how to get twice the result with half the effort. We consider that the safety inspections organized by the office shall be flexible to be performed, with strong emphasis on specific topic, and be small but complete. So, GRO annual inspection plans are not fixed automatically year by year, but arranged on the basis of specific status of units, problems and importance to safety, and were planned with certain purpose, precaution and protection ability to events.

(1) Of the 12 non-planned inspection items in 2003, most of them were related to GNPS. The fact is that designs and constructions of GNPS and LNPS are successful, so problem possibility of the younger one is less than of the old one, GNPS, no matter system or equipment. The meaning of the fact is that as the reactor age increases, problems of system and equipment will increase, and the demands of reactive inspection items will increase. Meanwhile, attention and influences on NPP from society will increase reactive inspections and call for a high quality of inspectors, too.

TABLE 1. INSPECTIONS OF OPERATING UNITS FROM 1999 TO 2003

Year	Category	Item	Notice
2003	Routine	GNPS equipment management	Planned
	Routine	LNPS emergency diesel generator system	Planned
	STI	LNPS periodic testing	Planned
	STI	GNPS modification follow-up	Planned
	STI	GNPS new specification implementation	Reactive
	STI	GNPS 1st spent fuel transport	Reactive
	STI	DNMC corrective action follow-up	Reactive
	STI	Mis-adding KOH in RCP of LNP1	Reactive
	STI	LNP1 SEC system	Reactive
	STI	Protection from SARS on-site	Reactive
	STI	GNPS PTR tank bolt corrosion	Reactive
	STI	Investigation of 3 LOEs of GNP2	Reactive
	STI	Preparation of changing GNP1 RCP320VP	Reactive
	STI	GNP1 stretch-out operation	Reactive
2002	Routine	GNPS emergency diesel generator system	Planned
	Routine	GNPS operational limits and conditions control	Planned
	STI	GNPS core management	Planned
	STI	GNPS LOE corrective action follow-up	Planned
	STI	GNPS radiological protection	Planned
	STI	LNPS fire protection	Planned
	STI	LNPS operation quality assurance	Reactive
	STI	LNPS emergency diesel generator system	Reactive
2001	Routine	GNPS safety injection system	Planned
	Routine	GNPS auxiliary feedwater system	Planned
	STI	GNPS fire protection follow-up	Planned
	STI	GNPS RCP & RPR parameter shift	Planned
2000	Routine	GNPS periodic testing	Planned
	Routine	GNPS maintenance	Planned
	STI	GNPS training on accident procedures	Planned
	STI	GNPS corrective action follow-up	Planned
	STI	GNPS operation safety	Reactive

TABLE 1. INSPECTIONS OF OPERATING UNITS FROM 1999 TO 2003 (cont.)

Year	Category	Item	Notice
1999	Routine	GNPS operational limits and conditions control	Planned
	Routine	GNPS fire protection	Planned
	Routine	GNPS radioactive waste management	Planned
	STI	GNPS control area management	Planned
	STI	GNPS chemical & radioactive chemical	Planned
	STI	GNPS electronic equipment reliability	Reactive

(2) Along with promulgation of the new version of the Code on the Safety of Nuclear Power Plant Operation (HAF 103) on 18 April 2004, new GRO annual inspection plans will be modified to meet new regulation requirements.

(3) Regarding safety surveillance experience, there are insufficiencies in our work and surveillance to be improved, although great energy from GRO in these years was devoted with some achievements. GRO will face new demands of development from the improvement of regulations and society's needs. We will find new ideas and experience feedback from other offices' experience. Our goal is to develop and improve our office to meet new requirements of development of civil nuclear power markets in China. In the near future, the emphasis of GRO is on the following:

— To focus on the outcome of surveillance with flexible methods;
— To improve work procedures for formal management;
— To enhance the management of data, documents and documentation in the office;
— To train and develop inspection teams and ability.

4. OUTCOME OF GRO SURVEILLANCE

From more than ten years of safety surveillance in the Daya Bay area, GRO has gained a rich experience; meanwhile, surveillance promoted the improvement in nuclear safety of units and ensures operation safety.

From European data and experience, the best or successful commercial NPPs are coming from the best or successful safety management and safety culture. GRO is keeping the stratagem that precaution is essential. Once any latent event found and would be a severe event, GRO will report to NNSA in time, communicate with the owner, and deal with it as quickly as possible.

In 2003, both GNPS and LNPS have surpassed their respective annual generation plans for both stations with a total output of 27 694 billion kW·h generated over the year. Specifically, GNPS has generated a total output of 14 384 billion kW·h with a capacity factor of 87.46% recorded. LNPS has generated a total output of 13.31 billion kW·h with a capacity factor of 85.56% realized. All of the four units have experienced no unplanned reactor shutdowns during the year.

In 2003, for GNPS, six of eight WANO Performance Indicators have surpassed the intermediate level of the world's best performing nuclear power stations, of which one has joined ranks with the top quartile. For LNPS, five indicators have outperformed the intermediate level of the world's best performing nuclear power stations, of which two indicators have entered the top quartile.

5. SUGGESTIONS

- For the existing situation of safety surveillance resources and the development status of civilian nuclear installations, in order to meet the requirement of development within limited resources, it is necessary to reorganize the organization, to regulate suborganizations, and to enhance cooperation between suborganizations.
- It is necessary to study, research and adopt advanced management technologies and new methods in the world, to ensure operation safety of installations.
- Because of an increase in fresh inspectors and the retirement of experienced inspectors in these years, technology training of all inspectors should be enhanced to ensure the quality of surveillance. The training methodology and mechanism should be improved continually. The young inspectors should be pushed to the front line with help from experienced inspectors.
- To share experience between offices, it is necessary to enhance exchanges between offices regularly.
- To improve the quality of safety surveillance and to widen knowledge of inspectors, it is necessary to enhance cooperation and exchanges with inspectors from advanced foreign countries.

EXPERIENCE WITH LICENSING OF RUSSIAN NUCLEAR POWER PLANT OPERATION EXTENSION

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Abstract

Since 2000, work on the operation of first generation NPP unit extensions are being conducted in the Russian Federation. Gosatomnadzor of Russia developed regulatory documents with requirements in which way the possibility of those units' operation extension has to be substantiated. The operating organization carried out the unit's modification and performed the complex of measures on their preparation for operation extension, including survey works and in-depth safety assessment. A lot of deterministic as well as probabilistic safety analyses has been carried out. The independent expertise of the relevant substantiations was organized and conducted. The expertise results were considered by the regulatory body in the licensing of the operation extension.

1. INTRODUCTION

The terms of operation extension of NPP units were determined as one of the measures in the strategy of nuclear power development in the Russian Federation in the first half of the 21st century [1], which was approved by the Government of the Russian Federation. It is rather natural that, in the first place, this is relating to the first generation of NPPs.

It is evident from Table 1 that the first generation NPP units exhausted (or practically exhausted) the designed term of operation (30 years). Since 2000, work on these units' operation extension are being carried out in the Russian Federation (see, for example, Ref. [2]).

TABLE 1. FIRST GENERATION NPP UNITS

NPP (unit)	Reactor	Commissioning
Novovoronezh (3, 4)	WWER-440/V-179	1971, 1972
Kola (1, 2)	WWER-440/V-230	1973, 1974
Leningrad (1, 2)	RBMK-1000	1973, 1975
Kursk (1, 2)	RBMK-1000	1976, 1979

2. NORMATIVE REQUIREMENTS AND CRITERIA FOR OPERATION EXTENSION

On the strength of its authority on regulation of nuclear power usage safety, the Gosatomnadzor of Russia developed the system of requirements in such a way that the possibility of first generation NPP units' operation extension has to be substantiated and reflected in the following regulatory documents:

- Basic Requirements for Nuclear Power Plant Unit Lifetime Extension (NP-017-2000);
- Requirements for Justification of a Possibility to Extend Design Service Life of Facilities and Installations of Nuclear Energy Use (NP-024-2000);
- Requirements for the Structure and Content of the Set of Documents Justifying Nuclear Power Plant Safety during Extended Period of Operation (RD-04-31 2001).

The criteria are given in these documents for the possibility of NPP unit operation during an extended term. In particular, it is necessary that the remaining lifetime of expendable components important for safety must be justified and be sufficient during the extended term of the unit's operation, and that the technical and organizational measures undertaken are confirming its correspondence with the requirements of modern norms and rules, or providing compensation for the remaining digressions.

As early as 1997, Gosatomnadzor of Russia developed the document Guidelines for the In-Depth Safety Assessment of Operational NPP Units with VVER and RBMK Type Reactors (RB G-12-42-97) (OUOB AS), based on the regulatory documents and with consideration of the international expert group recommendations.

This report is one of the main documents in which the operating organization should justify the possibility of first generation unit operation extension. To get the long term licence for first generation unit operation (in a period of three years or more), the operating organization, known as the Federal State unitary enterprise concern ‘Rosenergoatom’, has to prepare OUOB AS and submit it to Gosatomnadzor of Russia, together with other documentation justifying nuclear and radiation safety of the unit.

3. FIRST GENERATION UNIT SAFETY ASSESSMENT BEFORE OPERATION EXTENSION BEYOND THE DESIGNED LIFETIME

In spite of the absence of special normative documents regulating periodical safety review performance in the Russian Federation, Gosatomnadzor constantly conducted such assessments, with respect to the first generation units on a regular basis, realizing continuous monitoring of their safety; which includes three types of assessments:

— *The most complete safety assessment* was carried out while granting an annual licence for unit operation;
— *Partial safety evaluation* is carried out during approval of the possibility of one or another change inserted in Conditions of Licence Validity (e.g. on equipment replacement or modernization which causes updating of operational documents and parts of safety justification documents);
— *Safety assessment limited to the problems of ensuring safety during operation,* which is based on the results presented by the operating organization in the Annual Report Dealing with an Assessment of the Safety State while the NPP Unit is in Operation.

4. PREPARATION OF UNITS FOR EXTENDED OPERATION

4.1. Prerequisites for long term operation

The system of physical protection barriers consecutively located on the path of release of ionizing radiation and radioactive substances into the environment is more or less realized in the design of all Russian NPP units. The operating organization is permanently assessing the state of protective barriers, submitting the data obtained on the protective barriers and the state of safety systems to Gosatomnadzor of Russia in the Annual Report Dealing with an Assessment of the Safety State while the NPP Unit is in Operation.

The absence of full value containment on first generation units is compensated by implementation of measures realizing the ‘leak before break’ concept, as well as by the system of operational measures directed on prevention of large diameter pipe damage. Moreover, the low specific activity of the coolant circulating through the reactor is maintaining technical-organizational measures.

The water chemistry regime of the units is continuously perfected, providing reduction of coolant and other media impact on the corrosion stability of the NPP systems equipment and the pipelines' structural materials.

The conservative approach had been to implement measures while Russian NPPs are being designed, which provides a reserve of systems important safety equipment and sluggishness of transients. This approach has the advantage of affirmation in the design of first generation NPPs, demonstrated during their safety assessment using modern safety analyses of accidents as, for example, ATWS, which had never been done previously. In-depth safety assessment of the installations with light water reactors revealed that design basis reserves provide operating personnel with sufficient response time to manage accidents even of that kind.

To prevent possible mistakes of operating personnel, the operating organization is deeply analysing:

— Interface 'personnel–machine' in specific workplaces, the influence of the environment and ergonomic conditions on the operator;
— The quality of operator training, including use of full scale and analytical simulators (all first generation units are equipped with such simulators).

4.2. Modernization and main measures in the preparation of units for operational term extension

In compliance with Gosatomnadzor of Russia requirements, the operating organization carried out main measures in the preparation of units for operation term extension, including *in-depth safety assessment* and *all-inclusive surveying,* the last aimed at determining the actual state of the unit and the remaining life of the unit's components (equipment, buildings, construction and building structures).

The programme of surveillance, evaluation, prognosis and managing the equipment's remaining life is implemented at each Russian NPP unit for assessment of the unit equipment's remaining life state. This programme fulfilment is one of the criteria, established in document NP-017-2000, determining the possibility of a unit's extension of operation.

In the framework of an in-depth safety assessment, an analysis of digressions from regulatory documents in force was carried out using the methodology recommended by the IAEA for a safety assessment of the units built according to early standards [3]. Besides, the results of the IAEA extrabudgetary programme on NPPs with WWER and RBMK reactors over a period of time from 1990 to 1998 [4] was taken into consideration.

The first level probabilistic safety assessment (PSA) was done for each unit planned for operation extension. Results of digression analysis, as well as PSA results, facilitate to a great extent the justification of units' modernization programmes. During the unit preparation for operational term extension, those programmes had been mainly realized before the design lifetime completion, which provides an improvement in unit safety assurance.

The most significant measures realized at the units are the following:

— Technical means ensuring that the leak before break concept is installed, which significantly reduces the probability of large diameter pipe breakages;
— Guidance developed and technical measures are installed for beyond design basis accident management, as well as elaboration and implementation of symptom oriented accident instructions being carried out.

4.2.1. At units with RBMK-1000s

— Substitution of technological canals (TC) and recovery of the 'canal TC' design gap;
— Reactor conversion of uranium–erbium fuel is proceeding, which improves thermophysical and nuclear–physical characteristics of the core, including enabling to reduce the steam reactivity coefficient;
— Modifying the reactor's control and protection system through the second reactor shutdown system implementation that significantly extends the system functions and increases its reliability;
— Emergency core cooling system based on the passive principle of water injection in the multifold forced circulation circuit from hydroballoons;
— Reactor protection system technological parameters improved;
— Safety of reactor core is enhanced by implementing the cluster regulating rods.

4.2.2. At units with WWER-440s

— Two independent channels of safety systems with internal reservation of active elements installed;
— Reactors vessel annealing done;
— Replacement of old protective valves by new valves, which are independent from aggregative states of media and provide the possibility

of heat abstraction in a ‘feed and bleed’ regime for the first and secondary circuits;

— For feedwater supply into steam generators, the NPPs equipped with transportable pump installation with diesel drive gear and an autonomous source of power;

— Reactor protection systems and control safety systems modified on the up to date software and hardware basis.

The modernization of units resulted in comparative core damage frequencies (CDF) assessed by PSA, shown in Table 2. It is evident from Table 2 that the CDF value for all units is lower than the value equal to 10^{-4} which is recommended by the IAEA’s INSAG-8 report [5] for first generation units.

5. LICENSING

One of the main principles of nuclear and radiation safety assurance is the provision of a permitted level of activity in the field of atomic energy using the licensing procedure mechanism [6].

Gosatomnadzor of Russia is implementing this mechanism with the help of Licensing Regulations Governing the Use of Nuclear Energy (approved by the Russian Federation Government on 14 July 1997), which stipulates the review of documentation, justifying nuclear and radiation safety assurance of the unit. By order of Gosatomnadzor of Russia, SEC NRS, in accordance with established procedure, organized and carried out expertise of documentation justifying unit safety during the term of operation extension.

Thematic questions of expertise were grouped in such subsections as, for example:

TABLE 2. COMPARATIVE CDFs THROUGH PSA

Unit	CDF	Unit	CDF
Novovoronezh-3	2.54×10^{-5} 1/a	Leningrad-1	9.5×10^{-6} 1/a
Novovoronezh-4	5.12×10^{-5} 1/a	Leningrad-2	not submitted*
Kola-1	2.9×10^{-5} 1/a	Kursk-1	6.2×10^{-5} 1/a
Kola-2	3.04×10^{-5} 1/a	Kursk-2	not submitted*

* PSA is not submitted to Gosatomnadzor of Russia as a part of an application for operation extension.

— Site characteristics, including questions on the site location changes with respect to administrative districts, population distribution and sanitary protection zone evaluation;
— Remaining life of the reactor elements and main expendability equipment;
— Modernization and upgrading of safety systems;
— Results of all-inclusive surveying of the unit;
— Safety analyses;
— Fuel and radwaste treatment (lifetime of spent fuel storage is being assessed, as well as lifetime of liquid radwaste storage);
— Radiation protection and the unit’s influence on the environment.

Review of an in-depth safety assessment and of all-inclusive survey results has not revealed any impediments for the operational extension of the units under consideration. Besides, inspections on the units with the participation of independent experts were organized to check the actual state of modernization measures on safety enhancement fulfilment.

The review results served as a basis for assignment of the terms under which the licence for operation was granted. Periods of validity of the already issued licences are given in Table 3. The applications for licences for other units have not been submitted, or relevant documentation is still under review.

TABLE 3. PERIODS OF VALIDITY OF ISSUED LICENCES

Unit	Period of validity	Unit	Period of validity
Novovoronezh-3	5 years	Leningrad-1	3 years[a]
Novovoronezh-4	5 years	Kursk-1	3 years
Kola-1	5 years		

[a] With the condition of operation at full power, permitted after all modernization work on the unit is completed.

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SAFETY AS HIGH AND AS HARMONIZED AS REASONABLY ACHIEVABLE
Nuclear regulators facing globalization

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1. INTRODUCTION

The use of nuclear energy and ionizing radiation is being extensively scrutinized once again in light of the present debate on its role in sustainable development and on global security problems.

Nuclear power is an important feature of today's energy supply. Commercial nuclear generation is a mature, established technology, having accumulated over 40 years of successful operation. Yet nuclear power raises passions as do few other energy issues. Within countries and among them, both support and opposition are strong.

Loyola de Palacio, the European Union Commissioner responsible for energy and transport, summed up the dilemma very succinctly: Either we shut down the nuclear sector and give up on Kyoto, or we do not shut down the nuclear sector and we respect Kyoto. It is as simple as that: sometimes you have to put it crudely so that people understand.

What is the role of nuclear regulators in this environment?

The primary objective of government intervention into nuclear business is to allow humankind to maximize the benefits and minimize the risks emanating from nuclear sciences and their applications.

Because both the nuclear power industry and the societal context within which it is regulated are dynamic, regulators must continuously assess their approaches to regulation to best achieve their regulatory mandate. This includes adjusting the boundaries of activity between the plant and the regulator. That is, working out the practical approaches that allow the power reactor operator/owner to achieve and maintain safety while allowing the regulatory body to assure itself and the public that appropriate levels of safety are achieved and maintained.

2. GOVERNMENT AND REGULATOR

A central function of any democratic government is to promote the economic and social well-being of its people. Governments seek to meet that objective in a wide variety of ways, including through policies aimed at macroeconomic stability, increased employment, improved education and training, equality of opportunity, promotion of innovation and entrepreneurship, and high standards of environmental quality, health and safety. Regulation also is an important tool that has helped governments to make impressive gains in attaining these and other desirable public policy goals.

Governments have long used economic, social and administrative regulations to align better public and private interests in markets. Regulations will continue to be an important tool for preserving and advancing public interests. There is a real risk, however, particularly in a time of profound and rapid change in economic and social conditions, that regulations can become an obstacle to achieving the very economic and social well-being for which they are intended. Regulations which impede innovation or create unnecessary barriers to trade, investment and economic efficiency; the influence of vested interests seeking protection from competition; and regulations that are outdated or poorly designed to achieve their intended policy goals are all part of the problem.

The main issue for nuclear safety regulation is how to make sure that it is both effective and cost efficient. Governments must also consider their role in maintaining or strengthening public confidence in safety authorities. Nuclear regulatory authorities must adapt both to the call for greater regulatory effectiveness and to the new conditions of electricity market competition. Safety regulators must adapt to changing plant technical operation and commercial arrangements within the nuclear generation industry. A significant challenge for governments is judging the effectiveness of a regulatory organization and justifying its operating budget. Electricity market competition will lead to stricter application of the principle that regulatory authorities should limit the scope of their actions to plant features and operations that protect the public and workers. Plant owners will wish to reinforce their ability, without undue regulatory intervention, to make decisions on how best to protect plant investment. Nuclear facility owners will seek increased independence in determining the commercial framework for plant operation, including, for example, ownership, corporate alliances or operating agreements. Nuclear safety regulators are confronted with two objectives that must be reconciled:

— Increasing interaction with the public and disseminating information on facility performance and regulatory actions.

— Ensuring that nuclear facility operators take primary responsibility for safety, for example, by self-regulation which tends to reduce reporting requirements and notification of actions with minor safety significance.

The first objective emphasizes the flow of information and dialogue with the public on regulatory issues. This tends to increase the importance of providing easily understandable measures of satisfactory safety performance and immediate explanations of any operating plant anomalies. The second objective emphasizes the importance of safety goals and the responsibility of plant operators in meeting them. Compliance, while still fundamental, varies in short term importance according to the safety significance of the regulation or standard.

A final issue is the need for scrupulous adherence to established regulations. The highest standards are not effective if nuclear facilities and operators do not comply with them. We cannot assume that the existence of a safety authority and satisfactory safety records to date guarantee continued safe operation. Recent events at nuclear facilities illustrate that constant vigilance and strong government support of nuclear safety institutions are essential to ensure safety in practice. Businesses may not comply with safety regulations for a variety of reasons. These include failure to understand the law, lack of commitment to the objectives that lie behind the law or to the rules. Complacency about meeting the requirements of specific regulations may develop if there are no safety incidents or problems for long periods. Yet lack of adherence to established regulations, even if public health is not in immediate danger, damages trust in the safety authority and the industry.

3. WHERE DO WE STAND TODAY IN THE CZECH REPUBLIC?

The Czech Government perceives the highest reasonably achievable level of nuclear safety and radiation protection as a necessary precondition for using nuclear power generating facilities. To make this aim feasible, the Czech legislative and regulatory framework for the use of nuclear energy and ionizing radiation has been profoundly reformed over the past decade. The legislation reflects not only the experience with more than 50 reactor years of the Dukovany NPP. It is based on a long history of the nuclear industry of the former Czechoslovakia, as well as on current international practices and the latest developments in science and technology. As a result, in the Czech Republic an effective legislation is available, under which the regulatory authority — State Office for Nuclear Safety (SÚJB) — is furnished with sufficient independence, resources and competencies to be able to define general safety objectives, to assess the efficiency of the solutions proposed by the licensee and check in the course of inspections that the provisions have been correctly implemented.

There are several aspects of SÚJB independence that are worth mentioning. The financial resources to cover the SÚJB activities are approved by the Czech Parliament in the framework of its annual consideration of the State budget. The SÚJB has no legal relation to a ministry or other governmental agencies and its chairperson is appointed by a resolution issued by the Council of Ministers. Under the existing legislation, in particular the so-called Atomic Act of 1997, the SÚJB is authorized to establish detailed requirements within the individual fields of its competence through implementing regulations. Resolutions and other administrative acts by the SÚJB may be revised only through a legal procedure. The described arguments supporting the claimed independence may be described in more detail, but it should be admitted here that its absolute independence could be actually hardly achieved. We live in a multipolar world with a high number of contact surfaces and interfaces. Nevertheless, in the history of State supervision of nuclear safety and radiation protection in the Czech Republic, the SÚJB is currently enjoying the highest level of respect. The SÚJB has all necessary preconditions to carry out its tasks and, also very importantly, all powers so that it may effectively resist direct or indirect pressure exerted by political, economic or other interest groups.

One of the key elements in the utilization of nuclear energy is a competent user operator. The only holder of a licence to construct and operate nuclear power plants in the Czech Republic is the shareholder company ČEZ. Since 1985–1987, the ČEZ company has been operating four nuclear power plant units at the Dukovany site. The units are equipped with VVER 440/V213 reactors of PWR type with total installed power of 1760 MW(e). The production of the plant represents about 18% of the total electricity production in the Czech Republic. The trial operation of Temelin nuclear power plant (two units with WWER 1000/V320 reactor type with the total installed power of 2000 MW(e)) is in the final stage and a proportion of nuclear electricity produced in the Czech Republic almost doubled and reached approximately 31% in 2003.

The country's Energy Policy Strategy update was approved by the Czech Government in the beginning of this year. This important document envisages the use of nuclear energy for electricity generation also in the future. This will contribute to the desirable diversification of energy sources, substantially support the efforts to reduce carbon dioxide emissions and also make it possible to reduce the exploitation of the limited fossil fuel deposits available in our country.

The Czech Republic is currently deregulating the electricity market. Nevertheless, in a deregulated market, the main task of the Czech nuclear safety regulatory authority will remain the same: to ensure that licensees fulfil their safety obligations under the law. What will be different will be how to discharge these tasks effectively and how to determine whether the legal requirements continue to be adequate. The challenges arising from the deregulation of the electricity market are already well known and widely discussed in the nuclear regulators international community. We would like to mention only some of them, quite urgent in our opinion in the Czech Republic.

3.1. Integrating new managers from outside the industry

There are examples of appointments to senior levels in utilities of persons who have little or no background or knowledge of the nuclear industry. The issue is how to provide an environment that could raise the awareness of new managers to the constraints imposed by working in a highly regulated industry where safety considerations are paramount. The worldwide nuclear industry is unique in many respects, not least of which is the fact that one accident or incident anywhere in the world has an impact on the whole industry. Therefore, it is essential that managers understand the consequences of their decisions and actions on safety and the industry through knowledge of subjects, such as international safety conventions, safety culture, nuclear regulations and licensing, and industry behaviours and practices.

3.2. Management of change

It is necessary to continue with the development of the regulatory approach to the assessment of safety implications arising from organizational changes in utilities with particular emphasis being placed on:

— Developing performance indicators to measure and monitor the changes;
— Developing a method to assess the benefits that have been realized by introducing the change not only to safety levels but to business and other issues as well;
— How to assess the risks and cost benefit associated with changes;
— Effective communication methods and practices.

There is also some concern regarding the use of external consultants to drive change who have little or no knowledge in the industry as they can introduce the methodology of change yet have no understanding of the special needs of the industry to ensure safety is not compromised.

3.3. Managing downsizing

An effect of deregulation is that organizations seek to become more efficient by reducing their cost base. Invariably this is achieved by downsizing the organization to reduce staffing levels. There are again some areas of concern for the regulatory body:

— How the utility maintains the capability to act as an 'informed customer/buyer';
— How the utility manages the knowledge transfer of employees leaving the organization;
— How and what controls should be applied to the use of contractors in key roles and activities and the extent of their use;
— Risk management of downsizing;
— Opportunities for regional cooperation in areas where there is a skill shortage;
— Assessing the cost effectiveness of engineering solutions.

There are many situations where proposals are put forward for modifications or the raising of engineering standards to modern practices for plant life extension is imposed with little or no understanding of the cost effectiveness of each proposal. Issues to be considered would also include:

— How to assess backfit solutions;
— How to prioritize, given that resources are more limited in a commercial company;
— What some of the current practices are that are being deployed by other utilities;
— Understanding the impact of 'market' regulations.

As the utilities move into a deregulated market, they have to ensure they meet the regulations of the market they operate in. It is important that the 'market' regulator has an appreciation of the effect of their regulations on the nuclear aspects of managing a utility and that the nuclear regulator understands the constraints the utility is being asked to operate within.

3.4. Foreign ownership

There is the very real possibility that some utilities may be purchased by a foreign parent company and consequently there are numerous issues:

— Regulatory requirements, concerns and interfaces;
— Jurisdiction in cases of litigation;
— Risks associated with foreign ownership and the contingencies to manage those risks;
— Possibilities of relicensing to a new owner;
— The issues surrounding part ownership;
— Funding of decommissioning/liabilities and the provision of warranties.

These challenges put even more pressure for international regulatory consistency, resulting in harmonized safety requirements.

4. HARMONIZATION — ARE WE CLEAR ON HOW TO ACHIEVE IT?

Efforts in strengthening the global safety regime resulted in really positive achievements at the turn of the millennium. The quality of newly revised IAEA safety standards and a promising start to the review process, both under the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, represent two most visible achievements. The specific ‘European’ discussion on the ‘nuclear package’ proposal should, in our view, complement the worldwide effort. It brought up many questions with simple or difficult answers, arguments well justified or weak. But it also clearly brought to light contemplation about the overall concept that should be embedded in such an important initiative. On the other hand, there should not be any surprise in this respect — given that in this specific debate, we are balancing on the edge of technical and political objectives, and given we are pulling out a few components from a rather complex system of an overall safety regime. Let us elaborate on some of the technical issues and leave the political dimension aside.

What concerns the peaceful use of nuclear energy and ionizing radiation, the general safety objectives are already harmonized to a great extent. Key principles and the Basic Safety Standards to protect people and the environment against the adverse effects of ionizing radiation are widely accepted and implemented. Due to historical development, individual countries created their own specific nuclear safety approaches to establish and maintain effective defences against radiological hazards that may result from nuclear installations operation. Achievement of a high level of nuclear safety for every nuclear installation is declared both by operators and responsible State administration as an overriding general objective in every country. At this stage, the call for harmonization is not opposed by anyone. Terminology such as ‘high level of nuclear safety’ is frequently used to defend arguments and positions of different parties in ‘academic’ discussions, but only until the time one would like to encode necessary methodologies and criteria into a legal system of a particular country (or a community).

So, what does it really mean to say a high level of nuclear safety (with sufficient margins)? Nuclear safety cannot be measured objectively — in litres, metres or seconds. It has no absolute yardstick. When evaluating safety, there is always a subjective component — influenced by each individual’s or group’s perceptions. How to overcome this fact and embed this rather declarative term into operative paragraphs of a legal norm? Is full harmonization at the level of technical standards a necessary prerequisite? These are some of the most significant questions to be answered.

The safety of a particular nuclear installation is made up of many interlocking pieces, like a jigsaw puzzle. It is a network of safety measures that has to be viewed as a whole. In addition, nuclear installations have to be viewed as complex facilities with a large degree of singularity. Any complex evaluation cannot be performed without deep knowledge and day-to-day contact with the installation, and the legal and regulatory framework around it. We have a lot of experience in the Czech Republic in this respect. It took more than one decade to build a very subtle pool of experts from European Union countries capable of orienting themselves in-depth in some of the issues related to the safety of our nuclear installations. Due to historical development, the ability to judge effectively on overall safety levels of a particular nuclear installation is, therefore, only with the national regulator.

However, the Czech Government fully recognizes the international dimensions of nuclear safety and radiation protection issues. The Czech Republic respects the legitimate interest of the international community in being informed about the safety of our nuclear installations. The SÚJB always has stressed the importance of the international peer review processes for the overall system of ensuring safety in the Czech Republic, both in the regulatory and the industry domain. The opinion on nuclear safety levels reached at Czech nuclear installations may be built first on national reports prepared for the purpose of the Convention on Nuclear Safety and the Joint Convention. In addition to this, as for most countries, the independent third party peer review services of the IAEA are extensively used in the Czech Republic. In the past decade, there were more than 30 major missions dispatched by the IAEA to review different aspects of the nuclear safety and regulatory regime in our country. During the accession process, the Report on Nuclear Safety in the Context of European Union Enlargement was prepared by the AQG/WPNS. It evaluates legislation, organization and operations of regulatory authorities and the level of safety of the installations in each of the candidate States. And, last but not least, there is an update of the WENRA Report of 2000, once again discussing the safety of nuclear installations in candidate countries. In the last 15 years, and especially during the time of our accession negotiations, we have experienced overlapping and a multiplication of efforts in discussing nuclear safety matters at the international level. So we have good reasons to push for simplification and higher coordination, especially in reporting and peer review activities.

5. CONCLUSION

The effort to enhance the level of nuclear safety of nuclear installations is a continuous process. It has many dimensions. At the international level, European Union member States contributed significantly to visible progress made in the last decade. On the other hand, the community should utilize the existing multilateral tools and structures to the extent allowed, avoiding duplications and possible disintegration of global efforts to strengthen the global safety regime. Moreover, due to the nature of nuclear energy, it does not help much to bind its safety to specific regions.

Principal objectives and standards in the protection of people and the environment when utilizing nuclear energy and ionizing radiation are already set and widely accepted. In our view, harmonization should be more about the consistency of approaches to achieve the top level standards mentioned. However, we may think about how to organize ourselves even better, specifically in order to ensure higher efficiency and the effectiveness of our joint activities.

The level of public confidence in the existing safety regime and, consequently, public acceptance of nuclear power seem to be key issues. The effectiveness of nuclear safety regulators is closely tied to the openness and independence of their actions. Greater openness should help safety experts to improve public understanding of nuclear power in general. There is wide agreement that regulatory proceedings should be open to public scrutiny and that regulatory documents should be widely and easily available. The general public is ‘results oriented’, it does not care about sophisticated discussions of experts. On the other hand, it would not be wise to underestimate the ability of the general public and interest groups to judge the content and real value of any community initiative to set a framework (legally binding or not) for the safety of nuclear installations, radioactive waste and spent nuclear fuel. Simple but effective action is essential for convincing the public, but also for allowing us to concentrate on our basic duty: maintenance (and enhancement) of safety levels of nuclear installations and protection of the public.

APPLICATION OF IAEA NUCLEAR SAFETY STANDARDS TO THE LICENSING OF CHASHMA NUCLEAR POWER PLANT UNIT-2

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Abstract

The theme of the paper is to describe a methodology to validate and verify the IAEA safety standards by applying them to the whole licensing process of the second 325 MW(e) PWR (C2) to be constructed at Chashma, Pakistan. The IAEA safety standards have so far not been used to license a nuclear power plant. A surge in installation of new nuclear power plants is expected in the next decades due to restrictions on the emission of greenhouse gases, increased electricity demands, closure of coalfields, regulatory approval of new designs of nuclear power plants in the USA, economic competitiveness of existing plants, etc. Therefore, there is a need for internationally accepted nuclear safety standards. Before describing the methodology proposed by PNRA to achieve this aim, as a prelude, the rule making procedure and history of applying IAEA safety standards in Pakistan is briefly discussed. Pakistan has been applying the deterministic approach instead of reference plant approach for licensing of its nuclear power plants imported from China. The importance of a complete regulatory pyramid has been discussed and our experience of setting up such a regulatory pyramid has been highlighted. In addition, our experience of applying IAEA safety standards in conjunction with other standards to licensing of C1 has been described. The advantages and disadvantages of applying IAEA safety standards for licensing and some significant improvements needed in light of our experience have been identified. In view of the long history of cooperation between China and Pakistan in general, and particularly between regulatory bodies of the two countries, this validation and verification exercise can be put to mutual benefit. The international nuclear community can share the benefits and consequently, in the near future, IAEA safety standards may be used for licensing of imported nuclear power plants, especially when both the exporter and importer are developing countries. It would be the culmination point of the IAEA Nuclear Safety Standards Programme without assigning a nuclear regulatory role to the IAEA. In the end, the pilot project proposed by PNRA, including prerequisites, specific areas where assistance from the IAEA would be needed, has been presented.

1. INTRODUCTION

There is a fairly long history of cooperation between Pakistan and China in the area of nuclear power generation. The regulatory bodies of Pakistan and China have cooperated with each other during licensing of the first pressurized water reactor type nuclear power plant called Chashma Nuclear Power Plant Unit 1 (C1), which was supplied by China in the 1990s. The plant was successfully commissioned in 2000 and has been operating since then. Now in 2004, Pakistan and China signed a contract for the construction of Chashma Nuclear Power Plant Unit 2 (C2) of 325 MW(e) at the same site. It is expected that active cooperation would continue between regulatory bodies of the two countries.

For licensing of plants imported from China, either reference plant methodology or a deterministic approach could have been followed. In the case of the former approach, a plant is licensed on the basis of a similar plant already licensed elsewhere in the exporting or importing country, whereas in the case of the latter, detailed safety analysis reports are prepared and a sound scientific and technical review/evaluation is carried out followed by verification of compliance through inspections. The latter approach was followed by Pakistan.

Successful adoption of a deterministic approach requires a complete regulatory pyramid. Both Pakistan and China adopted the latest IAEA safety standards as the basis for their regulatory requirements for design and operation of their nuclear power plants. This reflected the desire of both countries to adopt the best international practices for their nuclear power plants. The rule making procedure in Pakistan as described below ensures completeness of the regulatory pyramid, although IAEA safety standards alone do not result in a complete regulatory pyramid.

2. RULE MAKING IN PAKISTAN

In Pakistan, the regulators and operators participate in rule making for nuclear power plants and a broad national consensus is achieved before issuing the regulations. For instance, the then regulatory body working under the Pakistan Atomic Energy Commission (PAEC) adopted IAEA NUSS (Rev. 0) [1] in 1981 and made these the basis of siting, design, operation and quality assurance of nuclear power plants to be constructed in Pakistan. Further, IAEA NUSS (Rev. 1) [2] was adopted in the year 1990 again with a national consensus. The supplier of C1, China National Nuclear Corporation (CNNC), had some difficulty in accepting IAEA NUSS (Rev. 1) for C1 but with the support of NNSA, CNNC was convinced to accept our regulatory position.

The Pakistan Nuclear Regulatory Authority (PNRA) was established in 2001 as an independent regulatory authority. The regulation on safety of the nuclear power plant design was issued in 2002 [3], based on the IAEA Safety Standard NS-R-1 [4]. This was prior to the start of negotiations between PAEC and CNNC, supplier of C2 plant. This was a step in the right direction. The adoption of this IAEA standard by China in 2004 has vindicated Pakistan's decision of 2002. Moreover, a current initiative is under way in Europe to compare European regulatory approaches and standards, and the IAEA standards are being used as a reference. Similarly, in Canada a project is under way to develop a licensing basis document, based on the IAEA Safety Standard for Design NS-R-1 [4] for regulatory review of the Advanced CANDU Reactor (ACR).

It would be pertinent to describe the rule making procedure here. The draft regulations prepared are first reviewed internally in PNRA and then are sent to PAEC[1] for comments. The comments received are duly considered and incorporated in the regulation as far as possible. PNRA has two members who are nuclear regulators, while seven members are from outside PNRA representing government departments, universities, PAEC, etc. PNRA accords final approval to these regulations. As a result of this prudent approach, although there is some talk regarding difficulties, PNRA has not received *to date* any request from C2 for waiver or relaxation of any of the clauses of the design regulation.

3. REASONS FOR BASING DESIGN REGULATION ON IAEA NS-R-1

The decision to base the current design regulation on NS-R-1 [4] was taken in view of several reasons of which the significant ones are given below:

— IAEA NS-R-1 was part of recently revised IAEA documentation representing the good practices used in developed countries with established nuclear power programmes and, as such, was the latest regulation available. There have been several changes in the design philosophy and approach since 1990 when IAEA NUSS (Rev. 1) [2] was adopted. Moreover, Qinshan Nuclear Power Plant Unit 1 (QNPP) was designed for 30 years while C1 was designed for 40 years. During the last few years,

[1] PAEC is the only operator of nuclear power plants in the country.

several plants have undergone life extension and now 60 years' life seems to be a reality. It would have been unfair to future generations if the new design regulation were not based on NS-R-1 as C2 is expected to be operating until 2071.

— NS-R-1 is comprehensive and systematic in its approach, and developed by international experts having extensive experience with input from the nuclear industry worldwide. It is generally accepted by the industry.
— NS-R-1, being a high level document, lists the key requirements that must be dealt with, but does not specifically invoke the requirements of any one country.
— Attempting to develop a wholly new design regulation by Pakistan would have been time consuming, expensive, unnecessary and would have been impossible for a regulatory body of our size and resources. Adopting NS-R-1, suitably modified to incorporate our specific requirements, was both practical and achievable.

However, a current design regulation based on NS-R-1 has few additional requirements. Since 1978, a gradual shift is taking place in the nature of IAEA safety standards. The five Codes issued in 1978 established the objectives [1] and 'minimum'[2] requirements that should be fulfilled to provide adequate safety in the operation of nuclear power plants. The word 'minimum' was replaced by 'basic'[3]in the 1988 version [2]. Now the current IAEA safety standards establish an 'essential basis'[4]for safety, and incorporation of more detailed requirements may be necessary in accordance with the national practices. Therefore, while preparing the design regulation, certain requirements additional to NS-R-1 were added. For example, installation of a Loose Parts Monitoring System based on QNPP experience was made mandatory. Another addition was to specify probabilistic target values (for new plants CDF < 10^{-5}). This is in line with risk informed and performance based regulation being adopted in other countries. It is noteworthy that no additions were made to IAEA safety standards while adopting these in 1981 and 1990.

[2] The word 'minimum' means the least quantity or degree, lowest possible value (Chambers Dictionary).

[3] The word 'basic' means fundamental, without extras (Chambers Dictionary).

[4] The word 'essential' means indispensable, important in the highest degree (Chambers Dictionary).

4. THE REGULATORY PYRAMID

Cognizant of the fact that a deterministic approach cannot be applied without a complete regulatory pyramid, the licensing regulation [5] allows the use of the relevant latest United States Nuclear Regulatory Commission (NRC) regulations and guides in areas where national regulations and regulatory guides do not provide the necessary guidance. Furthermore, the licensing regulation allows the use of standards of other countries, provided it can be shown that the same level of quality, reliability and safety can be achieved by applying such standards. Therefore, the licensee or its contractors, including designer, are not expected to face any difficulty on this ground. This arrangement ensures a complete regulatory pyramid, which would not have been possible if national nuclear regulations based only on IAEA safety standards were prescribed. Moreover, the licensing regulation requires that applicable standards be decided in the early phase (i.e. before PSAR) of licensing.

The supplier and the future operator should be concerned with the regulations in force in the country where the plant would be built and operated, and not with the regulations of the exporting country. It is a usual practice that any imported item should conform to the requirements of the importing country or else it cannot be marketed there. The limitations of NSSS vendor regarding experience and/or capability are not relevant. Accordingly, C2 through all stages of its life must conform to regulatory requirements in force in Pakistan and must not be allowed to be less safe than any other plant elsewhere in the world.

The concept of licensability in the country of origin has limitations due to, for example, differences in site conditions. It has no legal locus standi and there is no mechanism for its verification. Figure 1 shows the sequence of adaptation of an earlier version of plant design to a licensable version.

5. DIFFICULTIES ENCOUNTERED DURING LICENSING OF C1

In application of the IAEA NUSS (Rev. 1) [2] for licensing of C1, few difficulties were experienced. The most significant were in the area of severe accident analysis/management, which was included in IAEA NUSS (Rev. 1) but was not a requirement in IAEA NUSS Rev. 0 [1]. The NSSS vendor was of the opinion that the IAEA's lower tier guidelines did not provide the information necessary for implementing the IAEA's requirements related to severe accidents. The format and content of information related to severe

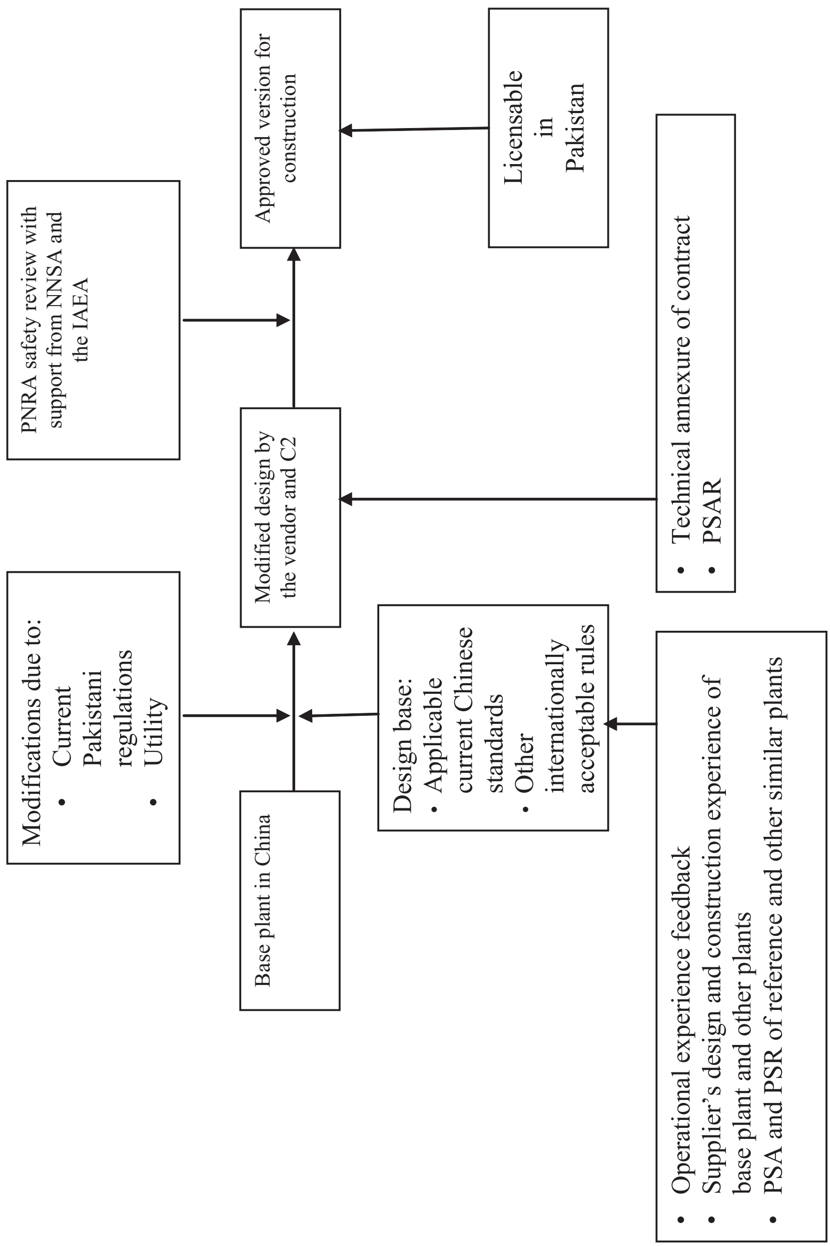


FIG. 1. Sequence of modifications in the earlier version of the plant design leading to a licensable plant in the importing country.

accidents and where it fitted in the prescribed format (NRC Regulation 1.70) was an additional issue.

Furthermore, IAEA safety standards do not specify industrial standards on which structures, systems and components are designed, manufactured and installed. As per licensing regulation, in the case of C1, these standards were mentioned in the safety reports and were accepted by the regulatory body. The industrial standards used were mostly of US origin but a few Chinese standards were also used. Some difficulties were encountered in establishing equivalence. For example, ASME Section II materials were to be used for ESF equipment but certain materials of Chinese origin were used instead. As Chinese standards prescribe different methods for determining the properties of material, it was difficult to establish an exact equivalence.

The safety reports were reviewed primarily by using the NRC Standard Review Plan (SRP). This document does not take into account IAEA safety standards. Therefore, during review it was ensured that the intent of the IAEA safety standards was generally fulfilled. However, during the licensing process these standards were found useful in the area of quality assurance and commissioning. There is a dire need for an SRP based on IAEA standards.

In view of the above, our experience of using IAEA safety standards for C1 in conjunction with our licensing regulations proved to be satisfactory. Emboldened, we intend to use the latest IAEA safety standards for C2 along with our regulations. The licensing process would be easier if some improvements are carried out in IAEA safety standards.

6. MERITS OF IAEA SAFETY STANDARDS AND NEEDED IMPROVEMENTS

The IAEA safety standards programme was launched in 1974 to address the question of the basis of safety of exported plants and how that safety was ensured. It was observed that there were significant differences in safety standards of exporting countries, such as France, Germany, the United Kingdom, the United States of America, etc. The aim was to establish a set of international nuclear safety rules by consensus. After Three Mile Island, export and installation of new nuclear power plants declined significantly. Consequently, few new safety standards related to design were issued. However, the IAEA continued its work on safety standards. Therefore, IAEA safety standards are the most up to date. Accordingly, these are a good option for countries desirous of importing nuclear power plants expected to operate for the next 60 years or more. However, there are areas where improvements are needed.

The deterministic regulatory approach cannot be applied without a complete regulatory pyramid. Consideration may be given to augment IAEA guides by adding other international standards, such as IEC and ISO standards. In addition, consideration may be given to add internationally followed standards, such as ASME, IEEE, etc.

A Westinghouse or Combustion Engineering or Babcock & Wilcox or General Electric plant would conform to NRC standards; a German plant would conform to RSK/GRS standards; while a Chinese plant would conform to Chinese standards. The design/safety philosophies and practices vary significantly from one design to another. It may not be easy to compare different design philosophies, for example, in the case of bid evaluation. However, if IAEA safety standards are used as a common basis, such a comparison may be easier. It is noteworthy that available NSSS designs have not been assessed against IAEA safety standards. This is an area where work is needed on lines similar to work being done in Canada on ACR.

For countries that intend to import nuclear power plants, IAEA safety standards provide a starting point for the development of a national regulatory framework into which typical vendor standards could be integrated. Furthermore, such countries are likely to seek assistance from the IAEA. The standards are binding on States in relation to operations assisted by the IAEA. Therefore, it is simpler and easier if national regulations are based on IAEA safety standards. This would further form a basis for standardization of plants worldwide and for gaining public confidence in the safety of the plant.

In spite of their increasing worldwide acceptance as reference international safety standards, IAEA safety standards have never been applied to the entire licensing process of a nuclear power plant. However, they have been used selectively in certain areas of design, operation, etc., such as Tianwan NPP, WWER upgrading projects, etc. The regulators and other stakeholders, therefore, might be hesitant in applying these standards in areas where these have not been validated or verified. Applying IAEA safety standards to the entire licensing process of a nuclear power plant can alleviate this concern. The lessons learnt from this exercise can then be incorporated in the standards for use by any country desirous of applying these in a nuclear power plant. This may be a high priority action area for IAEA.

7. ISSUES ASSOCIATED WITH THE LICENSING OF C2

The issues associated with the licensing of C2 are mainly linked to the application of IAEA safety standards. Some of the salient issues are given below:

— Difficulties may be encountered in the preparation of safety reports for new areas, such as severe accident, defence in depth, design verification, human factors, ageing management, etc., as acceptable format and contents for the new topics added in IAEA safety standards do not exist in a clear and formal form.
— The assumptions made in the beyond design basis analysis, PSA, validation of computer codes and the accuracy and applicability of results may be questioned, and in the absence of regulatory guides and an established standard review plan, the licensee and reviewer may have different interpretations.
— During the review, usually the results of the analysis are compared with other similar licensed plants but in the case of beyond design basis and severe accidents, this may be the first of a kind for a two-loop plant. The reviewer may be inclined to perform audit calculations, which may put extra demand on review time schedule and resources.
— The adequacy and effectiveness of systems installed for the mitigation of severe accidents may not be proven in previous equivalent applications and may have to be demonstrated to be adequate by appropriate research, testing and analysis.
— The combination of deterministic and probabilistic analysis in regulatory decision making may be problematic. The achievement of CDF below 10^{-5} may be difficult without augmenting the design and improving the site conditions.

PNRA has begun work to address the above issues in collaboration with the IAEA, but other stakeholders of C2 should also address the above issues, keeping in view the compliance with regulations, project schedule, resources available, etc. In this regard, additional assistance from the IAEA and elsewhere would be required which has to be of an on-line nature as the licensing process has already begun. With this background, a pilot project is proposed which will cater for the needs of PNRA and other stakeholders in addition to those of the IAEA.

8. PNRA PILOT PROJECT

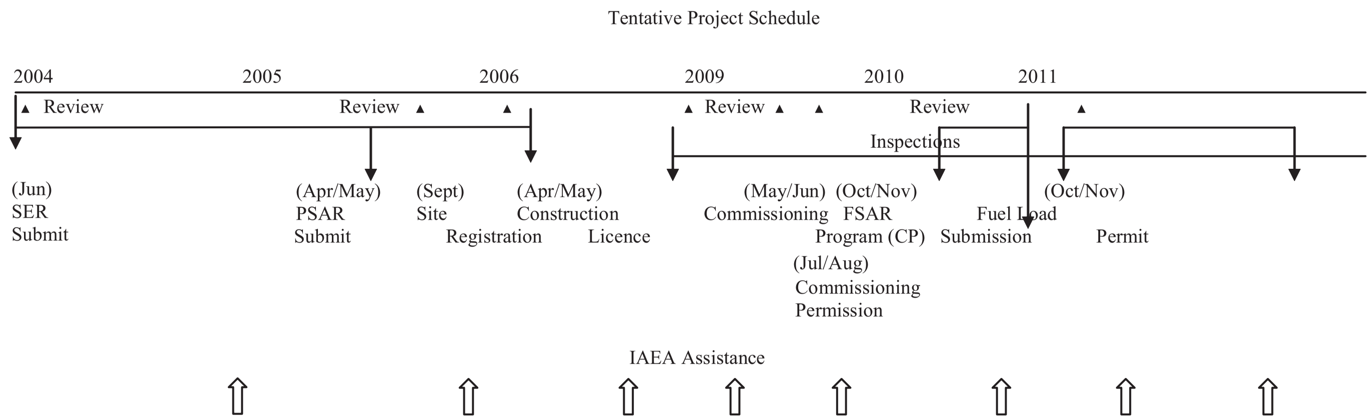
In this regard, a pilot project is being proposed by PNRA to the IAEA. The primary purpose of this project is the same as that of the international action plan (GOV/2004/6); that is, to fulfil the vision of the IAEA safety standards as a *global reference* for protecting people and the environment through the creation and maintenance of a set of harmonized safety standards of high technical quality that take into account recent trends and developments. The project does not assign to the IAEA the role of international nuclear regulator. It would aim at strengthening the application of the IAEA safety standards by Member States in connection with international conventions. The project would help in extending the outreach of the IAEA safety standards, as these would be referred to in safety reviews and regulatory inspections where stakeholders from different countries would be participating.

In addition, the IAEA would be able to show the world nuclear community that its standards are realistic enough to achieve an acceptable level of safety and can be applied to the entire licensing process. Moreover, as a spin-off, in addition to Pakistan, other importing countries may benefit from this exercise and opt to use the IAEA safety standards. This may be significant, as it is envisaged that there might be a surge in installation of new nuclear power plants in the next decades due to restrictions on emissions of greenhouse gases, increased electricity demands, closure of coalfields, etc. Moreover, current life extension and licence renewal decisions, approval of standard designs, economic viability of existing nuclear power plants, etc., are some indicators which point to a renaissance in nuclear power. It is likely that several new nuclear power plants would be imported for installation in energy starved developing countries. The licensing of these plants under the IAEA safety standards would be much simpler as these would already have been verified and validated in the case of C2. This would be advantageous to both exporters and importers and would be the culmination point of the IAEA Nuclear Safety Standards programme.

9. ASSISTANCE BEING SOUGHT FROM THE IAEA

The contract for C2 has been signed and the licensing process has begun with the submission of the Site Evaluation Report, though it is incomplete. The time has come for the stakeholders, namely PNRA, NNSA, IAEA, PAEC and CNNC, to chalk out a methodology to implement the pilot project. Figure 2 gives a tentative project schedule and areas in which assistance would be needed. Significant prerequisites to be completed prior to beginning this project are given below:

- A complete set of approved IAEA safety standards is available before the beginning of this validation and verification exercise.
- The IAEA has developed a standard format and contents of safety reports. It may consider preparing reference safety analysis reports on



Review of SER	Review of PSAR	Inspection	Review of CP	Review of FSAR
Area: Seismology	Areas: Management of design, defence in depth, internal events, confirmatory analysis, severe accidents, ageing, equipment qualification for severe accident environment, human factor, decommissioning, PSA, containment system, Reactor Coolant System, engineered safety features, I&C, control room habitability	Manufacturing of RPV, SG, RCP, MSIV, equipment qualification Construction: Pre-stressing, welding of Reactor Coolant System Commissioning: Management inspection Inspection of OQAP Implementation	Area: Commissioning organization	Area of assistance will depend on feedback from reviews and inspections of construction phase applicable regulations, and expertise available at PNRA at that time

FIG. 2. Assistance being sought from the IAEA during C2.

lines similar to RESAR and GESAR. Safety reports are usually based on these reference safety reports. In this regard, priority may be given to new areas, such as severe accident, safety management, defence in depth, etc.
- Similarly, the IAEA may consider developing generic safety review documents on lines similar to the NRC Standard Review Plan. An alternative may be to assist PNRA in developing a specific one for use in the safety review of C2. Some work was done on one review plan developed for containment design against severe accidents.

The regulators, licensee, vendor, etc., would need assistance from the IAEA in the following areas during the pilot project:

- Evaluation of design at system level as part of the PSAR/FSAR safety review to verify conformity with design requirements spelled out in the IAEA safety standards through a series of design safety review missions.
- Determination of design conformity to concepts, such as defence in depth and acceptability of safety management policies and procedures of the licensee vis-à-vis the requirements of IAEA safety standards.
- Peer reviews of confirmatory and audit calculations related to design basis accident analysis, beyond design basis accident analysis, probabilistic safety analysis, etc.
- Expert missions to owner, main contractor, contractors and manufacturing facilities in Pakistan, China or elsewhere for regulatory inspections. In addition, similar missions would be needed at the Chashma site for assistance in the verification of applicable standards during construction and commissioning phases.
- Missions in the area of the qualifications of owners and personnel of contractors responsible for commissioning and operation.
- Missions for advising on milestone decisions, such as site registration, construction licence, fuel load permit, various power ascension stages and operation licence.

10. CONCLUSION

It is submitted that application of the IAEA safety standards to the entire licensing process of a nuclear power plant presents a challenge and an opportunity that must be taken. If carried out successfully, it will result in an efficient regulatory process and help to support and contribute towards global nuclear safety standards.

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EXPERIENCE WITH LICENSING OF K2/R4 AND RESULTS OF THE IAEA/SNRCU SEMINAR ON SAFE COMMISSIONING OF NUCLEAR POWER PLANTS

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1. INTRODUCTION

According to the National Energy Program, in 2004, commissioning is planned in Ukraine for two new units at Khmelnitsky (referred to as K2) and Rivne (referred to as R4) NPPs. The design of these units is based on the unified reactor WWER-1000/V-320. Nine NPPs of this type have been already in operation at the Nuclear Power Stations of Ukraine since the 1980s.

During completion of K2/R4, their design has been sufficiently modified as a result of implementation of the Modernization Program [1]. The main advantages of K2 (connected to the grid since 8 August 2004) in comparison with the unified design are the following (Expert Conclusions [2]):

— New modification of nuclear fuel (TVS-A), which has no drawbacks peculiar to the previous design and which passed trial service at Zaporozh NPP Unit 3;
— Modern instrumentation and control system (I&C);
— Measures of the Modernization Program (implementation of the up to date radiation monitoring system at the unit and the 30 km surveillance zone, installation of the improved modern heat–mechanical and electrical equipment, fire safety improvement, water chemistry improvement, etc.);
— Comprehensive safety analysis report (SAR).

The same modifications (except TVS-A implementation) are also completed at R4, the commissioning of which is planned for October of this year.

Commissioning is one of the most important stages in an NPP lifetime. This stage covers the following:

— Final assessment of NPP safety, taking into account design modification during construction stage;
— Final inspection of quality of construction, assembling, fabrication of equipment, etc.;
— Inspection of staffing and training of operating personnel, operating documentation, etc.;
— Complex testing of functional ability of components, systems and plant as a whole;
— Final decision regarding fuel loading (point of no return). After that decision, the object of construction is fundamentally changed into a nuclear installation.

The faults during this stage are very difficult or impossible to be fixed.

The approaches used by the SNRCU and its scientific and technical support organization SSTC NRS on both: regulatory review of safety case and regulatory control of measures on safety upgrading of K2(R4), as well as experience obtained in K2/R4 licensing are described in this paper.

2. REGULATORY AND LEGISLATIVE FRAMEWORK OF K2/R4 LICENSING

The Ukraine law on Nuclear Energy Use and Radiation Safety establishes the basic principles of nuclear and radiation safety including licensing. The Ukraine law on Licensing Activity in the Field of Nuclear Energy Use, which has direct application, sets procedures to be followed by the regulatory authority and the operating organization during licensing process. In 2003, in accordance with legislation, the SNRCU issued regulations [3] to identify the requirements of the commissioning programme, work organization, testing procedure during commissioning, and communication with the regulator. In particular, the stages of commissioning, list of commissioning programmes to be submitted for regulatory review, reporting requirements, involvement of site inspectors, etc., were established. The regulations were developed with consideration of both the Ukrainian and international experience in commissioning, as stated in the IAEA Safety Guide [4].

In August 2003, the Chairman of SNRCU issued the order, by which the plan of regulatory activities on commissioning of K2/R4 was established. The plan consists of the schedule of regulatory review of all submissions of the utility, inspections of the regulatory team on the site of the NPP, dividing of duties and responsibilities between central office and resident inspectors, key points of licensing activity, responsible TSOs and scope of their work, project managers and communication with the utility. The regulatory plan was developed, taking into account the construction and commissioning schedule of the utility. The Deputy Chairman coordinated on a weekly basis the progress of the regulatory works and communication with the utility. The SSTC and Riskaudit conducted the regulatory review of the SAR and operating procedures on the basis of previous experience with the documents of the operating NPP same design. The main efforts were paid to the impact of modification to safety.

That organization of regulatory activities, strong control of the schedule of both: the regulator and the utility, elimination of unreasonable delays, concentration of resources, good communication between the regulator and the utility alloy to conduct all value of regulatory works during a very short period: one year.

In parallel with commissioning of K2/R4, negotiations between Ukraine and EBRD regarding the loan on implementation of the Modernization Programme continued. In the process of negotiation, the SNRCU summarized the experience of implementation of Safety Upgrading Programmes in operating NPPs, as well as the commissioning units. Riskaudit reviewed the summary reports and made its conclusions to the Bank. On the basis of recommendations and suggestions of the competent expert organization, the Bank Board made a positive decision.

According to the requirements stated above, the licensing packages submitted by the utility for licences for commissioning of K2 and R4 appropriately covered the following:

— Statutory documents and documents confirming the capability of the utility to ensure compliance with legislative requirements, regulations, rules and standards on nuclear and radiation safety (including confirmation of the financial capability to maintain the required safety level during operation, insurance of liability for nuclear damage);
— The preliminary safety analysis report (PSAR) that analyses all the factors impacting on safety and the results of accident analysis using modern codes and probabilistic safety analysis;
— Report on the environment impact assessment and conclusion of the ecological review;
— General commissioning programme and stage specific commissioning programmes;

— Operating documentation and emergency procedures (technical specifications, main instructions, accident management guides, protection plans, etc.)

The financial aspects of decommissioning are a very important part that should be taken into consideration in the licensing of the new unit. The basis for solving this issue is the Ukraine law on Regulation of Issues Connected with Nuclear Safety Assurance, passed by Parliament in June 2004. The law established a very strong schedule for creating of and allocation to the Decommissioning Fund. The Fund for K2/R4 is to be developed prior to receiving the licences for unit operation.

3. LICENSING THE NEW MODIFICATION OF NUCLEAR FUEL

TVS-A licensing, including safety analysis of its use, has some peculiarities in comparison with the licensing of, for example, modernization of heat and mechanical or electrical equipment, or with analysis of standard loadings.

Firstly, the following was additionally conducted through the implementation of fuel from a new developer for Ukraine:

— Assessment of the quality assurance systems under TVS-A designing;
— Analysis of the probability of common cause failure through errors in design (confirmation of the qualification and capability of the TVS-A developer to conduct the engineering work during design of fuel assemblies);
— Assessment of the developer’s documents as to the use of proven technologies and design features during TVS-A design.

Secondly, appropriate computer models based on independent codes (analogously with the practice accepted in the leading countries of Europe) were developed to verify the correctness of safety substantiation of the TVS-A operation conducted by the developer with the Russian codes. The library of two-group constants was prepared and the verification calculations were conducted using code NESSEL-4 together with DYN3D and DERAB. Comparative calculations with MCNP and SCALE were also conducted to verify the correctness of the TVS-A geometrical model.

Thirdly, the impact of coolant redistribution in the core for normal operation modes and for design basis accidents was analysed, taking account of the specificity of cooldown of the corner fuel elements.

All analyses and calculations were conducted, taking into account the results of the operating experience of TVS-A at power units of Kalinin NPP in Russia and Zaporizhzhya NPP Unit 3.

The analyses and verifications confirmed as a whole the developer conclusions on safety substantiation of TVS-A, in particular, as regards engineering advantages of TVS-A in comparison with standard fuel assemblies. The following may be marked out among such engineering advantages (see Fig. 1).

(1) Use of zirconium spacer grids and guide channels conditions the following:
 - —Increase of fuel assembly multiplication properties;
 - —Increase of uranium weight in fuel assemblies (~8%) with appropriate reduction of fuel rating and increase of burnup;
 - —The homogeneity of materials in fuel assembly active part: excluding additional forces inside TVS-A through different linear expansions;

(2) Use of the rigidity angle bars (rigidity increase of assembly framework and reduction of axial distortion) results in the following:
 - —Absence of rubbings of control rods;

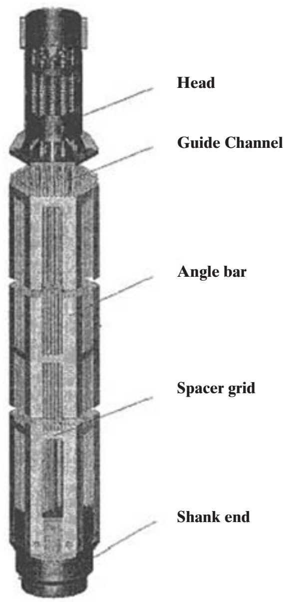

FIG. 1. Overall view of TVS-A.

- —Reduction of power peaks in peripheral fuel elements through reduction of non-design inter-assembly gaps;
- —Additional power flux reduction in corner fuel elements through water removal from inter-assembly space;

(3) Use of the gadolinium burnable absorber results in reduction of the number of irradiated materials and reduction of the amount of radioactive waste;

(4) Use of the anti-debris filter at the inlet to TVS-A results in reduction of fuel debris corrosion;

(5) Use of the new design of control rods increases the speed characteristics of emergency protection and increases the service lifetime up to two years in the control group and seven years in the emergency group;

(6) Use of the modernized head reduces the ‘absorbing’ effect and increases the accuracy of temperature measurements of coolant at the TVS-A outlet.

Open issues have been identified which are to be solved by the utility to continue TVS-A use along with the positive conclusions made by experts of the SNRCU/SSTC NRS, namely:

- — Analysis of radiation consequences of design basis accidents for large burnup and changes in isotope composition within burnup (this problem initiates after three years of operation);
- — Analysis of cooling ponds loading (through extending the time of TVS-A presence in the pond before placement into a dry storage facility) and identification of the long term storage criteria;
- — Additional confirmation of the possibility of reloading the core and its components after the design basis accident (individual issues on construction reliability substantiation).

4. LICENSING OF I&C MODERNIZATION

The commissioning of units K2/R4 is conducted practically with completely modernized equipment of instrumentation and control systems. The scope of modernization covers the following systems and equipment:

- — Parameter monitoring and control system;
- — Neutron flux monitoring system;
- — In-core monitoring system;
- — Group and individual protection system, K2;

— Alarm and protection system, K2 one division;
— Reactor power regulator and regulator of power limitation, R4;
— Technical means control system, R4, — completely; K2, safety systems, normal operation systems of reactor and turbine;
— Automated control system of reactor equipment, R4;
— Automated control system of turbine equipment, R4;
— Control system for refuelling machine, R4.

A conditional picture of correlation between modernized and 'old' equipment is shown in Fig. 2 on examples of I&C of Unit R4 (the filled part is modernized).

The following features are typical for K2/R4 modernized I&C systems:

— Digital technologies;
— High level of self-diagnostics;
— Low power consumption;
— Possibility of replacement of failed components without unit shutdown;
— Using the certified equipment;
— Electromagnetic compatibility;
— Compliance of new equipment with national regulations, IAEA and IEC requirements.

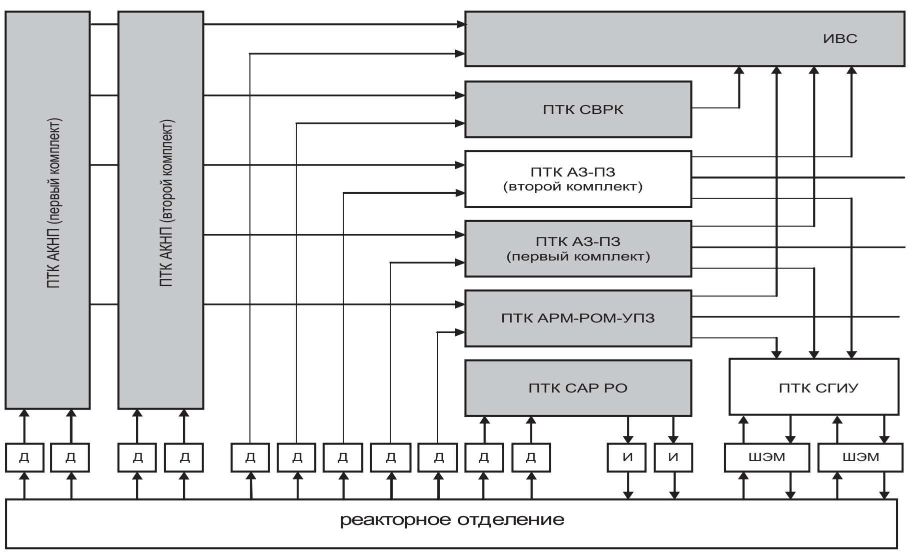

FIG. 2. Reproduction of the general flow chart scheme of R4 I&C modernization.

Procedure to implement new equipment includes several stages, as a rule, experts of the SNRCU and/or SSTC NRS take part in each stage. New equipment before delivery to NPP passes fabric tests on resistance to external impacts in the scope of requirements of technical specifications agreed upon by the SNRCU. This testing includes:

— Climate test;
— Seismic test;
— Electromagnetic compatibility test.

Equipment passes the approbation at one NPP in telemetry mode within the fuel campaign after agreement of the technical decision on the project implementation (assembling).

A report on the approbation results is the basis to agree the decision on the trial operation, which ends with acceptance tests and agreement of the decision on the permanent operation.

The licensing of modernization with the use of equipment which already passed the trial operation at other power units (part of the equipment installed at K2/R4 passed the trial operation at the south Ukrainian and Zaporizhzhya NPP) is conducted in accordance with the reduced procedure — the so-called ‘licensing based on differences’.

5. IDENTIFYING THE SCOPE OF SAFETY UPGRADES AND MONITORING THEIR IMPLEMENTATION

Simultaneously with the acceptance of the decision on cancelling the moratorium on NPP construction in 1993, the Government of Ukraine confirmed the intention to modernize K2/R4 for compliance of their safety level with the requirements of the national legislation, regulations, standards, rules on nuclear and radiation safety, as well as with international recommendations and practices. To achieve this objective, a set of safety upgrading measures was proposed by the utility and approved in the form of the Modernization Program [1] after numerous considerations and discussions of the design institutes, the regulatory authority, leading foreign experts from Germany, France, the United States of America, Spain, etc. This programme identifies the content of 147 measures on safety upgrading which are to be conducted before and after the K2/R4 startup.

Finally, the scope of the modernization before K2/R4 startup was specified and agreed through the technical decisions [5, 6] in April, last year.

Implementation of the safety upgrading measures is monitored by the SNRCU inspectorate on-site. Upon completion, the utility develops a summary report covering the following information:

- Title of the measure;
- Purpose of the measure and the technical essence of the decisions accepted;
- Stages of the measure implementation in accordance with the established licensing procedure;
- Reference to the design documentation developed to implement this measure;
- Reference to the materials on safety substantiation (SAR sections or individual analyses and substantiation if they are not stated in the SAR);
- Information on agreement of technical specifications (or technical requirements) for equipment (system) — in such cases, if new equipment is used and if such an agreement exists;
- Testing (acceptance) certificates.

Comprehensive analysis of the safety upgrading measures and assessment of their integral impact on safety are conducted in the SAR (partly in preliminary SAR and completely in the final SAR developed to receive the licence for operation considering the results of precommissioning and testing at the stage of commissioning).

More than 50% of the measures (74 of 147 measures of the Modernization Program) were implemented by the moment of K2 commissioning. Having met the principle of continuous safety improvement, the SNRCU established the requirement to complete the measures remaining within the following three years. The safety level of the other power units of Ukrainian NPPs will be brought to the level established at K2/R4 in parallel. This work is planned both within the loan of the European Bank for Reconstruction and Development, as well as within the costs envisaged in the budget of the utility.

6. REVIEW AND ASSESSMENT OF SAFETY SUBSTANTIATION

The State review on nuclear and radiation safety of the safety substantiation of K2/R4 commissioning was carried out with the involvement of SSTC NRS and the French–German Company Riskaudit, which upon SNRCU request performed the review and expert assessment with the purpose of making the following:

— Comprehensive assessment of all factors that have an impact on safety;
— Assessment of K2/R4 safety level as to compliance with internationally accepted requirements;
— Assessment as to compliance with legislative requirements, standards, rules and regulations on nuclear and radiation safety.

The assessment covered three main areas:

— Precommissioning programmes;
— Operational documentation and emergency procedures;
— The preliminary SAR.

Review and assessment also took into account findings of reviews in other areas, in particular:

— Expert conclusion of the State Fire Safety Department of the Ministry for Emergencies of Ukraine;
— Conclusion of State Ecological Review;
— Conclusion of State Health and Epidemiological Review;
— Conclusion of Review of the State Committee of Ukraine of Health and Safety at Work.

6.1. Precommissioning programmes

The main tasks, success criteria and precommissioning and testing procedures are presented in appropriate programmes developed for each of the following stages:

— Functional tests and component-by-component tests for systems and equipment;
— Test of the containment for strength and leaktightness;
— Hydraulic tests;
— Hot tests and inspection of the main equipment of the nuclear steam supply system.

The utility must ensure monitoring of the implementation of these programmes and submission of testing reports to the SNRCU in accordance with established procedure.

6.2. Operational documentation and emergency procedures

In this area, the expert assessment covered the technical specifications for safe operation, emergency and accident operating procedure for the reactor, accident management guides and plan of response to accidents and emergencies.

All these documents were developed on the basis of operating experiences of Ukrainian NPP units in service and have a number of drawbacks peculiar to documents for operating power units:

— Incomplete list of parameters that characterize individual states of a reactor;
— Incomplete compliance with results of design basis accident analysis as regards description and prediction of emergency processes;
— Lack of beyond design basis accident analysis and special calculational substantiation for symptom oriented procedures.

During the commissioning period (prior to the first scheduled outage), the operational documentation and emergency procedures must be revised and complemented to eliminate the revealed drawbacks, incorporate results of precommissioning and comply with the safety analysis report.

6.3. Preliminary Safety Analysis Report

The preliminary SAR contains information required to understand and substantiate the design basis of the power unit, safety principles and criteria incorporated in the design, operational issues and quality assurance aspects. The following was carried out in the scope of the preliminary SAR:

— Analysis of systems and NPP site, which includes determination of the design basis of systems, description of the structures and flow charts, information on control, monitoring and testing of systems, normal performance of system and their performance in failures, — based on the provided information, it was concluded that the system design complies with safety requirements, principles and criteria;
— Analysis of a design basis accident, which includes a list of initiating events, input data on computer models, description of accident development paths and results of initiating event analysis (as regards the possibility to maintain safety limits in normal operation violation, emergencies and design basis accidents);
— Level 1 probabilistic safety analysis, which includes analysis of equipment reliability data, analysis of abnormal events and occurrences,

identification and grouping of initiating events, success criteria, modelling of failure trees, analysis of accident sequences, analysis of personnel reliability and results of quantitative assessment and their interpretation (value of the reactor core integral damage frequency is 4.21 10^{-5} and is lower than the value of the safety target: 10^{-4}).

The SAR, as a preliminary report, has the following limitations:

- The Level 1 probabilistic safety analysis was carried out for internal initiating events relative to the core. The analysis did not cover other sources of radioactive materials and accident sequences resulting in abnormal releases. Moreover, the probabilistic safety analysis did not completely take into account potential effects (flooding, steaming, piping, whipping, etc.);
- The scope of applying the results of the design basis accident analysis to initiating events during reactor cooldown; unit shutdown; during management of radioactive waste and nuclear fuel is limited;
- The PSAR does not contain results of the beyond design basis accident analysis.

Based on the review of the K2/R4 safety and considering the principle of continuous safety improvement, the following basic areas of work continuation are identified:

- Complete implementation of the Modernization Program measures as planned after power unit startup;
- Develop remaining parts of the in-depth safety assessment;
- Revise operational documentation and emergency procedures;
- Implement a reliability system for reactor pressure vessel monitoring;
- Revise the preliminary SAR to incorporate comments of the State review on nuclear and radiation safety and take into account results of precommissioning work;
- Develop a regulation to determine methodological criteria for optimization of radiation protection of NPP personnel taking into account collective doses;
- Create a decommissioning fund;
- Create a system for long term storage of nuclear fuel.

7. RESULTS OF THE IAEA/SNRCU SEMINAR ON SAFE COMMISSIONING OF NPPs

During the licensing process of K2/R4 commissioning, the SNRCU widely informed the public and world community of the status and results of the safety assessment for the power units under completion. This was implemented through meetings, briefings, common seminars and workshops.

Immediately before the K2 commissioning, a seminar on Safe Commissioning of NPPs was organized at Rivne NPP from 14 to 16 July 2004 upon SNRCU request within the framework of the IAEA TC project UKR/009/021. More than 40 experts from the IAEA, Germany, France, the Russian Federation, Czech Republic, Slovakia and Ukraine participated in the seminar. The seminar was conducted in an open and transparent manner and was extensively covered by local and national mass media, and was intended for:

— Exchange of experience in commissioning;
— Maintainenance of international knowledge on commissioning aspects;
— Use of experience gained by Czech, Slovakian and Russian experts in K2/R4 commissioning;
— Drawing attention of the IAEA to commissioning activities in Member States and initiate the IAEA programme in this direction.

During the seminar, comprehensive information was exchanged on the experience gained and lessons learned from the many plants that have recently been commissioned or are currently under commissioning. The presentations and discussions focused on the following main issues:

— Regulatory body's review and assessment needed in the commissioning and licensing process; inspection activities and review of the commissioning test results;
— Development and implementation of commissioning programmes; major hold points related to the conduct of particular tests; assessment of acceptability of test results; effective use of technical and scientific support during commissioning phase;
— Application of IAEA safety standards (in particular, those applied at the commissioning stage as reference materials for the development of national regulatory safety requirements);
— Experience in preparation for and conduct of the IAEA OSART missions with regard to the issues of commissioning power units in the Asian region (Kuinshan, Lingao and Tianvan NPPs in China).

The Ukrainian participants reported on the progress achieved so far with the commissioning of the K2 and R4 units. It was pointed out that a comprehensive K2/R4 Modernization Program had been developed and approved by SNRCU. According to plans of the utility and in agreement with the SNRCU, more than half the measures of the Modernization Programme have been implemented prior to power unit commissioning. These are activities with the highest impact on safety. The rest of the measures will be gradually implemented within a few years after commissioning. The K2/R4 Modernization Program was closely monitored by the Riskaudit.

The following was concluded upon completion of the seminar:

— In the past few years, a number of nuclear power plants have been commissioned in Central or East European countries (Rostov 1 NPP, Temelin 1&2 NPP, Mochovce 1&2 NPP, Cernavoda 1 NPP, Zaporozh 6 NPP). Ukraine is currently commissioning two new WWER 1000 units at the Khmelnitsky and Rivno site, respectively. Although many countries dedicate considerable efforts to exchanging information at a bilateral level, there are no international forums or activities related to commissioning that could be of assistance to the interested countries. The IAEA is encouraged to foster the exchange of information on safe commissioning of NPPs through seminars, workshops and/or expert missions.

— Most of the countries represented at the seminar noted the use of the IAEA safety standards as reference documents when developing and establishing national nuclear regulations and guides, especially those relevant to commissioning activities. In general, the approaches espoused to the commissioning of WWER units in the different countries seemed to be similar and correspond to good international practices promulgated in the IAEA Safety Standards on commissioning. Ukraine could further benefit from the experience already gained in the Russian Federation, Slovakia and the Czech Republic. Similarly, the safety related information collected during commissioning of the K2/R4 units could be considered by other WWER countries when analysing experience feedback from WWER type plants.

— Ukraine has reported on the significant progress achieved with the implementation of safety upgrading programmes for K2/R4 units. According to the safety assessment performed by the SNRCU, both units have implemented the high priority safety modifications, have substantially upgraded the units design and achieved safety levels that correspond to the national safety requirements and standards. The SNRCU has been assisted by Riskaudit in the assessment of the preliminary safety analysis reports for the new units. The Ukrainian technical support organization, SSTC, performed detailed analyses of the nuclear and radiation safety submittals for the Khmelnitsky 2 NPP. The results from this expert review served as a basis on which the SNRCU licence for the K2 unit commissioning was issued.

— During the seminar, a discussion was held on the need to communicate, in a transparent and clear manner, both the constructor's (operator's) and the regulatory body's decisions related to the licensing and commissioning of NPPs. Difficulties have been experienced, when decisions on commissioning had to be communicated in conjunction with decisions on needed future safety improvements. How to explain to the public the idea of continuously striving for safety improvements, even when acceptable safety levels have been achieved, is a difficult issue, which could be further clarified and discussed at IAEA seminars or workshops.

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PHASED APPROACH TO ACHIEVING PRA QUALITY

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Abstract

The Nuclear Regulatory Commission's (NRC) risk informed approach to regulation uses insights from probabilistic risk assessments (PRAs), along with traditional deterministic requirements to help focus regulatory and licensee attention on safety significant issues. PRA quality is a key contributor to the success of this regulatory strategy. A phased approach to achievement of state of the art PRA quality is described, which the NRC believes will support the continued use of risk informed decision making while encouraging progress in improving the scope, level of detail and technical adequacy of PRA models. The phased approach also includes development of consensus standards and associated guidance to promote a common understanding, between the NRC and its licensees, of the definition of PRA quality, and to establish the NRC's expectations concerning licensee PRAs. Anticipated outcomes of the phased approach include consistent processes for PRA development, efficiency in regulatory decision making, and improved licensee and NRC understanding of the most important contributors to plant safety.

1. INTRODUCTION

In its Final Policy Statement on the Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities [1], the Nuclear Regulatory Commission (NRC) established the basis for the implementation of a risk informed approach to regulation. The NRC stated that a probabilistic approach to regulation enhances and extends the traditional deterministic regulatory process by:

- Allowing consideration of a broader set of challenges to safety;
- Providing a logical means for prioritizing those challenges based on risk significance;
- Allowing consideration of a broader set of resources to defend against those challenges.

For these reasons, the Commission encouraged the increased use of probabilistic risk assessment (PRA) technology to the extent supported by the state of the art in PRA methods and data and in a manner that complements the NRC's deterministic approach. The Commission also recognized, and encouraged, continuation of industry initiatives to improve PRA methods, applications and data collection to support increased use of PRA techniques in regulatory activities. However, the Commission also recognized the challenges with implementing a risk informed approach to regulation, including characterization of uncertainties in PRAs and the need to maintain adequate safety margins and defence in depth.

The policy statement also reflects the NRC's belief that:

> an overall policy on the use of PRA methods in nuclear regulatory activities should be established so that the many potential applications of PRA would be implemented in a consistent and predictable manner that would promote regulatory stability and efficiency.

To this end, the staff is directed to develop appropriate procedures for including PRA in the process for changing regulatory requirements. Although the term 'PRA quality' does not appear anywhere in the policy statement, the reliance on the state of the art as a basis for moving forward with risk informed regulation clearly implies the need for establishment of a common understanding of the elements of high quality PRAs, and commitment by both the NRC and the industry to take the necessary steps to ensure the development and maintenance of such tools.

Over the past several years, significant progress has been made in developing guidance and processes to define and improve PRA quality. For example:

— Reactor Owners Groups have been developing and applying a PRA peer review programme for several years [2]. The Nuclear Energy Institute (NEI) has developed guidance for self-assessments to address the use of industry peer review results in demonstrating conformity with the American Society of Mechanical Engineers (ASME) PRA standards.
— PRA standards are being developed by ASME [3, 4] and the American Nuclear Society (ANS) [5]. ASME has issued a standard for a full power, internal events (excluding internal fire) Level 1 PRA and a limited Level 2 PRA. The ANS has issued a standard for external events, which addresses seismic, high wind, external flood and other hazards. ANS is also developing a PRA standard for internal fires and for low power and shutdown conditions.

— Regulatory Guide (RG) 1.200 [6], An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities, has been issued for trial use. RG 1.200 is expected to provide the level of confidence that the technical adequacy of the PRA is sufficient to support the identified applications, so that an in-depth technical review by NRC staff would not be needed to ensure its quality to support the applications.

The NRC has also defined PRA quality as comprising three aspects: the scope of risk contributors addressed in the PRA (e.g. full power, low power and shutdown modes of operation, internal initiating events, external initiating events); level of detail; and technical adequacy of the model. Inherent in this definition is the NRC's view that a PRA of sufficient quality to support a specific application need have only the scope and level of detail necessary for the application, but must always be technically adequate.

As experience with risk informed regulation has increased, the NRC has recognized that the development of standards and guidance for PRA use, and the improvement of PRA quality, are incremental processes. Thus, the Commission recently instituted a phased approach, comprising three phases, for achieving an appropriate level of quality for PRAs to support risk informed regulatory decision making. This paper describes the staff's practical strategy for the implementation of the phased approach to PRA quality.

The role of the international community in the improvement of PRA must not be overlooked. Operating experience and other relevant data from outside the United States of America is an important source of information for improving PRA technology, and the NRC is an active participant in international cooperative efforts related to PRA. The NRC is also aware of increasing international interest in the potential applications of risk informed regulation; improvements in PRA capabilities and the development of standards for the use of PRA in risk informed regulatory applications should be of value to the implementation of risk informed regulatory policy in other countries.

2. OBJECTIVES AND DESCRIPTION OF THE PHASED APPROACH

The phased approach to PRA quality defines, using appropriate guidance documents, the necessary level of quality for current or anticipated applications and the process for achieving this quality, while allowing risk informed decisions to be made using currently available methods. This structured process takes advantage of improvements in PRA technology to permit an increased and enhanced understanding of and focus on safety, while encouraging advancements in the state of the art that will ultimately allow the completion of standards, guidance, and related processes and procedures for PRA development and use. The NRC expects that the phased approach will result in:

— Development and validation of improved and more complete (broader scope) PRAs;
— Improvements in the characterization and treatment of uncertainties;
— Increased efficiencies in the NRC staff's review of risk informed applications;
— Clarification of expectations for risk informed rule makings (e.g. 10 CFR 50.46 and 10 CFR 50.69);
— Integration of activities such that they complement one another and continue to meet the intent of the 1995 PRA Policy Statement.

The three levels of quality represented in the three phases can be expressed in terms of the breadth of application of the PRA which, as indicated above, is largely a function of the scope and level of detail of the PRA model. The expected increase in PRA quality from Phase 1 to Phase 2 to Phase 3 is driven in part by advances in PRA technology, as a result of increases in experience and available data, which improve the understanding of uncertainties and confidence in the PRA. In addition, improvements in quality will also be supported by improvements in guidance documents relating to PRA applications in risk informed activities, addressing the use and quality of the PRA with a scope and level of detail necessary to support an application. The technical guidance documents are primarily composed of:

— Regulatory guides and associated standard review plan (SRP) chapters;
— PRA consensus standards;
— Industry PRA application guides;
— NRC generated PRA reference documents (e.g. NUREGs, NUREG/CRs).

It is also expected that as PRA quality improves, staff review will become more focused, and the level of confidence in the capability of the baseline PRA to accurately represent the risk significance of a given application will increase. This should help to achieve the regulatory stability and efficiency that was a stated goal of the PRA Policy Statement.

Phase 1 (Application Specific PRA Quality) corresponds to the current status of the use of PRA in regulatory decision making. In this current phase, not all guidance documents that are necessary to support an application may be available. Guidance on technical adequacy of a PRA exists only for internal initiating events (excluding internal fire) for full-power plant operating conditions. In addition, contributions to risk from the different operational modes and initiating events have to be addressed in making a regulatory determination; however, if the PRA does not include an assessment of some of these contributions, they may be addressed qualitatively, by bounding methods, by implementing compensatory measures, or by defining the change so that the risk from these missing contributions is not changed (i.e. does not significantly affect the decision).

Phase 2 (Application Type PRA Quality) corresponds to the situation where, for each general application type (e.g. risk informed in-service inspection (ISI) applications, risk informed technical specifications applications and 10 CFR 50.69 applications), the necessary guidance documents are available to support development and evaluation of a PRA that is of sufficient scope (internal and external initiating events, plant operating modes) to support each application type. The scope of the PRA includes all contributors whose consideration can substantially affect the decision being made. Therefore, for Phase 2, the baseline PRA that supports the application meets applicable consensus standards, such as the ASME PRA Standard as endorsed in RG 1.200 for each significant contributor. For a specific application type to be considered Phase 2, guidance must be in place for (1) performing the PRA analyses needed to support the application, and (2) assessing whether the level of detail and technical adequacy of the PRA models for the significant modes of operation and initiating events (i.e. those whose inclusion could change the regulatory decision substantially) is sufficient to support the application.

Phase 3 (All-Applications PRA Quality) corresponds to the situation where PRA guidance documents are available for all envisioned applications. Therefore, for Phase 3, the regulatory framework is in place (i.e. guidance documents are available) for the operational modes and initiating events that could substantially affect a decision for existing and expected risk informed applications. Consequently, to transition to Phase 3, a licensee will need a PRA that is of sufficient scope (in terms of operational modes and initiating events) to address currently envisioned applications and will meet the requirements of the applicable industry consensus standards.

3. CHALLENGES

The technical challenges associated with the implementation of the phased approach to PRA quality have been discussed above. In addition, the NRC and the industry will face several process related challenges in reaching the goal of an all-applications phase of PRA quality.

The successful achievement of Phase 3 will require that all necessary PRA guidance documents have been both developed and implemented. That is, the standards development organizations (SDOs) have developed the necessary PRA consensus standards, the staff has developed the necessary regulatory guides and has endorsed the consensus standards, and the licensees have updated their baseline PRAs to reflect the appropriate guidance. There are, however, several challenges faced by both the staff and stakeholders for the successful implementation of the phased approach.

In the development and implementation of the phased approach, technical issues will be identified that will require resolution. Some technical issues will be resolved by the development of the PRA guidance document(s). A major challenge in the development of the PRA guidance documents (e.g. PRA standards) is identifying the technical issues, and then resolving the issue on a schedule compatible with the development of the guidance document. It is anticipated that the pilot applications for RG 1.200 will identify some technical issues. In addition, it is the staff's intention to use the standardized plant analysis risk (SPAR) models to assist in identifying any additional technical issues and in prioritizing their resolution. One important issue is that of model uncertainty. There are elements of the PRA where there is uncertainty concerning the appropriate model to use (e.g. human reliability analysis). When a consensus cannot be reached as to whether there is a clearly preferred approach, a decision must be made to account for the impact of adopting different models. The staff is developing an approach for addressing model uncertainty in decision making.

In implementing the phased approach, specific application types will be defined and the necessary guidance documents identified. Additional guidance documents will be developed on a schedule that is a function of the schedule for standards development. However, participation in risk informed regulatory activities is primarily a voluntary effort by the licensees, as is development of the consensus standards. The consensus process can inherently be a lengthy process. The challenge is to provide the incentive to licensees and industry to participate in risk informed activities and to develop consensus PRA standards. Part of the challenge is to identify and agree on the priority of the guidance documents and standards to be developed. A major aspect of this prioritization is to identify the benefits, to both the staff and industry, in the risk informed activities, and therefore, the need for the guidance documents.

The phased approach allows risk informed activities to occur without having all the PRA guidance documents in place. Until Phase 3 is achieved (i.e. PRA guidance documents are available for all currently envisioned applications), another challenge will be to develop a process for prioritizing and scheduling submittal reviews during Phase 1 and Phase 2. This prioritization process is necessary to balance the need to use staff resources effectively and efficiently and the need to provide incentives for licensees to develop more complete PRA models. Because the development of the guidance documents will be achieved over an extended time, the staff intends to continue to use other opportunities (e.g. review of licensee submittals, review of licensee Phase 3 Significance Determination Process (SDP) evaluations, Accident Sequence Precursor Analyses) to monitor the scope, level of detail and technical adequacy of licensee PRAs.

The guidance for the implementation (or use) of the PRA standards is provided in RG 1.200, and SRP Chapter 19.1. This guide describes an acceptable approach for determining that the quality of the PRA, in total or in part, is sufficient to provide the confidence in the results such that the PRA can be used in regulatory decision making. The approach provided in RG 1.200 relies heavily on the use of consensus standards and on industry PRA peer reviews to document the strengths and weaknesses of the licensees' baseline PRAs. The goal is to obviate the need for an in-depth review of the licensee's PRA by the staff, and to provide for a more focused and consistent review process by the staff. The biggest challenges with implementation of this RG is interpretation of the consensus standards and the judgement of the peer reviewers. To address this challenge, RG 1.200 has been issued for trial use and is being tested in several different pilot applications. The objective of these pilots is to identify and resolve the implementation challenges and, ultimately, to modify the RG and SRP as appropriate.

4. SUMMARY

The NRC has established a phased approach to PRA quality that permits the continued use of risk informed methods and encourages continued progress towards adoption of state of the art methodologies. This approach lays out a path, in a phased manner, for implementation of risk informed applications while PRA technology improves and necessary guidance documents defining PRA standards and capabilities for risk informed applications are developed.

As the international community moves forward in risk informed regulation, the challenges laid out in this paper represent a common concern. Joint resolution of these challenges will more rapidly accomplish the goal of establishing PRA quality, result in a consistent and uniform understanding, and be instrumental in continued assurance of safe operation of nuclear facilities worldwide.

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Session Summary

REGULATORY MANAGEMENT SYSTEMS: ADAPTING TO CHANGES IN THE ENVIRONMENT

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The presentations and the discussions identified a number of key challenges that regulatory bodies are facing. These include challenges in maintaining and improving competence, as well as establishing the necessary policies and approaches to deal with new situations, mainly resulting from ageing or the prolonged operation of NPPs, the construction of new NPPs, the decommissioning of nuclear installations and the establishment of the waste management infrastructure. Declining education and research infrastructure is also observed in many countries.

There is, therefore, an increasing need to:

(1) Create an attractive environment for students in the nuclear safety area, to implement more aggressive recruitment strategies, to ensure that sustainable education and training capabilities are in place in the Member States and that a comprehensive knowledge management system is implemented in the regulatory bodies;
(2) Consider cooperative efforts for activities demanding high resources. Further discussion may be needed on cooperation efforts for activities, such as new reactor design certification.

The globalization of the energy market and the resulting changes in the structure and the management of the operating organizations lead the regulatory bodies to adapt their strategies. Particular attention is requested for ensuring the qualification of the operating organizations, and reviewing and inspecting the organizational performance in achieving and maintaining a high level of safety for the short term and the long term.

Globalization also calls for more harmonization of regulatory requirements where appropriate. Efforts in this direction are pursued at the regional levels, acknowledging that harmonization does not mean uniformity. The role of the IAEA safety standards in building an international nuclear safety regime has also increased. The regulatory community will benefit strongly from cross-fertilization between the regional and multinational efforts, and the international development of more user friendly safety standards that take into account the feedback from the different users. Consideration should also be given to mapping the coverage and identifying differences and gaps between IAEA and industrial safety standards.

Regulatory bodies have reached a high level of performance in terms of effectiveness and efficiency, and most of them are now implementing self-assessment as one methodology towards ensuring continuous improvement. It was recognized during the Conference that the peer review IAEA services, such as the IRRT missions, provide a unique opportunity to stimulate this continuous improvement process. The Conference supported the proposal to develop an advanced IRRT service based on peer review of self-assessments. It was also recommended by the Conference that the regulatory bodies of countries with nuclear power programmes should consider inviting an IRRT mission by the end of 2012.

The effectiveness of the operational experience feedback exchange mechanisms was particularly addressed during Topical Session 2. It was recognized that it is primarily the responsibility of the operating organizations and that one of the priorities for the future will be to make better use in the Member States of the knowledge already accumulated in international databases. The participants felt that the IAEA should explore ways to consolidate diverse databases (such as NPRDS, 50.73, IRS, WANO SOER) containing reportable information and make it useful for Member States. Additionally, databases containing information on minor or near miss events that may constitute precursors for more significant events and other feedback, such as OSART and PROSPER reports, regulatory body inspection and lessons learned reports, should be considered for mining for important safety insights.

With regard to the use of probabilistic approaches, the presentation and discussions highlighted the progress achieved but also the difficulties encountered, in particular, in ensuring an acceptable level of quality of the PSA studies and in communicating PSA results to the public. The conference concluded that there is a need to establish a better balance in using, in a complementary manner, both deterministic and probabilistic approaches.

Finally, the importance of communications in building public confidence in the regulatory body was reinforced.

LONG TERM OPERATION: MAINTAINING SAFETY MARGINS WHILE EXTENDING PLANT LIFETIMES

(Topical Issue 4)

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LONG TERM OPERATION OF NUCLEAR POWER PLANTS: MAINTAINING SAFETY MARGINS WHILE EXTENDING PLANT LIFETIMES

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1. RATIONALE/BACKGROUND

During the last two decades, the number of IAEA Member States giving high priority to continuing the operation of nuclear power plants, beyond the time frame originally anticipated, is increasing. This is related to the age of NPPs connected to the grid worldwide; out of a total of 441, 81 have operated for more than 30 years, and 253 for more than 20 years. The initially assumed time of operation was typically 30–40 years. A rather limited number of new plants is being put into operation. Therefore, the time of operation of older plants is being extended to maintain the current level of electricity supply. The extension of the time of operation is also an economically attractive option.

The initially assumed time of operation was, in most cases, based on considerations other than technical, in most cases economic. From a technical point of view, it should be possible, therefore, to continue plant operation beyond the initially assumed time frame, i.e. long term operation (LTO), provided that the required safety level can be maintained or achieved in an economic way. Care should be taken to adequately treat those aspects where an economics based time of operation has been reflected in the design. The term LTO is used to accommodate the various approaches in the Member States (operating licence, design lifetime, etc.) to achieve this and is defined as 'operation beyond an established time frame (licence, design, etc.)', which was derived considering life limiting processes and features for systems, structures and components (SSCs).

Decisions on LTO involve the evaluation of a number of aspects, such as plant design, actual condition of plant equipment, equipment qualification, ageing, safety assessment, safety performance, maintenance, surveillance, plant modifications, configuration management, design basis information availability, spent fuel management, waste management and decommissioning, etc., including their relationships and dependences. While many of these decisions concern economic viability, all are grounded in the premise of maintaining plant safety.

In order to comply with safety requirements, most of the operating nuclear power plants are pursuing activities focused on physical ageing and plant life management. Some Member States have already developed and implemented regulations that cover LTO (e.g. the United States of America, the Russian Federation, Sweden, Finland). Many other Member States have just started the planning and development of such measures.

2. PRESENT STATUS OF THE ISSUE

For safe LTO of a plant, analysis must show that the plant will continue to operate within its design basis. Therefore, there is a need to:

— Have a good knowledge of the current design basis of the plant;
— Have a correct picture of the actual state of the plant;
— Define the analysis needed to support LTO and demonstrate that the plant will still operate within its design basis [1].

Further, mechanisms providing an effective feedback of operating experience and due consideration of advances in science and technology need to be in place.

Safe LTO of a nuclear power plant involves consideration of a number of aspects and is a rather complex challenge. A first step in addressing it, therefore, should be the definition of a starting point, which could be achieved by a comprehensive safety review involving all LTO relevant and important aspects. The importance of an adequate safety review for decisions on LTO is also highlighted by INSAG in its report on Safe Management of the Operating Lifetimes of Nuclear Power Plants [2].

Many Member States have initiated systematic safety reassessment of their operating nuclear power plants, termed periodic safety review (PSR), to assess the cumulative effects of plant ageing, plant modifications, operating experience, technical developments, site related aspects, as well as development of regulatory requirements and improvements of analysis tools. The reviews include an assessment of plant design and operation against current safety standards and practices, and they have the objective of ensuring a high level of safety throughout the plant's operating lifetime. The interval between PSRs is typically ten years. This period is sufficiently long to identify trends and draw conclusions based on operational and safety records. The conduct of PSR is also an excellent tool for knowledge preservation and management within a plant, utility, technical support organizations, etc.

The IAEA Safety Guide on Periodic Safety Review of Nuclear Power Plants [3] introduces the concept of 14 safety factors (and a number of associated elements), covering the whole scope of overall plant safety. The 14 safety factors and associated elements provide a breakdown of the rather complex issue of overall plant safety to a complete and manageable set. The Safety Guide was not developed specifically for LTO, but is used or considered for this purpose in several Member States. The viability and usefulness of a PSR for safe operation during the planned and the extended plant lifetime is addressed in the present activities. A set of training documents on the PSR 14 safety factors will be developed.

Current IAEA activities on LTO are based on an index, which follows the PSR Safety Guide safety factors and elements. The experience with PSR conduct indicates that the focus is changing with the age of reviewed plants or time of review in general (development of safety requirements, plants' vintage, etc.). PSR could provide the starting point for decisions on LTO. This needs to be complemented by a more comprehensive 'LTO review', capable of providing a good basis for assumptions and justification of plant safety for usually a much longer period (e.g. 20 years), as compared with a typical PSR interval of 10 years. Such an 'LTO review' would address a subset of selected safety factors of high importance for LTO.

Safety factors of high importance for LTO are also important at any point during a plant's lifetime. The IAEA continues to pursue activities which address selected safety factors, such as ageing, deterministic and probabilistic safety assessment tools, etc., and followed by other specific technical areas with high importance for LTO, such as design basis documentation and configuration management.

2.1. Ageing management

While early in the 1980s most people believed that routine maintenance programmes were adequate for dealing with the ageing of nuclear installations, in the 1990s the need for ageing and life management of NPPs became widely recognized. The IAEA initiated activities to promote information exchange on safety aspects of NPP ageing in 1985 to increase awareness of the emerging safety issues relating to physical ageing of plant SSCs.

IAEA follow-up activities were focused on understanding ageing of SSCs important to safety and on effective ageing management of these SSCs. To assist Member States in managing NPP ageing effectively, the IAEA has developed a technical document on Safety Aspects of Nuclear Power Plant

Ageing [4] and a set of programmatic guidelines, component specific guidelines for major NPP components important to safety and ageing management review guidelines.

The following programmatic guidelines on ageing management provide advice on generic ageing management programmes:

— Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing [5];
— Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety [6];
— Implementation and Review of Nuclear Power Plant Ageing Management Programmes [7];
— Equipment Qualification in Operational Nuclear Power Plants [8];
— Proactive Ageing Management [9].

The component specific guidelines on ageing management provide component description and design basis, potential ageing mechanisms and their significance, operating guidelines to control age related degradation, inspection and monitoring requirements and technologies, and assessment and maintenance methods. Respective roles of major NPP programmes in the management of ageing and an approach for integrating them within a systematic component specific ageing management programme are shown using an application of the systematic ageing management process. The following comprehensive technical documents on assessment and management of ageing of major nuclear power plant components important to safety have been published:

— Steam generators [10];
— Concrete containment buildings [11];
— CANDU pressure tubes [12];
— PWR pressure vessels [13;]
— PWR vessel internals [14];
— Metal components of BWR containment [15];
— In-containment I&C cables Volume I and II [16];
— CANDU reactor assemblies [17];
— PWR primary piping [18];
— BWR reactor pressure vessel [19];
— BWR rector pressure vessel internals [20].

Reference [21] is a guidelines document for IAEA Ageing Management Assessment Teams and for utility self-assessments. These reviews can be programmatic (strategy, organization, activities, results and monitoring) or problem oriented (components or structures or mechanisms).

Development of these guidance documents is beneficial in itself because it provides opportunities to address important issues of common interest and to learn from each other. However, it is the actual application of guidance that has a more significant impact on nuclear safety. The IAEA, therefore, devotes significant effort in assisting Member States in the application of its guidance through training courses and advisory safety review services.

2.2. Design basis documentation

The design basis for SSCs is the information that identifies the specific functions to be performed and the controlling design parameters and specific values or ranges of values for these parameters. The design bases stipulate the function of the SSCs, essential SSC parameters of the stated functions and processes, the basic safety margins to be included in the design, accident and fault scenario expectations, environmental considerations and applicability of safety and industry codes and standards. The design bases of NPPs are used by the plant staff and the regulatory authority in judging the acceptability of the original design and of modifications to the NPP with respect to the safety of the NPP's personnel, public and environment.

As a pilot project, the IAEA has drafted a Guideline for Design Basis Documents (DBD) Collation and Maintenance for WWER Reactors [22] and is providing assistance in this area through training and the exchange of experience. In the next step, this Guideline will be generalized to be applicable to all reactor types.

To initiate efforts to consolidate the design basis documentation is particularly important for LTO of older plants. Older plants may require a number of modifications to meet current safety requirements, for which the likelihood that the original designer/vendor may not be able to provide the needed support is highest and which, for technical, organizational or other reasons, do not have this information available.

2.3. Configuration management

Configuration management (CM) is the process of identifying and documenting the characteristics of a facility's SSCs and of ensuring that changes to these characteristics are properly developed, assessed, approved, issued, implemented, verified, recorded and incorporated into the facility documentation [23]. The main challenges are caused particularly by ageing plant technology, plant modifications, the application of new safety and operational requirements, and in general by human factors arising from plant personnel turnover and possible human failure. The IAEA Incident Reporting System shows that on average 25% of recorded events could have been caused by configuration management errors or deficiencies. Correctly applied, CM processes ensure that the construction, operation, maintenance and testing of a physical facility are in accordance with design requirements as expressed in the design documentation. An important objective of a configuration management programme is to ensure that accurate information consistent with the physical and operational characteristics of the nuclear installations is available in a timely manner for making safe, knowledgeable and cost effective decisions with confidence, including decisions on LTO. CM is another important element of maintaining plant safety and adequate safety margins during LTO.

2.4. Defence in depth preservation

Defence in depth is expected to remain an essential strategy of nuclear safety for both existing as well as new NPPs. The concept ensures that a high level of safety is reliably achieved with sufficient margins to compensate for equipment failures and human errors. The general objective of defence in depth is to ensure that a single failure, whether equipment failure or human failure, at one level of defence, and even combinations of failures at more than one level of defence, would not propagate to jeopardize defence in depth at subsequent levels. The broad concept of defence in depth is applied to all safety activities of diverse natures, including those which are organizational, behavioural or design related. The importance of defence in depth is underlined in IAEA Safety Standards, in particular, in Requirements on Safety of Nuclear Power Plants: Design [24], Operation [25] and in the Safety Guide on Safety Assessment and Verification for Nuclear Power Plants [26]. A Safety Report on the assessment of defence in depth for nuclear power plants [27] provides more specific technical information on the implementation of this concept in the site evaluation, design, construction and operation of nuclear power plants. It describes a method for comprehensive and balanced review of the provisions required for implementing defence in depth in existing plants.

The effectiveness of defence in depth is evaluated through engineering investigations, combining qualitative analysis and quantitative methods, typically using computational analytical tools to evaluate the performance of the barriers and the safety systems. In the past, nuclear safety measures were established and evaluated exclusively by the deterministic approach. Although explicitly or implicitly probabilistic considerations were included, these were converted to deterministic requirements, such as single failure criterion, redundancy and diversity of equipment, or definition of safety margins.

However, with the advances in PSA methodology, increasing use is now made of the probabilistic approach to complement, but not to replace, the deterministic approach to nuclear safety. Safety analyses used to justify LTO should be performed in accordance with progress made in computational tools and methods for both deterministic and probabilistic analyses.

2.5. Safety aspects of long term operation

The activities under way at the IAEA provide, or will provide when completed, a detailed guidance on how to deal with a particular safety factor or element important to LTO. It was recognized, however, that internationally agreed comprehensive guidance on what has to be done to ensure overall plant safety when dealing with LTO was needed.

Therefore, in 2003, the IAEA initiated the Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors (SALTO) (see http://www-ns.iaea.org/projects/salto). The Programme's objective is to establish guidance on the scope and content of activities to ensure safe long term operation of water moderated reactors [28].

The Programme Steering Committee, composed of senior representatives from the participating Member States, guides the programme efforts implemented through four Working Groups dedicated to specific technical areas (see Fig. 1).

The Programme should assist regulators and operators of water moderated reactors in ensuring that the required safety level of their plants is maintained during LTO. It should also provide generic tools to support the identification of safety criteria and practices at the national level applicable to LTO, and should serve as a forum in which Member States can freely exchange information and experience. The combined experience of all Member States participating in this Programme will be used as an input to developing an optimal approach to safe LTO.

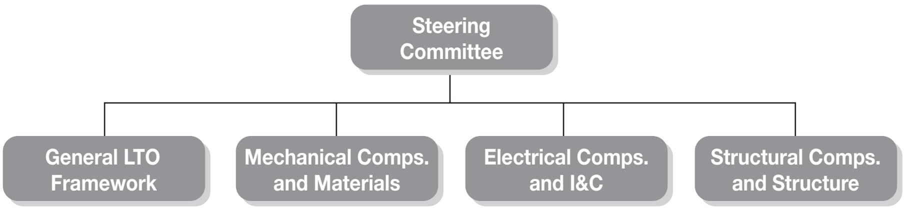

FIG. 1. The Steering Committee guides the programme efforts implemented through four Working Groups dedicated to specific technical areas.

The Programme's final outcome, the report Recommendations on the Scope and Content of Programmes for Safe Long Term Operation of Water Moderated Reactors, will specify what needs to be done using the index based on the PSR Safety Guide [2]. Further, the EBP will provide detailed guidance in the areas of general LTO framework, mechanical components and materials, electrical components and I&C, structural components and structures, as well as a database of LTO related technical information in these areas.

In the initial phase, the experts participating in the Programme have identified the following PSR Safety Guide safety factors as important for LTO:

— Plant design;
— Actual condition of structures, systems and components;
— Equipment qualification;
— Ageing;
— Deterministic safety analysis;
— Probabilistic safety analysis;
— Safety performance;
— Use of experience from other plants and of research findings;
— Organization and administration;
— Procedures.

These safety factors will be addressed in the frame of the Programme's activities. The others were either not considered important for LTO and/or too country specific.

The Programme's final outcome will be based on a concerted effort, conducted in several steps:

— Collect available information from participating Member States;
— Review and compare the information collected, evaluate and document common elements and the differences;
— Reconcile the differences and identify future challenges;
— Consolidate the information available and develop guidelines.

2.6. Preserving the knowledge

The IAEA developed a Safety Knowledge Base on Ageing and Long Term Operation (SKALTO) of NPPs as a pilot project and a first practical application of knowledge management techniques in the Department of Nuclear Safety and Security. IAEA guidance on ageing management for nuclear power plants [7] and a Safety Guide on Periodic Safety Review of

Nuclear Power Plants [3] provided the core for SKALTO's knowledge inventory.

The objective and goal of SKALTO is to identify and store relevant knowledge (or provide links to relevant knowledge sites) in order to facilitate its retrieval, updating, extension and dissemination to potential users and thus to promote more creative and effective ageing management and LTO programmes and activities. The scope of SKALTO is limited to:

— Management of physical ageing of nuclear plant SSCs important to safety;
— Other LTO programmes, such as periodic safety review (PSR), configuration management (CM) and design basis data management (DBDM).

The reduced scope SKALTO that includes open documents can be accessed on:

http://www-ns.iaea.org/projects/salto.

3. PRIORITIES FOR FUTURE WORK

3.1. Integrating Member State regulatory requirements, practices and approaches for LTO

The trend for globalization and the 'ageing' of the industry increase the need for an internationally accepted approach for LTO. It is recognized that, due to the differences in national requirements, regulatory approaches and other related issues, it would be rather difficult to define detailed international standards to cover LTO. However, considering the fact that the technical issues connected with LTO are rather similar, it should be feasible to formulate guidance on optimal approaches to LTO covering all the aspects involved.

3.2. Required safety level

For LTO, safety improvements and upgrading should be considered where reasonably practicable or where changes in the state of the art in the technology require it. Development in safety assessment tools should assist in the decisions by providing better quantification.

In accordance with progress in requirements on nuclear safety, more and more attention is devoted to the capability of NPPs to cope with severe accidents. Even for existing plants, their safety margins, together with practicable safety improvements, can be effectively used in the prevention of severe accidents and in the development of severe accident management strategies aimed at mitigation of severe accidents.

3.3. Exchange and feedback of operating experience

Exchange and feedback of operating experience are instrumental for safe LTO. Recent events (Ringhals, V.C. Summer, Davis Besse, Mihama, etc.) indicate a lack of respect for the technology. Further promotion of activities in this area and improving related mechanisms or developing new and more effective ones is rather important. For several reasons, different mechanisms may be needed to address in the best way good practices, including ways to achieve them, lessons learned from events, including solutions or corrective measures, and actual implementation.

3.4. Knowledge management

Ensuring the availability of safety related information is a key to safe LTO. This includes past and current information, as well as mechanisms to incorporate effectively the information to become available in the future. This is dictated by the 'ageing' industry and includes plants, vendors, technical support organizations, regulators, etc., and, in all these areas, the competent personnel (education and training). A detailed understanding of why the design is as it is (design basis documentation) and of all related aspects, including the impact of operating experience and ageing, is of high importance for safe LTO. An adequate configuration management should provide an accurate picture of the actual status of the plant. Both are instrumental if the introduction of new technologies is considered during LTO.

3.5. Succession planning

During a typical time of operation of an NPP, several generations of personnel are required for its operation, maintenance, technical support, as well as regulation. There is a need to ensure a continuous supply of competent qualified personnel to facilitate, ideally, a uniform distribution of generations and their overlapping to maintain and transfer knowledge and experience. This is of particular importance for LTO of older plants with less well documented design, technical, etc., information.

3.6. Other issues

LTO is connected with other issues, such as spent fuel and radioactive waste management, decommissioning, etc. Adequate provisions are required in LTO programmes.

4. NEED FOR STRENGTHENING INTERNATIONAL COOPERATION

Despite ageing nuclear power plants, the availability or status of the development of LTO related requirements is at a different level. While some countries have well established approaches, others are at the very beginning. An internationally agreed approach is not available. This highlights the need for strengthening international cooperation in this area.

Strengthening international cooperation could provide for:

— Harmonization of the approaches used;
— Exchange of experience on lessons learned from previous events;
— Transfer of technology on good practices.

5. POTENTIAL AREAS FOR FUTURE IAEA ACTIVITIES

The IAEA mission in the area of nuclear safety is to establish safety standards and promote their use, and to provide a mechanism for its Member States to cooperate. In line with these, the following areas are proposed to be addressed in future IAEA activities:

— Developing a Safety Guide on LTO. It was recognized that an internationally agreed comprehensive guidance was needed to assist regulators and operators in dealing with the unique challenges associated with LTO. The outcome of the EBP on safety aspects of LTO for water moderated reactors, in combination with other IAEA activities, will provide a solid basis for the Safety Guide, which should be complemented by technical documents providing detailed information on related issues, such as ageing, configuration management, safety assessment, etc. The use/extension of the approach developed for defence in depth assessment is considered as a tool for safety evaluation.
— Establishing a service on the safety aspects of LTO, which will integrate the narrow scope of existing services and complement the OSART

service to facilitate technology transfer, peer to peer discussions, and to strengthen international cooperation in the area of design and engineering issues of LTO. The service will primarily focus on nuclear power plants as the main ‘customer’ and will provide a mechanism for feedback of positive experience, i.e. good practices and ways to achieve them.

— Establishing a nuclear industry (plants, TSOs, regulators) forum for an exchange of experience through regular meetings (annually) to facilitate open and thorough discussion of recent events, including regulatory, operational and engineering issues.
— Continuing to develop mechanisms to maintain the knowledge. Databases or knowledge bases containing LTO related information on technical issues, lessons learned from events, as well as good practices, need to be established and kept up to date, including updating of the resulting guidance.
— Promoting education and training in this area through organizing workshops and training courses.

It should be noted that the technical areas or issues mentioned in connection with LTO, such as ageing management, configuration management, safety assessment and operating experience feedback, are or should be a part of the daily routine at any operating NPP. Preparation for LTO highlights their importance. Adequate attention should be paid to them from the very beginning of the ‘plant life’.

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FRENCH APPROACH TO PLANT SAFETY REASSESSMENT
The benefits of visits to European nuclear fuel fabrication plants

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Abstract

With a ten year periodicity, the French nuclear safety authority (DGSNR) and its technical support (IRSN) reassess the safety of the plants under survey. A special part is devoted to internal experience feedback, and the events that occurred during the past working period are carefully analysed. In the case of the French FBFC uranium fuel fabrication plant, it was decided to make a more systematic use of international feedback in the usual reassessment work for non-reactor facilities. A programme has been set up on the basis of peer to peer level bilateral meetings organized with the European safety authorities having similar plants under their responsibility. A special safety-oriented standard questionnaire was previously sent to each and returned. Each bilateral contact consists of a two day visit, which began with discussions about particular topics in the regulation area and methods for an efficient survey. In order to illustrate this, the two authorities visited the nuclear site the second day. In this way, European safety authorities of five countries (Belgium, Germany, United Kingdom, Spain and Sweden) have met, and plants belonging to Framatome-ANP, Westinghouse and ENUSA groups were visited. All the contacted authorities participated and when this programme was completed, it was possible for DGSNR and IRSN to get a more accurate measure of particular reassessment work. The main results of these actions were to 'standardize' the consultancy's judgement and, taking advantage of encountered good safety practices and good safety designs, it was possible to reinforce specific

requests during the reassessment work. Moreover, it was an opportunity for the operators to participate in deepening information exchanges about safety topics.

1. INTRODUCTION

For a long time, the safety reassessment of NPPs has been the subject of a large exchange of experience between European regulators. In addition, the 58 French power reactors are characterized by an overall standardization which offers the opportunity of a very efficient national operating experience feedback. On the other hand, fuel cycle installations, as fuel fabrication plant, are in most cases unique and the related domestic database is comparatively reduced. So, it appeared to be interesting to improve this with external sources, by means of consulting other national nuclear safety authorities. This has been recently done in France, for the safety reassessment of the FBFC uranium oxide fuel fabrication plant.

In the last months of 2001, a programme was set up; it may be presented as follows:

— General approach and principle;
— Preparation and organization of the programme;
— Results and benefit of the programme to the FBFC plant reassessment.

2. GENERAL APPROACH AND PRINCIPLES

— Bilateral meetings preferred to multilateral;
— Peer to peer level (senior staff not directly involved in order to enhance free discussion);
— The host nuclear authority is the only interface with the French team;
— Be aware that the visit to the nuclear site is not regarded as an inspection by an operator;
— The visit of the plant and associated options are organized by the host authority.

A final meeting was organized and took place in Lyon, France in January 2004. All the involved European nuclear safety authorities attended this meeting and a synthesis of the information coming from the different visits has been presented, followed the day after by a visit of the FBFC manufacturing plant in Romans-sur-Isre, France.

3. PREPARATION AND ORGANIZATION OF THE PROGRAMME

3.1. The programme

The initial choice has been to restrict the programme to western European nuclear authorities, the US, Japanese and Russian ones remaining optional.

Six European countries have an established nuclear fuel fabrication plant: Belgium, Germany, United Kingdom, Spain, Sweden and France. Most of these facilities belong to Westinghouse or Areva/Siemens Group, except the Juzbado case in Spain, which is a subsidiary of the Spanish industrial group ENUSA but works using a Westinghouse licence (see the appendix for general information on the different plants visited.

3.2. Standard questionnaire

To make it easier to undertake the final analysis and get a common outline, a Standard Questionnaire had been established and previously sent (in the early months of 2002) to each nuclear authority. The main structure of this document roughly consists of two parts:

- A description, including plant production functions (UF_6 conversion, pelletization, etc.) and main authorizations (production level, on-site nuclear material storage capacity, radioactive releases, etc.);
- A set of more detailed questions related to different hazards usually reviewed during a reassessment operation;
- Nuclear material containment (ventilation principle, contamination level, workstation specially contained);
- Criticality (design principle, codes);
- Radiation exposure (regulation, limit, improvement approach, target figure, ALARA);
- Fire and explosion (prevention, intervention and training programme, use of pure hydrogen or gas mixture in the process).

Special attention was paid to prevention, measurements and a quality assurance programme. Except in the case of criticality, the questions related to human factors were considered as more difficult to approach because of their cultural sensibility and were not accounted for.

3.3. Organization of the visits

A two day work programme had been finalized for a five member French visiting group composed of two representatives from DGSNR, one from DSNR (regional bureau of the French authority) and two IRSN experts.

The following agenda had been proposed to the visited nuclear safety authorities and accepted.

The first day was essentially devoted to discussions with host authority representatives and the involved topics that were generally discussed being:

— Regulation principle and recent evolutions;
— Nuclear safety authority organization and relation with technical support (if relevant);
— Control and survey practices, inspection (site inspectors or not);
— Practice of delegation of safety related decisions to plant operator, safety contract;
— Quality assurance controls;
— Radiation protection.

By way of illustration, the second day was devoted to a visit to the facility, the French group being accompanied by at least one member of the host safety authority. For evidence, specialized technical discussions were spontaneous with technical staff and safety managers.

4. RESULTS

The visiting programme started in July 2002 with the German safety authorities (Federal and Lower Saxony) and arrived to completion in mid-November 2002, with the Belgian authority.

4.1. Authority action

Considering specifically the authority point of view, the main interest was to compare organizations and practices to ours and highlight the topics that may be of use in future improvement work. In this way, it is possible to mention the following items:

— Efficiency of safety control by authority and responsibility delegation to operator;

— The balance between technical arrangements and operator response;
— Practice of site inspections and safety reviews.

Concerning public information, practices generally appeared to be very different from the French ones and it was estimated to be not possible to efficiently use, directly, these external references.

4.2. FBFC reassessment benefit

Once the programme was over, and taking into account the results of the received standard questionnaires analysis, it was possible to identify some purely technical or relevant human factor points to reinforce the reassessment work.

At first, the most important external feedback concerns nuclear material containment. This point is strongly related to radiation protection (internal dosimetry), and the following points have been particularly highlighted and finally taken into account within the FBFC reassessment framework:

— General workstation containment;
— Safety arrangements for containment losses due to process design.

The autoclave used for the conversion process in each plant having this process stage is the best solution to limit the risk linked to the hexafluoride uranium in liquid phase and will replace the ovens used in the FBFC plant.

This programme equally shows that:

— It is possible to manufacture uranium oxide fuel using a mixture of gas in the sintering furnace, like that for MOX fuel manufacturing;
— Quality assurance validation procedures, when applied to codes (criticality), remains a difficult question.

Considering the human factor question, the importance of:

— Keeping and improving the competence level;
— Preventing workers' turnover and ageing.

These latter points have been mentioned by some of the visited operators, university level students having less interest in nuclear industry in comparison with previous generations.

4.3. European safety benefit

This exercise showed that the approach is sometimes different in European countries, especially in the case of:

— Gaseous and liquid discharge authorizations;
— Worker internal dose monitoring.

Technical exchanges on these topics would pave the way for a better understanding and would foster harmonization of practices.

5. CONCLUSIONS

The initial targeted objectives have been reached. Our initial judgement was often confirmed and some of the recommendations we formulated have been reinforced or justified by the foreign experience feedback. These original objectives have been exceeded, plant visits and information exchanges among the industry's representatives related to safety lead to define and share good practices.

The obtained results, at the end of this programme, demonstrated the possibility of an international contribution to installation nuclear safety improvement. However, we believe this could be further improved by:

— European harmonization of practices;
— Recognition of these practices at the international level.

These latter points, with the possibility of joint international inspections, have been discussed during the final meeting we organized and, looking forward, they may be regarded as starting points for further international discussions or actions in the fuel cycle nuclear plant safety area.

Appendix

TABLE 1. PLANTS VISITED

Plant	Lingen	Västeras	Springfield	Juzbado	Dessel	Romans
Fuel design	PWR BWR	PWR BWR	AGR PWR[1] BWR[1]	PWR BWR	PWR	PWR
Startup date	1979	?	1995	1985	1972	1978
Conversion process	Dry	Wet	Dry	None	None	Dry
Conversion capacity	500 (authorized)	600 (authorized)	Not transmitted	n/a	n/a	1200 (authorized)
Number of conversion lines	2	2	3	—	—	7
Assembly capacity	650 (authorized)	420 (authorized)	Not transmitted	400	No limit[2]	820 (authorized)
Number of assembly lines	2	3	2	3 (+ 1 Gd)	1 (+ 1 Gd)	2
Authorized UF_6 storage capacity	169.5 (TU)	No limit	No limit	n/a	n/a	285 (TUF_6)
Max-enrichment (%)	5	5	5	5	5	5

[1] Mothballed.
[2] Storage limit: 80 t of powder, 50 t of pellets and 400 assemblies.

SAFE LONG TERM OPERATION OF WATER MODERATED REACTORS
The need to index, integrate and implement existing international databases

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Abstract

In response to an increasing number of nuclear installations pursuing extended operations beyond their initial design life, the IAEA recently initiated an Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water-Moderated Reactors (SALTO EBP) to assist Member States to reconcile related processes, establish a general framework and provide a forum to develop international consensus on long term operation (LTO). The IAEA Programme and the paper address periodic safety reviews (PSR) and different approaches to ensuring adequate safety margins, regulatory approaches for LTO, balancing power uprates versus maintaining safety margins, and the need to address the monitoring, mitigation, replacement and ageing management programmes of active and passive systems, structures and components. The SALTO EBP addresses concepts such as life cycle management, obsolescence management, preconditions for LTO, ageing management, life extension and licence renewal under the rubric of 'long term operation'. Mandated to look for cross-cutting LTO similarities, the SALTO EBP is divided into four Working Groups with a focus on indexing, integrating and implementing the great wealth of existing international databases to ultimately create a 'living' guidance document, regularly updated with new lessons learned from all Member States to ensure that major safety issues are addressed. One such database, now being revised and expanded to a relational database format, is the Generic Ageing Lessons Learned (GALL) Report that catalogues plant structures and components; lists the materials, environments, ageing effects and mechanisms; and documents Nuclear Regulatory Commission evaluation of existing plant programmes that can mitigate or manage these ageing effects. With continuing long term support, this Programme can create an International GALL (IGALL) database that Member States can use to evaluate the safety of nuclear plant LTO. Due to the variability of Member States laws and regulations, IGALL may be supplemented by national or regional documents that address specific regulatory environments.

1. CURRENT STATUS: EMPHASIZE COMMONALITY OF INTERNATIONAL EXPERIENCE

At present, there are over 400 operational nuclear power plants (NPPs) in the IAEA Member States. Many of these operating NPPs are approaching the end of their original design life; the possibility of long term operation (LTO) is an issue of critical concern. Operating experience has shown that ineffective control of the ageing degradation of major NPP components can jeopardize plant safety and life [1]. NPP operators are facing the choice of either decommissioning the plants or upgrading the plants for LTO, providing that the required safety can be maintained during the period of extended life. Some IAEA Member States have already developed regulations and regulatory infrastructures for operation beyond the originally designed life, but many others have just started this process. Although there is no international consensus on requirements for long term operation of nuclear power plants, a strong common interest in LTO and maintaining or improving the safety of these facilities has emerged at international meetings. However, most of these meetings have focused on high level programmes to develop safety standards [2] or on very specific issues [3]. In 2001, the IAEA's International Conference on Topical Issues in Nuclear Safety identified the need to develop international guidance on the use of probabilistic safety insights and to define a small set of safety performance indicators with international uniformity and relevance to operators, regulators and the public [4]. Key conference findings, transferred to the IAEA's Medium Term Strategy for 2001–2006 [5], included the need to optimize synergies with traditional partners and develop cooperation with non-traditional partners.

1.1. Develop consensus approach to long term operation

A prerequisite for consideration of LTO of water moderated NPPs is the implementation of appropriate ageing management programmes (AMPs), such as those identified in IAEA nuclear installation safety publications [6]. While most LTO safety concerns are understood generically, difficulties remain in the identification of the vulnerable plant systems, structures and components (SSCs) and of associated safety criteria on a design or reactor type basis. A common LTO approach, determined by international consensus, and including regulatory framework, processes and practices, needs to be developed to serve the interests of Member States. In May 2003, the IAEA started the SALTO EBP, in which Bulgaria, the Czech Republic, Finland, Hungary, the Russian Federation, Slovakia, Spain, Sweden, Ukraine, the United Kingdom, the

United States of America and the European Commission are currently participating [7].

1.2. Index existing guidance documents from Member States

The IAEA recognized the importance of safety aspects of nuclear power plant ageing in the 1980s and initiated activities to address emerging safety concerns related to physical ageing of plant SSCs. Numerous publications were issued since that time, including guidelines on programmatic aspects, specific components and ageing management review. Many of these documents are accessible through the Safety Knowledge Base on Ageing and Long Term Operation [8]. Although a standalone internationally comprehensive LTO guidance publication is not yet available, many relevant publications are readily available through Internet sources, such as the IAEA and the OECD/NEA web sites, the European Commission's database on nuclear safety and radiation protection, and the United States Nuclear Regulatory Commission (NRC) reactor licence renewal web site [8–11]. Such guidelines need to be systematically reviewed, compiled and consolidated into a user friendly publication that would provide Member States with specific guidance for long term operation. Although the IAEA Safety Standard NS-G-2.10 [12], Periodic Safety Review of Nuclear Power Plants, provides guidance on safety factors which have to be assessed periodically to ensure safe operation throughout the plant life, it does not contain any explicit guidance for long term operation. Soon after its 2003 inception, the SALTO EBP realized that an internationally agreed, comprehensive guidance publication was needed to address unique LTO challenges. The SALTO EBP is working towards developing a 'living' guidance publication, regularly updated with new lessons learned from all Member States to ensure that major LTO safety issues are addressed.

2. PRIORITIES FOR FUTURE WORK: OPTIMIZE AND INTEGRATE INTERNATIONAL DATABASES

2.1. Learn from operating experience in Member States

Understanding international operating experience is an important attribute of the LTO transition. Lessons learned in outage and configuration management must be applied to the development and comprehensive implementation of effective corrective action programmes. Given public expectations, operators and regulators must be proactive and trend precursors, and rely on the use of low level event and near miss information. Attention must be paid to the signs of a localized industry dysfunction — complacency, overconfidence, loss of safety focus, production versus safety. The SALTO EBP is an integrating effort to bring together in a structured way all of the LTO efforts over the past decade into a single frame of reference. The combined experience of all participating Member States is necessary in developing an optimal approach to safe LTO, but such an optimal approach can only be achieved if built upon the foundation of operating experience and corrective and mitigative efforts across the broadest spectrum of facilities. Being able to create a document to index and integrate such wisdom is the next step towards technical implementation of optimal ageing management and monitoring practices at reactor sites.

Safety is affected by what happens at the plant. Such operating experience is independent of the country specific requirements originating from a US style licensing process and oversight [11] or an equivalent process that incorporates PSR [12], as developed and practiced in many countries. Reactors start to appear very similar when reduced to functions, components, materials, environment and ageing effects and mechanisms (Fig. 1). The effort for safe LTO also appears more consistent when different designs are conceptually visualized as ageing management and monitoring needs that must be met to ensure safety.

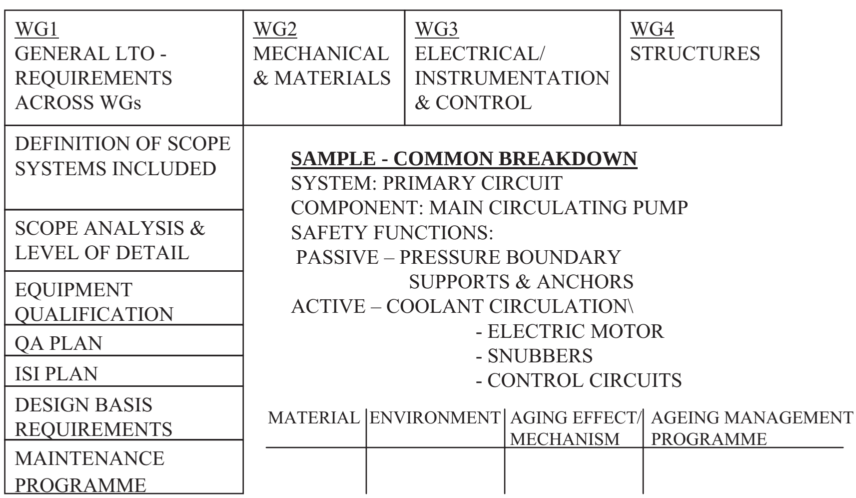

FIG. 1. Relationship between the functionality of working groups in IAEA SALTO EBP Working Groups (WGs) and parameters affecting long term operation — safety functions, components, materials, ageing effects/ageing mechanisms, and ageing management programmes.

The new SALTO EBP, mandated to look for such cross-cutting similarities, is divided into four Working Groups. The objectives of Working Group One are to identify preconditions for LTO; review regulatory approaches to LTO in participating Member States; reach a consensus on a regulatory approach and safety criteria for LTO via deterministic and/or probabilistic analyses; identify necessary information contained in design and safety basis documents to establish a baseline for LTO; identify attributes of acceptable plant upgrading and AMPs; and discuss future challenges. Working Groups Two, Three and Four each evaluate Member States' ageing management processes for all safety related SSCs affecting the integrity of the reactor coolant pressure boundary; the capability to shut down the reactor and maintain it in a safe shutdown condition; and the capability to prevent or mitigate the consequences of accidents that could result in potential off-site exposure. Working Group 2 focuses on mechanical components and materials; Working Group 3 emphasizes electrical components, instrumentation and control; and Working Group 4 targets structures and structural components.

2.2. Implement country specific lessons learned: US experience in licence renewal

During the past 20 years, in an effort to provide credit for existing NPP programmes, the NRC undertook a complete evaluation of common existing plant programmes to determine which AMPs would be adequate to manage ageing effects without change and which should be augmented. NUREG-6490 [13], issued in December 1996, provided the foundation for this evaluation and contained information gleaned from a number of sources, including more than 150 reports resulting from the NRC's research programme, Nuclear Plant Ageing Research, initiated in the early 1980s [14]. NUREG-6490 also includes information documented in ten industry reports addressing licence renewal submitted by the former Nuclear Management and Resource Council, as well as operating experience documented in the NRC's generic communications and Licensees' Event Reports throughout the years. The results of an updated evaluation are documented in NUREG-1801, Generic Ageing Lessons Learned (GALL) Report, published in July 2001 [15].

Countries are at different stages of addressing this topic of licence renewal and long term operation. The extensively documented licence renewal programme within the USA [11], by virtue of the size and age of US nuclear power plants, is currently going through an evolution towards attributable information available through both hard copy reference documents and relational databases (Fig. 2). This process could be improved by broader technical knowledge gained from international operating experience and, reciprocally, may provide valuable insight for beneficial multilateral efforts. The review of licence renewal applications may be expanded in the future beyond passive SSCs to encompass inspection and monitoring of active components as the SALTO EBP recognizes the similarities of different designs and the pervasive nature and uncertainty of observed degradation. Knowing that Member States are conducting similar NPP inspections, audits and monitoring, without observing unanticipated LTO related degradation, provides added assurance of the effectiveness of the AMPs that have been implemented.

3. STRENGTHEN INTERNATIONAL ACTIVITIES BETWEEN THE IAEA, UTILITIES AND REGULATORY AUTHORITIES

The world's demand for power is driving both the LTO and power up-rates of ageing reactors, as well as the design and certification of new reactors. The desire to increase operating plant efficiency and performance has led to other initiatives, such as reducing the refuelling outage duration, extending the period between refuelling outages, decreasing the frequency of preventive maintenance, increasing the reliance on condition monitoring (vibrations

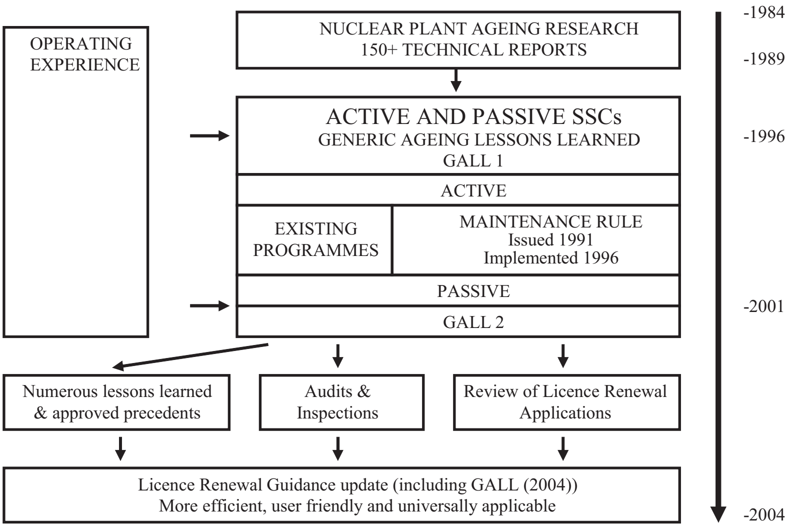

FIG. 2. The evolutionary process in the USA for developing NPP licence renewal guidance and long term reactor operation.

analysis, thermography, oil analysis) in lieu of time directed tasks (overhauls). The operating experience associated with these initiatives on LTO should also be shared by Member States. The need for increased energy at the same time as the NPP fleet is approaching the end of its design life links the power uprates to LTO. This linkage and possible changes in safety margins increase the need for international collaboration as reactors must be operated in a region of increased flow, temperature and pressure despite limited operating experience. By establishing a systematic focal point for collecting and disseminating information necessary for monitoring, mitigation and ageing management, the SALTO EBP can provide a greater degree of certainty to international efforts to ensure safety with a broader technical basis. The NRC has already certified three new reactor designs pursuant to 10 CFR Part 52, including GE's advanced boiling water reactor and Westinghouse's advanced passive 600 (AP600) and System 80+ designs [16]. Long term operation is as important for new reactors as for the existing fleet facing licence renewal.

4. CONCLUSION: SALTO EBP PROACTIVELY TARGETS EMERGING INTERNATIONAL LTO ISSUES

Diversity and globalization of the nuclear industry present challenges in the context of long term operation. Issues include ensuring quality; obtaining, maintaining and managing knowledge; utilizing common, internationally accepted safety standards; balancing the needs between safety and security; promoting cooperation and sharing of experience between regulatory authorities; and dealing with suppliers, vendors and contractors from different national backgrounds. Licensing of facilities designed to different standards and criteria and applying safety standards from different supplier countries is an increasing concern as operating organizations and vendors are consolidated across national boundaries. Networking through programmes such as the IAEA SALTO EBP is critical in terms of bridging geographical and cultural barriers. With the dedication and vision of SALTO EBP Member States, as well as continued support from the IAEA over the next five years, this Programme can create an IGALL database and standard review process that together can be used around the world as the primary reference in evaluating the safety of life extension and long term operation of nuclear power plants.

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LIFETIME EXTENSION OF RUSSIAN NUCLEAR POWER PLANTS

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1. LIFETIME EXTENSION OF OPERATING NUCLEAR POWER PLANTS

A lifetime extension of the operating NPPs is an important tendency at the modern stage of nuclear power development and the most efficient area for investments in order to maintain the existing generation capacities.

The lifetime extension activities at the operating NPPs are performed in accordance with legislation entitled the Programme of Nuclear Industry Development in 1998–2005 and up to 2010, approved by Decree of the Russian Government No. 815 of 21 July 1998. The performance of these activities in the development of the Russian nuclear industry is promoted by two main factors:

— The 30 year duration of the operational NPP lifetime established in the design was determined in the 1950s and 1960s, and reflects a certain conservatism of the accepted calculation basis for its justification when there were no factual operational data on the NPP equipment wear. The experience of the NPP operation now allows justifying the revision of the previously established operational life durations for the power units and terms for the NPP equipment decommissioning.

— The lifetime extension activities performed in the Russian Federation demonstrated that the specific financial expenditures necessary to comply with all the regulatory requirements to obtain the lifetime extension licence are significantly lower than the costs for any new unit construction.

2. STRATEGY OF NUCLEAR INDUSTRY DEVELOPMENT IN THE FIRST HALF OF THE 21st CENTURY FORESEES THE LIFETIME EXTENSION OF OPERATING POWER UNITS

The strategy of nuclear industry development in the first half of the 21st century, approved by the Government of the Russian Federation on 25 February 2000, foresees ensuring the lifetime extension of the operating power units upon expiry of their designed lifetime. The lifetime extension of the first generation NPP units is of a general industry character. It is necessary to perform a set of activities on modernization and lifetime extension for ten NPP units of 4345 MW total rated power.

3. NPP LIFETIME EXTENSION ACTIVITIES AND LEGAL REQUIREMENTS

NPP lifetime extension activities are performed in accordance with the requirements of valid Russian legislation and Federal norms and rules in the area of atomic energy use, outlined in the following subsections.

3.1. Federal law: On the use of atomic energy

Article 9 authorizes the Government in the area of atomic energy use to make decisions regarding design, construction, operation and decommissioning of the nuclear installations owned by the Federal State.

3.2. Federal norms in the area of atomic energy use

The following are relevant Federal norms:

— General Provisions of Ensuring NPP Safety (OPB-88/97; NP-001-97; PNAE G-1-011-97);
— Rules for Configuration and Safe Operation of NPP Equipment and Pipelines (PNAE-G-7-008-89).

They allow the principle possibility of a lifetime extension of NPP equipment and NPPs on the whole.

3.3. State standard: NPP and NPP equipment reliability

The State standard, NPP and NPP equipment reliability, determines the NPP established lifetime as a calendar period of the NPP operation pointed out in the design, upon expiry of which the further NPP operation could be extended with a decision made on the basis of its safety and economic efficiency investigation.

To develop the existing normative and methodological basis concerning the issues of the NPP lifetime extension in 1999–2001, Federal documents were developed and put into force containing technical requirements in the area of the works performance and preparation of the NPP units for lifetime extension and criteria to estimate its successfulness, namely:

- Federal Norms: Main Requirements for Lifetime Extension of the NPP Unit (NP-017-2000);
- Regulation: Requirements to the Content and Composition of the Documents Justifying Safety for the Period of the NPP Extended Life (RD-04-31-2001).

In addition, the utility Rosenergoatom, in order to develop the Federal norms and rules, developed and put into force in the established order a set of guidelines and methodological documents, including:

- Guidelines for Organization and Performance of the NPP Equipment Modernization;
- General Programme for Comprehensive NPP Unit Investigation to Extend the Lifetime;
- Guidelines for Management of the Life Features of the NPP Unit Elements (RD EO 0283-01);
- Quality Assurance Programme for Design, Construction and Operation Activities at the First Generation NPP Units (RD EO 0281-01);
- General Guidelines for the First Generation Units Life Extension (RD EO 0291-01);
- General Guidelines for the Second Generation Units Life Extension (RD EO 0327-01);
- Methodology of the Equipment Residual Lifetime Justification.

4. ACTIVITIES OF LIFETIME EXTENSIONS OF NPP UNITS

According to the valid Russian normative documents, the activities of lifetime extensions of NPP units shall include:

— Comprehensive NPP unit examination;
— NPP unit safety assessment;
— Assessment of the economic 'reasonability' for the lifetime extension of the NPP unit under consideration.

The result of the completed activities is the decision to be made regarding 'reasonability' for the lifetime extension of the NPP unit considered.

Further activities are devoted to the development of the programme for NPP unit preparation to the additional operation period. It includes:

— Justification for the lifetime extension of irreplaceable elements;
— Implementation of the comprehensive programme for NPP unit modernization;
— Testing of the NPP systems and elements;
— Justification of NPP unit safety.

The results of these activities are reviewed in Minatom[1] and submitted by the utility to the regulator[2] for independent expertise and licensing of the NPP operation during the additional period.

When performing the NPP unit lifetime extension activities, it is necessary to take into account the following:

— Determination of the necessary scope of the modernization activities for the unit to be performed for the lifetime extension is executed on the following results:
  - Deterministic analysis of the NPP unit design compliance with the valid normative documents in the area of safety, including identification of the discrepancies and their impact to ensuring the in-depth protection and development of the corrective measures on elimination of the main safety issues;

[1] Since April 2004, the Federal Atomic Energy Agency of the Russian Federation.

[2] Formerly Gosatomnadzor, since 2004 the Federal Ecological, Technological and Nuclear Regulatory Authority (Rostechnadzor).

  - Probabilistic safety assessment, including identification of the total core damage frequency and its significance upon completion of modernization activities.
- The main purposes of the unit comprehensive investigation are as follows:
  - Obtaining and analysis of information regarding real status of the unit elements;
  - Preliminary residual lifetime assessment of the unit elements;
  - Identification of the unit elements, including 'critical' with residual life remaining and planned for further operation;
  - Identification of the unit elements to be replaced due to the lifetime expiry.

The following is planned on the basis of the unit comprehensive investigation results:

- Replacement of the expired elements;
- Maintenance and repair of the elements, of which lifetime restoration is necessary to meet the normative requirements;
- Justification of the residual lifetime of the 'critical' (irreplaceable) elements, i.e. operating in the most severe conditions and endured to the maximum impact of the operating factors.

5. ACTIVITIES ACCOMPLISHED AT UNIT 3 OF NOVOVORONEZH NPP (NV NPP)

As an example of implementation of the lifetime extension programme, the activities accomplished at Unit 3 of Novovoronezh NPP (NV NPP) are described below.

The activities aimed at NV NPP Unit 3 lifetime extension have been carried out on the basis of existing Federal norms and rules in the field of use of atomic energy, as well as guidances and methodological documents of the operating utility, the most part of which has been developed during the period of implementation of the activities. The development of a regulatory basis for unit lifetime extension was carried out with international experience and IAEA recommendations for NPPs built in accordance with earlier standards taken into account.

In 1999–2001, the first time in domestic nuclear power history, the comprehensive examination programme towards unit lifetime extension had been fully accomplished for NV NPP Unit 3. The results are as follows:

- — Regulatory basis for lifetime extension of existing power units has been established;
- — Economic feasibility studies for unit lifetime extension have been fulfilled;
- — Unit modernization aimed at enhancement of its safety has been carried out;
- — The comprehensive examination has been accomplished, and equipment residual life has been justified;
- — An In-depth Safety Assessment Report (IDSR) has been prepared taking into account all the modifications implemented at the unit;
- — Startup activities, including necessary tests of the upgraded systems and equipment and the unit as a whole, have been completed;
- — Novovoronezh NPP Unit 3 personnel were correspondingly retrained.

A more detailed description of the activities is as follows. During 1999–2001, all the planned activities on implementation of the technical measures at Novovoronezh Unit 3 NPP had been completed, including upgrading of the accident mitigation system on the basis of implementation of the vortex stream condenser.

In addition, the reactor control, monitoring and protection system, reliable power supply system, process systems and safety systems had been upgraded.

The startup activities and necessary testing of the upgraded systems and equipment had been completed, which confirms their operability within the scope of the design and construction requirements.

Novovoronezh NPP Unit 3 personnel were correspondingly trained. The operating documents had been revised in accordance with the established order.

As a result of the performed modernization, the safety of NV NPP Unit 3 had been significantly enhanced. The modernization results are reflected in the final report, Lifetime Extension and Safety Enhancement as a Result of the First Generation WWER-440 Units Modernization (NV NPP Unit 3).

The core damage frequency upon completion of the modernization did not exceed the value of 3.44×10^{-5} per reactor annually. Prior to the modernization, that value was 1.8×10^{-3} per reactor annually.

The utility developed and approved the In-depth Safety Assessment Report in the scope necessary for obtaining NV NPP Unit 3 long term operation licence in accordance with the Recommendations of the Russian Regulatory Body (RB G-12-42-97). IDSR reflects the state of NV NPP Unit 3 equipment and systems for the time of its preparation to the operation within the additional life period.

IDSR materials were endured to the independent expertise in the Russian regulatory body.

On 28 December 2001, the utility obtained a long term licence from the Russian regulatory body No. GP-03-101-0734 for operation of Novovoronezh NPP Unit 3 beyond the limits of the design lifetime.

6. CONCLUSIONS

The activities performed in the area of the NPP life extension resulted in the following:

— Justification of the NPP lifetime extension technical and economic 'feasibility';
— As of October 2004, the lifetime extension activities have been accomplished for five power units with a total installed capacity of 2760 MW. The same activities are being carried out at seven more power units;
— There is continuous work on further improvement of the legislative, regulatory, methodological and guideline documentation in the area of the NPP units lifetime extension.

All the necessary prerequisites and preconditions required for successful implementation of the lifetime extension programmes for the first and second generation NPP units exist in the Russian Federation.

NUCLEAR SAFETY, RADIATION PROTECTION, AVAILABILITY AND ENVIRONMENT BODY (OSRDE) AT EDF
A tool for optimizing safety in terms of major decisions

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Abstract

The production of electricity at nuclear power plants is one of the foundations of development of Electricité de France (EDF). Alongside renewable energies, it will remain one of the most important areas for EDF in future years. The durability of this commitment is closely linked to public confidence in this energy and in those managing it. Professionals in the nuclear domain are faced with a great many demands, including safety, radiation protection, availability and the environment. Occasionally these requirements can conflict with each other and, in view of the fact that safety must always remain the number one priority, they necessitate complex and difficult arbitration methods that must be explained to the persons responsible for applying the decisions. The actions taken to improve quality on a daily basis both at an individual and group level constitute the most effective means of reconciling the requirements linked to nuclear safety, radiation protection, availability and the environment, and will consequently improve the safety performance of all its nuclear power plants by optimizing the way in which the other domains are taken into consideration. From 1996 onwards, the management of the Nuclear Production Division has been identifying these arbitration issues and it has deployed the General Directorate of Safety and Radiation Protection, one of the levers of safety management. The job of this directorate is to perform a post-analysis of the decision making process leading up to an important decision with a view to improving the professionalism of the decision makers by ensuring that the existing processes are subjected to constant scrutiny. The opening up of the energy market increases the importance of this lever in guaranteeing that the aspect of safety remains the number one priority uppermost in the minds of all the decision makers. Following the major commitment made by the Nuclear Production Division in terms of the management of radiation protection and then the environment, the French acronym of the general directorate will change from OSD to OSRD (incorporating the radiation protection aspect) and, consequently, the OSRDE (incorporating the environmental aspect). This name will thus incorporate the major issues identified by the Nuclear Production Division and piloted via its managerial processes.

1. INTRODUCTION

The Nuclear Safety, Radiation Protection, Availability and Environment Body (l'Observatoire Sûreté, Radioprotection, Disponibilité, Environnement, or OSRDE) is a decisive and effective safety management lever which develops:

— Exemplary management;
— The capacity for collective questioning;
— Discussions within work teams.

It is in synergy with the risk analysis used for preparing decisions.

2. PRIORITY GIVEN TO SAFETY — OBJECTIVES

The OSRDE represents a willingness to progress, openly, with regard to operation choices so that all safety requirements are complied with by ensuring performances which are an integral part of the responsibility of the nuclear operator serving the electricity network.

In tandem with renewable energies, nuclear energy is one of the main issues for Électricité de France (EDF) in future years as part of its contribution to sustainable development. The durability of this commitment is closely linked to the trust that the public affords and will afford to this energy and to the operators.

The nuclear operator must respond to very varied demands, such as safety, radiation protection, availability, the environment, that are sometimes in opposition and which, while always giving priority to safety, require deliberations which are difficult and complex to explain to those having to implement decisions.

The initiatives for daily improvement in quality at the individual and collective level form an effective method for reconciling these requirements and increasing performances of the electronuclear installations in the safety domain by optimizing the involvement of other domains. With the opening up of the energy market, all these initiatives play a part in ensuring that safety remains at the top of the decision maker's agenda.

Since 1996, the management of the EDF Nuclear Operations Division (DPN) has identified these deliberation issues and decided to analyse the decision making processes which have led to key decisions, by means of a Safety Availability Body (referred to as OSD), one of the management levers for safety.

Following the firm commitment of the DPN to managing radiation protection, OSD then included this domain in examining the decision making process (OSRD) in 2000. The heatwave in August 2003 required deliberations between safety, availability and the environment; OSRD then became OSRDE. Moreover, this name sums up the major issues identified by the DPN.

In 2003, the Director of the EDF Nuclear Production Division reaffirmed the importance that he attributes to the OSRDE and requested that all the DPN Units commit themselves to continuously improving the decision making process. The management of the DPN, in a step towards optimization, applies the OSRDE to decisions that it needs to take. A quarterly assessment on the use of this lever within the units is carried out by the DPN management teams:

The initiatives for daily improvement in quality at the individual and collective level form the most effective means for reconciling the requirements concerning nuclear safety, radiation protection, availability, environment, and increasing performances of the electronuclear installations in the safety domain by optimising the involvement of other domains.

3. OSRDE OBJECTIVES

The OSRDE objectives is to continuously improve the decision making process so that the key deliberations reconciling scrupulous compliance with safety with all of the other requirements are better understood by all of the agents and external monitors. A key deliberation is a deliberation that could undermine safety, radiation protection, availability or the environment in relation to the requirements of each of these domains. When badly expressed or not expressed at all, this would then have an impact on the trust afforded us by the public, the agents, and the control and monitoring bodies both internal and external to EDF.

Therefore, improving our decision making processes also involves the professionalization of decision makers and agents who help in the process. To achieve this, when the management of the unit has identified a decision before being examined by a safety, radiation protection, availability and environment body, the players involved in the decision are requested, in retrospect, to consider the way in which they took the decision. The essential steps towards taking a decision, such as the way to present the problem, identification of the contributors to the decision, identification of the risks linked to the problem but also the risks linked to the decision, the traceability of the decision, communication of it internally or externally, the steering of the actions that accompany it, etc., are then examined.

The interoccupation exchanges on the way in which the process has been implemented are a means for improving safety since they promote a better understanding of their knowledge, their occupation, their expectations and the way in which they understand their position in decision making.

4. IMPLEMENTING THE OSRDE ON THE SITES

The OSRDE is the property of each site. Implementation methods are adapted to each local situation, in particular, to ensure consistency with site decisions on safety management and related aims, including:

— Key situations and those of an educational nature are retained; the exhaustiveness of the situations has not been researched;
— The OSRDE is a collective teaching aid for situations encountered; it does not enable the level of safety during operation to be measured;
— The situations analysed must involve a sufficiently significant decision which does not obviously ensue from compliance with requirements. Compliance with safety, radiation protection and environmental requirements is a priority and any differing decision must be subject to a justifiable request for dispensation;
— The OSRDE must mainly concern itself with well managed situations for which the correct method of dealing with them can be shared or with situations which have a favourable solution and in which the process raises questions and not only in situations leading to an incident;
— The OSRDE initiates feedback on the decision making process, mainly concerning operating safety, and is not a substitute for real time management;
— The quality of analysis in the OSRDE brings together technical skills, analysis of the human element and communication so that it fulfils its educational objective.

5. METHOD

Implementation relies on organization which:

— Detects key deliberations (detection system at different levels of superiority: Head of Operations/Safety Engineer exchange, various safety committees, validation before management, etc.);
— Prioritizes and decides on the process;

— Encourages analysis, discussion, communication within the team which has contributed to decision making and identification of actions for improving the process;
— Validates the analysis and the proposals for improvement and monitors the implementation and the impact;
— Allows for a reduction in the analysis of results and improvements by the groups of people involved.

5.1. Prerequisites

The following describes the prerequisites:

— The objectives must be clearly communicated to all of the agents.
— The organization must be defined and explained.
— Management must set an example and not hesitate to analyse its decision making processes.
— Management must get involved in creating awareness of the OSRDE and in detection.
— The participative aspect (self-diagnosis) must be emphasized.
— The body requires skills for coordinating cross-analyses.

5.2. Detection of situations

Detection is carried out in all the decision making authorities, in the service EDs, in Head of Operations/Safety Engineer exchanges, etc. In the latter case, management must motivate detection.

5.3. Steering of the OSRDE

An operational guide is appointed to gather together the preparatory elements for the body. He writes a chronological summary of the decision making process as it unfolded (the document will serve as a guideline for exchanges within the OSRDE group).

The OSRDE, chaired by a member of management, brings together, in accordance with the site organizations, the decision makers, a meeting coordinator, the OSRDE Unit support who guarantees methodology, and the human element consultant. The objective is to carry out self-diagnosis of the decision making process.

The following (non-exhaustive) points can be examined:

— Has the problem been set out clearly?
— Have the risks (technical, statutory, media, social, etc.) been identified and solutions provided?
— Were all of the necessary supports in place?
— Did all of the supports respond to the expectations of the decision maker? Did they properly understand what was expected of them?
— What are the elements which would have facilitated the decision? Why did we not have them?
— Was the decision tracked?
— Was communication of the decision and the ensuing actions sufficient and inclusive?
— Were the actions accompanying the decision steered and implemented?
— Did these actions produce the expected results?
— A summary to be drawn up with proposals, if necessary, of progress points.

5.4. Validation, communication

The validation phase is frequently carried out by a safety authority or management but there is still progress to be made in passing on conclusions of the OSRDE to staff, with a better involvement of management.

6. SUCCESS FACTORS, IMPEDIMENTS AND PROGRESS POINTS

6.1. Success factors

The following are the main factors of success:

— The first element of success of the OSRDE is motivation, team spirit and the in-depth involvement of the operational managerial role, by its capacity to question the way in which decisions are taken and communicated. However, it is also its capacity to communicate on the direction and the issues relating to the OSRDE, as well as the gains which can be obtained in terms of development in the culture of safety. Cross-work, communication, a better knowledge of other occupations with the expectation and the capability of mutual support can all be given as an example.
— The second element is to define with the agents what a key decision can be.

— The third element is to implement a simple and effective OSRDE organization so that the workload is not too heavy.

6.2. Main impediment

The OSRDE must be used to promote the transparency and discussion in the decision making process, and not to justify a posteriori the decision taken by the manager.

6.3. Progress points

The OSRDEs have increased awareness of weaknesses in decision making processes and have enabled them to be better structured by:

— Traceability of decisions;
— Systematic implementation of risk analysis to evaluate consequences of the decision as regards safety and also the other domains, as well as social and media impacts;
— Communication of an explanation of the decision to the agents and principally to those responsible for implementing actions decided on;
— The contribution of each player to decision making by means of a better awareness of the role of each one and what is expected of him (role of Head of Operations, Safety Engineer, trade representatives, etc.).

LIFE EXTENSION AND SAFETY UPGRADING IN INDIAN NUCLEAR POWER PLANTS
A regulatory perspective

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Abstract

The Indian nuclear power generation programme started with the commissioning of twin unit BWRs at Tarapur way back in 1969. Today 14 units, mostly PHWRs, with total installed capacity of 2720 MW are in operation and eight units with installed capacity of 3880 MW are under various stages of construction. The new plants are built to current standards and employ the present day technology and hence easily meet the present day safety requirements. The old plants obviously cannot meet these requirements to the same extent since they were built to the standards that existed at the time of their construction. The Atomic Energy Regulatory Board (AERB) therefore has instituted certain mechanisms and procedures to address the issue of relicensing vintage plants. Licence renewal, periodic safety review (PSR) and life extension programmes are used as regulatory tools for authorizing continued operation of nuclear power plants with a high level of safety. The regulatory criteria evolve continuously, based on operating experience, identified generic safety issues and new developments in technology. The licensing as well as relicensing procedure in India is designed to respond to these evolving safety criteria.

The technical assessment of components with respect to ageing, review of the original design basis along with final safety analysis reports, life assessment of irreplaceable equipment, structures and components, and plant specific PSAs and their relationship to the traditional deterministic methods are identified as key issues in the relicensing or safety upgrading process. The paper deals with the present approach and regulatory mechanisms being followed for life extension and safety upgrading in Indian nuclear power plants. Also, the safety upgrading and licence renewal of older PHWRs and life extension studies carried out in vintage BWRs are described.

1. INTRODUCTION

While the first twin unit plant in India at Tarapur was commissioned way back in 1969, the last four units at Kaiga and Rajasthan have started commercial operation in the year 2000. Thus, we have today 14 units of different vintages operating in the country. The new plants are built to current standards and employ the present day technology and hence easily meet the present day safety requirements. The old plants obviously cannot meet these requirements to the same extent since they were built to the standards that existed at the time of their construction. Though modifications and repair are carried out from time to time, ageing of equipment is another challenge that can impair safety. The regulator and the utility, therefore, have an additional responsibility of ensuring the validity of the safety case of such old plants.

In India, both life extension and safety upgrading programmes are embedded in licence renewal procedures. Through safety upgrading and backfitting, measures are taken to enhance the safety level of the plant at any point in the life of the plant if it is necessary and convenient, whereas the life extension programme allows a plant continuing operation with an acceptable safety level beyond the design life which was initially established by a safety evaluation. The opportunity of life extension is used to review the entire design basis of the plant and decide what safety improvements the user might reasonably be expected to make. The licence renewal process focuses its review on detrimental effects of ageing and 're-reviews' a plant's current licensing basis to comply with its regulatory regime, including generic safety issues. In India, the licence renewal by application for renewal of authorization (ARA) is done once in three years as the current regulatory regime allows that. Therefore, a brief but comprehensive safety review is done every three years. During a periodic safety review (PSR), done once in ten years, an integral safety assessment is made and the fitness for continuing operation of the plant is assessed.

2. REGULATORY APPROACH

It is a basic requirement of the Atomic Energy Act, India, 1962 and the Rules framed thereunder that the licensees should carry out a continuous review of the safety of their plants and make whatever safety upgrades are necessary. It is normally their responsibility to propose the safety upgrades that they deem to be necessary and reasonably practicable, while it is the responsibility of the regulatory authority to assess and approve such proposals before the upgrades are carried out.

The Atomic Energy Regulatory Board (AERB) issues fixed term (for three years) licences for nuclear power plants. Continuous monitoring of operational and safety performance is done to check the conformity with licensing conditions; comprehensive periodic safety reviews (PSRs) every ten years are also carried out. The objectives of these PSRs are summarized as follows:

— To show that the plant is as safe as originally designed;
— To show that it will still be safe for the next ten years;
— To compare it against the most recent safety standards and determine which safety improvements are reasonably practicable.

Regulators apply various codes and guides in judging the acceptability of a licence renewal application (ARA) or a PSR. However, the main guide for the above purpose is the AERB Guide on Renewal of Authorization for Operation of Nuclear Power Plants (AERB/SG/0-12), which was published in 2000.

New regulatory rules are not generally expected to apply retrospectively, in their totality, to existing plants. However, during the PSR or life extension process, licensees are required to assess the impact of new rules on the existing plants and determine the safety significance of any deviations. They then have to justify any such deviations to the regulator in terms of the risk involved or propose modifications to achieve the level of safety required by the current rules. Such modifications have to be shown to be reasonably practicable in terms of the safety gains to be achieved.

In recent years, AERB has instituted certain mechanisms and procedures to address this, and these are described in the following sections.

2.1. Periodic Safety Review

In addition to the three yearly review of the application for renewal of authorization (ARA), the AERB has prescribed a more comprehensive periodic safety review (PSR), as mentioned earlier. In addition to the normal review of safety performance and operating experience feedback, PSR requires a review of plant safety analysis in the light of current standards and the actual condition of the plant. Due to modifications carried out from time to time and the effect of ageing, the present actual condition of the plant could be significantly different from the time it was constructed or since the last review. In addition, factors such as human performance and organizational changes are also considered. An integrated review of all these factors is carried out to provide assurance that until the next PSR, the plant can continue to operate with adequate safety margins.

While PSR needs to bring out the differences or shortcomings of the plant in its present condition, in comparison to requirements of the current standards, it is not expected that the old plant should be upgraded to the same extent as a new plant. The plant has to study the safety impact of all these differences and propose modifications wherever necessary. For deficiencies proposed to be left unaddressed, adequate justification needs to be provided.

Several such reviews have been conducted by the AERB over a period of time, especially for older plants that include RAPS and MAPS. It was decided that all upgrading work identified as a result of these reviews will be carried out during long outages connected with en masse coolant channel replacement.

2.2. Licence renewal

For plants nearing the end of the original licensed life, such as the two boiling water reactor (BWR) based units at the Tarapur Atomic Power Station (TAPS) which are over 30 years old, a much more exhaustive review has to be carried out for considering continued long term operation. While formal guidelines for such processes are under preparation, the AERB had prescribed a procedure under which TAPS was required to prepare and submit reports covering the following:

— Review of operational performance;
— Ageing management studies and residual life assessment;
— Level 1 PSA;
— Review of design basis and safety analysis.

Continued long term operation of TAPS will depend upon the outcome of these reviews, consequent modifications and upgrades proposed and their implementation schedule.

3. PSA

The older plants were designed based on deterministic assessments only, as PSA techniques were still in the development stage. The AERB has now recommended that a PSA study should be carried out at the time of submission of the first PSR or licence renewal application. It is expected that such a study will provide insights into important contributors to the core damage frequency based on which appropriate upgrades and modifications can be carried out to achieve a more balanced design. The effect of modifications already carried out or proposed to be carried out can also be evaluated by PSA studies.

Accordingly, a full scope Level 1 PSA is a requirement for licence renewal for TAPS.

4. SAFETY UPGRADING IN RAPS AND MAPS

All the nuclear power plants are designed and operated to meet the prescribed level of safety required by the standards and practices that existed at the time of their design. However, safety standards are revised from time to time based on operating experience, new developments in technology and improved understanding. Hence, it is necessary that all operating plants be periodically assessed to demonstrate that the required level of safety is maintained. Towards this end, the AERB conducts comprehensive periodic safety reviews (PSR) for all operating nuclear power plants. Based on several such reviews conducted by the AERB, safety upgrading jobs had been undertaken.

4.1. Upgrading in RAPS Unit 2

RAPS Unit 2 is one of our old generation pressurized heavy water reactor (PHWR) based nuclear power plants of 200 MW(e) capacity. It was commissioned in 1981 and was meeting the specified safety requirements applicable at that time. The design of PHWRs has changed substantially over a period of time and the present day Indian PHWRs are built after taking account of all current safety requirements. In accordance with AERB requirements, a detailed review of RAPS Unit 2 was conducted and a plan for required upgrades and modifications was finalized.

RAPS Unit 2 was shut down in 1996 for en masse replacement of all of its 306 coolant channels. The old coolant channels made of Zircaloy-2 pressure tubes were judged unsuitable for continued operation and were replaced with pressure tubes made of a zirconium–niobium alloy. This was done in a long shutdown of the reactor when major upgrading to improve safety was also implemented. All proposals concerning modifications to safety related systems were reviewed and approved by the AERB before execution of the jobs. Some of the major modifications to safety related systems carried out during this shutdown are described below:

(1) *Retrofitting of high pressure heavy water injection system into the emergency core cooling system*. Pursuant to the recommendations of the AERB, a high pressure heavy water injection provision was retrofitted in the emergency core cooling system (ECCS). The retrofitted ECCS in RAPS Unit 2 provides for high pressure heavy water injection during the initial short term following a postulated break in the reactor coolant piping. This is in addition to the already existing long term core cooling from low pressure moderator system.

(2) *Supplementary control room.* A supplementary control room (SCR) was provided in a separate building from where important safety functions can be carried out in case the main control room becomes uninhabitable due to postulated initiating events, such as a localized fire or damage caused by turbine missiles. Functions that can be carried out from the SCR include: (a) tripping of the reactor, (b) opening of steam discharge valves for ensured core cooling, and (c) monitoring of essential system parameters. Independent sensors with separate power supply have been provided for instrumentation in the SCR to ensure their operability under emergency conditions.

(3) *Segregation of power and control cables.* For the purpose of minimizing the impact of fire and other common mode failures to an acceptable level, segregation of routes of safety related power and control cables was carried out. With this, control cables of triplicated channel instrumentation signals run through three separate cable tray routes from the reactor building to the control equipment room. In addition, a minimum physical separation has been maintained between the power cables and the high energy steam lines.

(4) *Additional diesel generator of 600 kVA.* An additional diesel generator of 600 kVA capacity has been provided at a high elevation to ensure availability of essential power supply during a postulated scenario of total loss of power due to flooding, following a postulated failure of the Gandhi Sagar Dam which is located upstream of the Rana Pratap Sagar Lake that provides condenser cooling water to RAPS.

After completion of the above and various other upgrading jobs, RAPS Unit 2 was recommissioned in 1998 as per the commissioning procedures approved by the AERB.

4.2. Upgrading in MAPS Units 1 and 2

MAPS Unit 1 and MAPS Unit 2 have been in operation since 1984 and 1986, respectively. In the same line as done for RAPS Unit 2, the job of en masse replacement of all coolant channels was taken up in MAPS Unit 2 after 8.5 EFPY and MAPS Unit 1 after 10.1 EFPY of operation. Also a number of steam generator tube leaks had occurred in these units in the past few years. All upgrades similar to RAPS Unit 2 have been carried out in MAPS Unit 2 and are being done for MAPS Unit 1. In addition to the replacement of a steam generator, the shutdown has also been used to install spargers in the calandria for improving moderator flow. This will enable the unit to be operated at 220 MW.

5. LICENCE RENEWAL FOR TAPS

Both units of the Tarapur Atomic Power Station (TAPS) were designed and constructed in the late 1960s with the assistance of GE of the United States of America and were made operational in 1969. The design and analysis report specifies the design life of the reactor vessel and major safety related equipments as 40 years. The continued operation of TAPS beyond the design life has been under consideration in the AERB for quite some time. Based on this discussion, the AERB approach for a renewal of licence for TAPS beyond its design life of 40 years was formulated. The AERB did not have guidelines for a renewal of licence beyond design life. It was felt that the review of design basis and safety analysis in the light of current standards would be required and also of the other safety factors mentioned in the AERB guide (AERB/SG/0-12). This was exhaustive work comparable to the safety review of the new plant.

After about 30 years of service in May 2000, the AERB directed NPCIL, the utility, to conduct a thorough review covering the following areas:

- Review of performance of equipment from operational experience;
- Review of design basis and safety analysis report;
- Ageing assessment of systems, structures and components;
- Seismic re-evaluation.

All the studies have been completed and their reports have been reviewed by the AERB. Based on these reviews, retrofits and upgrading requirements have been identified. Their implementation will be now progressively carried out over the next two and a half years as per an agreed schedule between the AERB and NPCIL.

5.1. Review of operational performance

Operational performance of TAPS for the past ten years was reviewed in accordance with the guidelines given in AERB/SG/0-12. The following safety factors relevant to operational performance were reviewed:

- Safety performance;
- Actual physical condition of the plant;
- Operating experience from other plants and research findings;
- Procedures;
- Organization and administration;
- Human factors;

— Emergency preparedness;
— Environmental impact.

5.2. Ageing management and residual life assessment

For reviewing ageing management and residual life assessment, guidelines given in the AERB guide AERB/SG/0-12 were used. For the purpose of this review the components were categorized as:

(1) *Major critical components:* The major critical components, systems and structures are those that must remain functional during normal power operation and during those conditions and events for which the plant was designed, including various anticipated operational occurrences, design basis accidents and external events. In general, these components were:

— Part of a reactor coolant pressure boundary;
— Necessary to shut down the reactor and maintain it in a safe shutdown condition;
— Necessary to mitigate the consequences of serious accidents and prevent off-site exposure.

Based on the above, the major critical components identified were:

— Components of a reactor coolant pressure boundary;
— Reactor containment;
— Control rod drive mechanism;
— Reactor recirculation pumps.

(2) *Important systems:* The important systems are the engineered safety systems and other supporting systems necessary to operate the reactor in a safe condition. These include:

— Emergency power supply systems;
— Emergency coolant systems;
— Decay heat removal systems;
— Ultimate heat sink.

(3) *Other critical components:* These are some important components necessary for the safe operation of the plant and are not covered in the points mentioned above. These include:

— Reactor relief valves;
— Primary steam isolation valves;
— Primary feed pumps;
— Reactor building ventilation fans;
— Civil structures other than containment.

5.3. Review of design basis and safety analysis

The objectives of this review are to assess the continued validity of (a) the original design basis for the plant systems, and (b) the original safety analysis.

The design basis of the plant systems is being reviewed, taking into account changes in application codes and standards, a better understanding of degradation mechanisms and availability of database onloads, etc. The safety analysis is being reviewed to identify areas requiring revision in view of inputs from the review of design basis, changes in plant configuration, availability of better analytical tools, etc. The review of the design basis covers the following systems:

(1) Reactor coolant system and components;
(2) Reactor protection system;
(3) Residual heat removal system;
(4) Engineered safety features:

— Primary containment system;
— Secondary containment system;
— Emergency core cooling system;

(5) Waste management system.
(6) Instrument air system;
(7) Station power supply system;
(8) Ultimate heat sink;
(9) Fine protection;
(10) Control and instrumentation systems.

Apart from the above, the following issues are also considered for review:

— ISI of important systems;
— Plant diagnostic systems;
— Results of Level 1 PSA;
— Safety classification of systems.

The system-wise review is being carried out based on the guidelines of the United States Nuclear Regulatory Commission Standards Review Plan (SRP) for review of the Safety Analysis Reports for Nuclear Power Plants (NUREG-0800).

5.4. Irreplaceable components

In addition to the above reviews, the key components, which cannot be replaced, are also being assessed carefully from the point of view of safety. These include reactor pressure vessel, containment, reactor pedestal, reactor vessel support skirt, reactor vessel brackets and fuel storage pools.

(1) *Reactor pressure vessel.* The reactor vessel (RPV) is made of carbon steel (ASME SA-302 Grade B) and is 4.87 inches (approximately 123 mm) thick. The inside of the vessel is cladded with stainless steel (5.6 mm thick). The state of the pressure vessel is monitored with the surveillance specimen programme. This includes specimens drawn from the vessel base material, weld region and heat affected zone. So far, it is found that RPV material has adequate fracture toughness to assume safety of the pressure vessel until the end of its service life of 40 EFPYs. In addition, fatigue analysis of the RPV is being done considering thermal and pressure cycles. Certain welds and nozzles in the RPV are not accessible and have not been inspected. A programme for inspection of some of these welds and nozzles is prepared and the inspection will be taken after the development of remote tooling. The findings of these inspections will be extrapolated to assess the status of other welds and nozzles in the RPV.

(2) *Containment.* Periodic inspection and monitoring of the status of the containment is carried out through an integrated leak rate test and the thickness measurement of the dry well. No apparent reduction in thickness of the dry well has been observed. Weld inspections of the dry well are also planned to be carried out. Visual inspection and thickness measurement of the common chamber liner and suppression pool liners are also being carried out.

(3) *Other non-replaceable SSCs.* The remaining non-replaceable SSCs, such as the reactor pedestal, reactor vessel support skirt, reactor vessel bracket and fuel storage pools, can be inspected. Visual inspection of all these components indicated that their condition is satisfactory. In the case of the reactor pedestal and fuel storage pools, an evaluation of concrete samples will be carried out. With respect to civil structures, monitoring by visual and non-destructive techniques and necessary repairs based on an assessment of the condition of the structures will be carried out.

6. CONCLUSION

Since a licence renewal review for BWRs at the Tarapur plant (commissioned in 1969) was the first exercise of its kind, the AERB had to formulate the principles to be adopted and guidelines to be followed for such a review. Safety upgrades identified after the regulatory review are being implemented to achieve a reasonable safety margin.

First generation PHWRs at RAPS Unit 2, MAPS Units 1 and 2 were commissioned in 1980, 1983 and 1985, respectively. Standardized Indian PHWRs were constructed from 1990 onwards and the current design conforms to the present regulatory requirements. A regulatory approach for safety upgrading and licence review of these three earlier PHWRs was, therefore, different. The most recent version of standard PHWR was taken as reference for reviewing the design basis. Safety upgrades were carried out in these plants during available long shutdowns.

The regulatory issues identified by the AERB for the purpose of life extension and licence renewals are:

- Review of the original design basis along with FSAR;
- Systematic evaluation of plant and all safety related structures and components;
- Review of past plant performance and evaluation of safety improvement measures;
- Review of all relevant unresolved or generic safety issues;
- The implications of modern research and technology advancements;
- Plant specific PSAs and their relationship to the traditional deterministic methods;
- Review of the effects of ageing on safety related structures and components;
- Safety management and safety culture issues.

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AGEING MANAGEMENT PROGRAMMES AND THEIR IMPLEMENTATION IN SLOVAK NUCLEAR POWER PLANTS

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Abstract

Some of the basic attributes negatively affecting operational safety of nuclear power plants are the ageing processes, and it is obvious and necessary that the damage due to ageing is — as much as possible — slowed down, eliminated or corrected in such a way that operational safety and effectiveness of the operation is ensured. With regard to the assurance of safety and reliability of the plant operation, as well as with regard to the optimum use of the plant, it is recommended to develop and implement ageing management programmes for individual systems, structures and components (SSCs), which would make it possible to monitor and to evaluate the impact of the operation and degradation processes on the list of SSCs, and to monitor trends in the changes of the evaluated parameters, as well as to take corrective measures in time. The number of old nuclear units has been increasing worldwide. At the same time, requirements on their long term operation have been increasing while high operational safety levels have been maintained. Successful implementation of ageing management programmes in conjunction with plant modernization programmes is the basic requirement for the operation of nuclear power plants in extended periods. The approach obtained results and objectives in the field of ageing management and modernization of the Slovakian nuclear power plants are dealt with in the paper.

1. INTRODUCTION

Nuclear power plants in Slovakia were designed and built in line with the lifetimes postulated in the design. The lifetime postulated in the design was defined with regard to the lifetime expiration of the most critical components in the reactor coolant system.

Nuclear power plants in Slovakia with their capacity of 2640 MW provide 31% of the total capacity and produce 55% of total electricity consumption in Slovakia (Table 1).

TABLE 1. NUCLEAR POWER PLANTS IN SLOVAKIA

V-1 Bohunice	2 × 440 MW/230	Commissioned in 1978–1980
V-2 Bohunice	2 × 440 MW/213	Commissioned in 1984–1985
EMO - Mochovce	2 × 440 MW/213	Commissioned in 1998–2000

These facts indicate an importance of electricity generation from nuclear sources and it is obvious that — by implementing the ageing management programmes — the operating organization contributes to the safe operation and creates a precondition for the reliable long term operation of the nuclear power plant.

The current worldwide practice demonstrates, and in the IAEA, development trends are considered also the implementation, maintaining and documentation of the results of ageing management programmes as an important factor in the field of techniques and processes how to obtain operating licences for VVER units beyond their design lifetime.

2. AGEING MANAGEMENT PROGRAMMES

2.1. Legislative background and guidelines

In Act No. 130/1998 on the peaceful utilization of nuclear energy in Slovakia, the possibility of a licence extension for nuclear power plant operation, depending on the current conditions of operational equipment, safety analysis results and supplementary safety documentation, is defined.

The content of the supplementary safety documentation required is defined in relation to long term operation:

— Evaluation of equipment conditions;
— Evaluation of operation;
— Evaluation of ageing management programmes;
— Evaluation of the modifications needed for lifetime extension;
— Safety evaluation of the modifications proposed.

In line with IAEA recommendations and with requirements resulting from the assumption of extension of nuclear unit operation in Slovakia, the Nuclear Regulatory Authority of Slovakia issued a safety guide defining the requirements on ageing management for nuclear power plants. The objective is to propose to the operating organization and to the supporting technical organizations a methodology for the development and implementation of ageing management programmes.

The document is not defined as a legally mandatory one, but it describes the minimum requirements that should be met by the operator, in the form of a guide. The guide can be used for all nuclear installations in Slovakia.

2.2. Implemented ageing management programmes

The evaluation of lifetime expiration and the evaluation of degradation of selected SSCs were implemented already at the time of nuclear unit commissioning. However, it was not a comprehensive programme of ageing management, but a partial evaluation of certain SSCs.

The most important programmes implemented continuously in nuclear unit operation are as follows:

— Evaluation of the condition of reactor vessel and of major components in the reactor coolant system;
— Monitoring reactor pressure vessel resistance against brittle fracture;
— Analysis of pressure–thermal shocks and proposal of recommended operating ‘p–T’ curves for selected parts;
— Monitoring damage possibility and periodic lifetime expiration calculations of critical components, piping, nozzles, pressure parts of pumps and valves;
— Periodic evaluation of the acceptability of damage from defects revealed during in-service inspections by applying available standards;
— Monitoring the possibility of fatigue initiation by thermal stratification in horizontal piping by applying experimental and calculation methods;
— Corrosion–erosion programme for components in primary and secondary systems;
— Evaluation of confinement integrity;
— Monitoring conditions and lifetime expiration of electric cables in nuclear power plant operation;
— Monitoring programme for selected parameters of degradation of the working environment in nuclear power plant operation

2.3. R&D programme for ageing management programme

Since 2001, a research and development project has been in progress co-funded by the State and nuclear power plant operators in the field of ageing management and lifetime evaluation of nuclear power plants.

The main objectives of the project are as follows:

- Identify mechanisms of ageing and degradation with long term influence on safety related systems and components;
- Propose and develop a uniform information database system for this area;
- Propose possibilities about how to use the existing monitoring systems and to complete them with new systems for the monitoring of all important degradation effects;
- Develop ageing management programmes for selected groups of components; establish methodologies and tools for risk estimates from a functional loss of important equipment;
- Optimize requirements on the database of input information for selected equipment, to determine trends in lifetime expiration and to evaluate retroactively the tasks related to lifetime management;
- Develop software tools for the safety and technical–economic evaluations of the maintenance of safety related equipment;
- Prepare basic documentation for the creation of licensing applications with the objective to extend the operation of nuclear units.

Within this project, lists of SSCs were specified and methodologies for the evaluation of selected SSCs will be proposed and implemented. By implementing this project that will be terminated in 2005, a mutually interconnected complex of information and tools will be developed and established based on international experience and good practice relevant to ageing management and lifetime extension.

The objective of the project was to provide answers and technical arguments that the ageing process for safety important components is deducible and the operating organization has a sufficient amount of tools for the evaluation of system degradation against the loss of their performance.

3. RECONSTRUCTION OF PLANTS WITH WWER-440 REACTOR

3.1. Global reconstruction at the V-1 Bohunice plant

The most extensive global reconstruction of a nuclear power plant with WWER-440/V230 type reactor worldwide has been completed at the V-1 Bohunice plant in the middle of 2000, after implementing all the work planned. Extensive reconstruction activities in the area of process systems, electric systems, instrumentation and control systems, and in the civil engineering part, which significantly upgraded the level of nuclear safety, were carried out by REKON consortium. The consortium — established purposefully for the action of gradual reconstruction of V-1 Bohunice — consisted of the German Siemens KWU and Slovak VUJE, Inc. The gradual reconstruction was carried out based on Decision No. 1/94 of the Nuclear Regulatory Authority of the Slovak Republic, which conditioned future operation of the plant by a gradual upgrading of nuclear safety up to a safety level accepted in operating European NPPs.

4. MODIFICATIONS IN THE SMALL RECONSTRUCTION PHASE

The process of nuclear safety level upgrading and operational reliability increasing started immediately after the commissioning of V-1 Bohunice. More than 1200 changes against the original design, which resulted from operation evaluation, operating experience, international recommendations and new safety rules, were implemented gradually. Another significant phase was the so-called small reconstruction, implemented between 1991 and 1993.

Based on short term and long term measures and recommendations resulting from international expert missions, the regulatory body issued its Decision No. 5/1991 in which 81 measures for further enhancement of nuclear safety and reliability level were specified, and Decision No. 213/1992 in which additional 14 measures were specified.

Significant improvements resulting from the small reconstruction were achieved in the following areas:

- Core damage probability was reduced from 1.7×10^{-3}/a down to 8.9×10^{-4}/a;
- Low probability of a break in reactor coolant system piping (10^{-6}/a) was demonstrated using the 'leak before break' (LBB) methodology;
- Reactor pressure vessels were annealed;
- Confinement integrity was improved;
- Emergency control rooms for unit emergency shutdown were created;
- Reactor protection systems were modified;
- New diesel generators and accumulator batteries were installed;
- Seismic resistance was strengthened.

By implementing these measures during the small reconstruction, the V-1 plant joined — according to the core damage probability — the plants the continuing operation of which is acceptable but continuation of safety enhancement work in this area was necessary.

The small reconstruction, with its design and implementation provided by Slovak companies, paved the way to a significantly more extensive, comprehensive gradual reconstruction of V-1 Bohunice to comply with the regulatory requirements.

5. MAIN GOALS OF THE GRADUAL RECONSTRUCTION

The regulatory Decision No. 1/1994 conditioned the operation of the V-1 plant after 1995 by a gradual upgrading of nuclear safety up to the level accepted by the regulatory body. The results of the gradual reconstruction were required to evaluate annually and regulatory approval for operation was given for the subsequent year based on the work results.

The regulatory decision specified the fundamental objectives of the gradual reconstruction:

— Establishing two separate fully independent safety systems;
— Modification of the systems providing capability to cope with defined DBA and some BDBA accidents;
— Modification of the reactor protection system in such a way that its probability of failure is less than 10^{-5} on demand;
— Enhancement of safety and reliability of the mode with residual heat removal during a seismic event (F&B secondary and primary system);
— Increasing the reliability of emergency power supply;
— Enhancement of seismic resistance and fire safety.

To implement the design of the gradual reconstruction, the REKON consortium was established in April 1996.

6. MANAGEMENT AND IMPLEMENTATION OF THE PROJECT

The philosophy of implementation of the gradual reconstruction was based on a gradual implementation of particular projects in the course of extended unit outages. It means that work activities related to the reconstruction of the unit in question, shutdown for refuelling, provided by the REKON consortium, by the Bohunice plant and by subcontractors, and the standard activities of the plant operator related to the general maintenance and reactor refuelling, were being performed in parallel.

The implementation work, in line with the accepted philosophy of the gradual reconstruction according to the detail designs developed, started

TABLE 2. PROBABILISTIC AND DETERMINISTIC GOALS

Probabilistic goals:	Deterministic goals:
— Safety systems failure probability $<10^{-3}$ on demand; — Core damage frequency $<10^{-4}$ reactor/a; — Reactor trip system failure probability $<10^{-5}$ on demand; — LBB concept implemented: probability of sudden double ended guillotine break of primary pipe $<10^{-6}$/a	— Safety systems will cope with new DBA (LOCA 2 × ϕ200 mm) using *conservative approach,* — BDBA (LOCA 2 × ϕ500 mm) using *best estimate approach:* • Peak fuel cladding temperature <1200°C • Fuel melting prevented • Total cladding oxidation <1% from the total cladding amount • Peak local cladding oxidation <18% from the initial cladding thickness — Confinement tightness and localization system ensure dose equivalent <50 mSv in case of DBA, <250 mSv/BDBA for entire body and dose equivalent <500 mSv/DBA, <1500 mSv/BDBA for thyroid

during Unit 2 refuelling outage in 1996. The largest scope of work at Unit 2 was carried out in 1998; the largest scope of work at Unit 1 and even during the whole gradual reconstruction was carried out during the last outage of Unit 1 in 2000. In the course of this outage, also a common outage of both units occurred to make it possible to connect the designated consumers to the essential service water system.

The VUJE task within the consortium was to provide for the following 14 functional process systems (besides I&C systems and seismic strengthening) the following actions:

— Documentation of actual conditions;
— Elaboration of concepts as a basis for detail design;
— Provision of system and equipment deliveries;
— Management of installation;
— Development of installation schedules;
— Coordination of installation work;
— Unit startup;
— Development of programmes for testing newly installed systems;
— Performance of test programmes;
— Evaluation of programmes;

— Provision of spare parts for new equipment;
— Personnel training;
— Development of training documentation;
— Assurance of training at equipment manufacturer;
— Development of technical documentation;
— Operating procedures — updating after each unit outage in line with the scope of implementation work within the gradual reconstruction;
— Updating of safety documentation;
— Safety documentation for licensing;
— Complete control and coordination of all suppliers in the area of the development of design documentation, deliveries, installation, equipment and unit commissioning.

6.1. Bohunice V-2 programme of modernization and safety upgrading

Even prior to the completion of the reconstruction of Bohunice V-1 Units 1 and 2, the operators took a decision to modernize and upgrade the safety of Bohunice V-2 Units 3 and 4.

The following documents were developed:

— V-2 Periodic Safety Analysis Report, after ten years of operation. It contains an assessment of V-2 safety status after ten years of operation, in line with IAEA recommendations;
— V-2 safety improvement project and proposals how to address them. Review of the up to date results of safety assessment of nuclear power plants of the WWER-440/V-213 type (IAEA, WWER-SC-108) for the V-2 conditions, development of proposals on how to resolve safety issues;
— Principal goals and concepts of I&C innovation programme.

Based on the documents developed, the management of the utility Slovenské elektrárne, a.s. (Slovak Electric, Inc.) defined in 1997 the objectives of the Programme for Bohunice V-2 Modernization and Safety Upgrading to ensure safe and reliable operation of V-2 units until the end of their design lifetimes and to create conditions for an extension of their lifetimes up to 40 years.

In addition to V-2 safety issues, also operational issues related to 15 years of operation are addressed, i.e. issues related to equipment, physical wear and moral obsolescence, which — mainly for I&C and electric systems — lead to problems in the areas of equipment operational reliability, spare parts and service.

Within the programme, a safety concept for V-2 modernization and safety upgrading was developed in the period 1998–2000. This document defines the objectives, scope and content of the programme down to the following levels:

— Specifications for design;
— Specification for the Safety Analysis Report.

In the documentation of the safety concept, tasks were grouped with regard to reference of measures to the particular process expertise (systems, electric, I&C), into a group of universal character with the applicability for the whole unit or plant, and into a group of measures related to computer analysis. The modernization tasks are arranged in such a way that they can be addressed gradually depending on the needs and possibilities of the operators (requirements on safety, requirements on operation, planning of unit outages, financial resources).

A concept was developed on how to address the modernization tasks, requirements on systems and equipment were specified and possible options of solutions were proposed.

The priorities for decision making on the assignment of particular modernization tasks into an implementation schedule were determined based on the following criteria:

— Safety categorization of safety issues and safety benefits from the solutions proposed;
— Categorization of needs for equipment innovation according to the operators and benefits from the solutions proposed;
— Interrelations among the implementation works;
— Relations between unit operation and planned outages;
— Costs and economy benefits;
— Possibilities of the investor.

The schedule of progression of the preparation, implementation of design, and implementation of modernization tasks was developed for the period 2001–2008.

7. CONCLUSIONS

By incorporating programmes of ageing management, by implementing reconstructions and by implementing safety measures, all the requirements of the national nuclear safety authority on operational safety upgrading, and at the same time the ideas of the operators in relation to the long term operation of nuclear units will, be met.

Implementation of modernization programmes, particularly the major reconstruction of Bohunice V-1 units, have been reviewed by international review missions (mainly the IAEA and WENRA team) several times, and the high professional and technical level of the implementations were acknowledged.

The results achieved in Slovakia in the areas of interest demonstrate the feasibility of a safe, long term operation of units with WWER reactors complying with the most stringent safety requirements.

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CHALLENGES TO MAINTAIN THE SAFETY LEVEL OF NUCLEAR POWER PLANTS IN GERMANY

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Abstract

One possible tool to identify new challenges is the evaluation of operating experience. For example, the evaluation of operating experience has resulted in the further development of safety standards and regulations. Also, it is highly useful in connection with the identification of generic weak points. The development of safety management systems in German nuclear power plants was initiated in the wake of two events with high safety significance. As a result, the Fundamentals of Safety Management Systems were published by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in 2004. Another important challenge is the need for an ageing management system in nuclear power plants. In 2004, the German Reactor Safety Commission submitted a comprehensive recommendation on the control of ageing processes. The aim was to include all possible ageing mechanisms. Finally, a further challenge is the increasing tendency to perform realistic or so-called best estimate calculations. Improved analyses increase the degree of certainty associated with calculated safety margins of acceptance criteria. Once this increased margin has been identified, the best possible uses of this gain of margin have to be identified. One of them might be to improve the plant's performance. The lessons learned from these examples can be summarized in the following statement: to maintain safety under changing boundary conditions, progress is necessary.

1. INTRODUCTION

The boundary conditions under which nuclear power plants are nowadays operated are changing in most countries as well as in Germany. A few of these changes are as follows: the average age of the plants is increasing and the liberalization of the electricity market creates pressure to reduce production costs and maximize the output of the operating plants. This may, for example, lead to staff reductions and a tightening of work processes. On the other hand, knowledge in science and technology is growing every day.

The following examples illustrate which challenges we have had to face in recent years to maintain the safety level of the nuclear power plants in

Germany. To maintain the safety level is understood here as to improve or continuously improve, as the process to guarantee safety is a dynamic process and not a static one. It was the evaluation of operating experience, in particular, which helped recognize these challenges. Important examples of such challenges are the implementation of safety management systems in German nuclear power plants and the associated requirements, the recommendations of the German Reactor Safety Commission on ageing management programmes, and the discussion about safety margins and their use in the licensing processes. A conclusion at the end of the paper gives an outlook on future challenges.

2. EVALUATION OF OPERATING EXPERIENCE AS A BASIS FOR THE DETECTION OF NEW CHALLENGES

The first question when talking about challenges to maintain the safety level of German plants is: How can these new challenges be identified? One possible tool to detect new challenges is the evaluation of operating experience. Of course, there are many reasons for the evaluation of operating experience, and this goal may not be the most important one — nevertheless, some of the examples presented here have been derived from the evaluation of operating experience.

Operating experience in Germany is evaluated by the industry and by the authorities. These evaluations are mainly performed by the licensees of the plants and by different expert organizations, among them GRS.

The corresponding work of GRS in this field consists of four different major activity areas:

— The first, very important, one is the evaluation of national and international reported events.
— To quantify the safety significance of different reported events, GRS performs precursor analyses of preselected events. This probabilistic approach helps to assess the real safety significance of events and can therefore be used to initiate further actions.
— Additionally, GRS performs trend analyses of reported events with the help of databases. Each event is encoded according to the operational status of the plant and the system affected, the level of damage, the kind of failure, the measures taken, etc. The aim of the databases is to assess the safety level of the plants and to detect specific vulnerabilities.
— The final area of activity is the evaluation of operating experience below the reporting threshold, for example, to check the preventive maintenance concepts of different components. This area may have the most significant potential of improvement.

One outcome of the evaluation of operating experience can be the further development of safety standards and regulations. A famous example is the event at Barsebäck, Sweden, in 1992, revealing the problem of insulation material debris in the sump after a loss of coolant accident. As a consequence, worldwide research started, with several experiments and theoretical approaches to explain and calculate the different phenomena. The event initiated backfitting measures and led to changes in regulations such as the Nuclear Regulatory Commission's Regulatory Guide 1.82, Rev. 3 [1], and in Germany to recommendations by the Reactor Safety Commission in 2004 [2].

Another application of the evaluation of operating experience is the identification of generic weak points. Examples are the recent events with radiolysis gas explosions in Brunsbüttel, Germany, and in Hamaoka, Japan. The history of radiolysis gas detonations in German nuclear power plants already started in 1984. Still, the problem has not been totally solved yet. The event in Brunsbüttel showed that despite the existing regulations in Germany to inhibit radiolysis gas explosions, single failures or slightly different boundary conditions can still lead to an accumulation and explosion of radiolysis gas. Former examinations did not include these aspects.

As a consequence of these events, the German Reactor Safety Commission has issued staggered procedures to preclude radiolysis gas explosions [3].

3. DEVELOPMENT OF SAFETY MANAGEMENT SYSTEMS IN GERMAN NUCLEAR POWER PLANTS

Another important challenge is the development of safety management systems in German nuclear power plants. The different areas of a safety management system comprise specifications, regulations and organizational tools for working on safety relevant tasks, defining and controlling targets, and improving safety performance by using the feedback from experiences. Therefore, an optimized safety management system is an important tool for the promotion of a highly developed safety culture. Although safety has highest priority in nuclear power plants, a systematic approach for the management of safety had been missing.

In the last years, two events with high safety significance illustrated different problem areas:

— Firstly, blocked pilot valves in a pressurized water reactor caused the failure to open the main steam safety and relief valve of one steam generator during a transient. The reason for the blocked pilot valves was their closure during an outage and the failure to reopen them during system normalization. The root cause analysis of the event revealed incautious behaviour, such as shortcuts of safety relevant procedures and inappropriate communication during shift changeover. The investigations after the event revealed overreliance on the technology and an incautious attitude throughout almost the entire staff. This attitude went along with a loss of knowledge of why regulations and procedures existed and why they should be followed.

— The second event also occurred in a German PWR. During the startup of the plant after its refuelling outage, the refuelling water storage tanks of three of the four trains of the emergency core cooling system were partly refilled with demineralized water instead of borated water. This was not recognized by plant staff and the plant was brought into power operation. The direct cause of the event was the wrong position of a manual valve in the boric acid and demineralized water injection system. In the past, there had been several problems with this particular valve. The position of the valve was difficult to determine and occasionally the valve was sticking due to boric acid deposits. These problems had not been resolved. But the problem was not only the defective valve. The main problem was that the staff decided to continue power operation after detection of the too low boron concentration in three of the four borated water storage tanks. The event showed that the assessment of the risk of the prevailing situation was not adequate. The staff should have decided to stop power operation until the correct boric acid concentration in the refuelling water storage tanks would have been re-established.

Starting from these events, the German authorities asked for more information about the status of the utilities' safety management systems and actual practices in the plants. Therefore, a questionnaire, developed by the authorities with the support of GRS, was sent to each plant. The main questions addressed the safety policy and safety objectives, as well as rules, instruments for planning, performing, auditing and reviewing safety relevant tasks.

The answers to the questionnaire showed that specific safety management system elements had been established in German nuclear power plants, but that no integral system existed at the time. The utilities promised to develop and implement plant specific safety management systems.

In parallel, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety published Fundamentals for Safety Management Systems [4] that are based mainly on INSAG 13 [5], EN ISO 9000:2000ff standards and the IAEA Safety Guide NS-G-2.4 [6]. These principles should be applied to the safety management systems in German nuclear power plants.

The Fundamentals describe the requirements for the organization, organizational regulations and safety related processes.

The main requirement of the Fundamentals for Safety Management Systems is the company's obligation to plan, develop, document, implement, maintain and continuously improve an effective safety management system. Compliance with these obligations is the task and responsibility of the company's management.

Safety management has to be an integral part of an integrated management system. The limits and interfaces, as well as the interaction of the safety management system with other management systems, have to be specified and laid down in a suitable manner. Other relevant company areas and the interfaces with external parties, e.g. authorities, contractors or suppliers, have to be considered. A safety management system has to consider all activities that have a direct or indirect impact on safety.

The Fundamentals for Safety Management Systems demand a process oriented approach for the description and assessment of the safety relevant processes within the company. The safety relevant processes have to be identified, and the sequence and interaction of the processes in the overall system have to be defined.

Finally, an organizational structure expedient with regard to safety has to be established. This includes, for example, a clear specification of the positions, tasks, responsibilities and competences of executives.

4. CONCEPT OF AGEING MANAGEMENT

The discussions about the contents of an ageing management programme have been going on for a while now. The IAEA has issued several recommendations concerning this topic. Measures for maintaining quality over a long period of time have been an integral part of the quality requirements specified in German nuclear safety requirements. Examples are inspections and preventive maintenance, which are also major items of an ageing management programme. Nevertheless, ageing problems are handled differently and sometimes not systematically. For the assessment of ageing in nuclear power plants beyond a plant specific level, GRS has been working on the development of a computer based knowledge basis on ageing relevant damage mechanisms that can be used in the licensing and supervisory process.

On this basis, the Ministry for the Environment, Nature Conservation and Nuclear Safety requested a statement from the Reactor Safety Commission (RSK) on the preparation of an ageing management system. The aim was to standardize generic plant procedures referring to testing, acquisition and evaluation concepts, in addition to necessary handling procedures.

Ageing management refers to all organizational and technical changes put into place by the licensee to counteract important safety related ageing phenomena. The main goal of ageing management is the acquisition and evaluation of ageing mechanism data and systematic damage prevention.

In 2004, the German RSK submitted a comprehensive recommendation on the control of the ageing processes [7]. The aim of this recommendation is to cover all possible ageing mechanisms. Therefore, the recommendation considers four main topics. The largest part is related to the ageing of technical equipment, such as mechanical components, instrumentation and control components, structural systems (buildings) and operating supplies. The next item is the ageing of the documentation and of the integrated operation management systems. Besides these kinds of ageing, the loss of competence due to the retirement of plant personnel is also an important problem which the plant management has to face. The final topic of the Reactor Safety Commission's recommendation refers to requirements to consider the state of the art in science and technology in relation to conceptional and technological ageing.

The RSK concluded that a systematic ageing management system for nuclear power plants covering the topics described above is necessary. The RSK assumes that the licensees will establish and follow an effective plan for an ageing management system. On an organizational level, the ageing management concept is the task of top management in cooperation with the licensee's safety management staff.

The RSK recommends that annual reports on ageing management be presented to the competent authority, with other reporting cycles being permissible in justified cases. As far as obligations go, they exist already to report on other individual ageing phenomena; the RSK considers it necessary that these should be integrated in the report on ageing management. To achieve a standard procedure for ageing management on a broad knowledge base, the RSK recommends to carry out generic evaluations of the licensees' plant specific reports. Any findings from these evaluations have to be considered in the ageing management of the individual plants; corresponding procedures have to be defined.

5. SAFETY MARGINS

When the nuclear power plants were designed, in many cases the margins of the acceptance criteria were determined by conservative evaluation model calculations. The uncertain knowledge of a system made it necessary to calculate a pessimistic estimate of the processes in the plant. Each step in the conservative analysis, starting from the selection of initiating events, had to ensure that there were safety margins.

Today, there is an increasing tendency to use realistic or so-called best estimate calculations with uncertainty analyses. A prerequisite of this approach is the availability of qualified computer codes which are validated by pre- and post-test calculations of appropriate experiments and plant experience. An obvious advantage of these realistic calculations is the much better knowledge of the processes compared with the knowledge gained from conservative evaluation calculations. These best estimate calculations are already used in licensing procedures, although there are no formal regulations for their use in Germany yet.

The usual effect of reducing conservatism in an analysis is that calculated margins to acceptance criteria are increasing. Once this increased margin has been identified, there are different options for how this gain of margins can be treated. The preferred option might be to improve the plant's performance.

Usually a safety margin is defined as the difference or ratio in physical units between the limiting value of an assigned parameter which, if exceeded, leads to the failure of a system or component, and the actual value of that parameter in the plant. The existence of safety margins ensures that nuclear power plants operate safely in all modes of operation. The most important safety margins relate to physical barriers against the release of radioactive material [8].

The limiting value is referred to as the safety limit or the acceptance criterion. Safety limits are design limits based on accepted codes and standards. Acceptance criteria are the criteria stipulated by the regulatory body and are based on national and international requirements. The regulatory acceptance criteria are often more restrictive than the limits in design. The safety margin to the limiting value can be determined by different methods, namely, by conservative evaluation model calculations and realistic best estimate calculations.

As already mentioned, the calculated increase of safety margins by improving analytical methods can be used to improve the plant's performance. But there are also examples which illustrate that the increase of the safety margin for one value is needed to regain a reduced safety margin for another value because of the further development of knowledge and regulations.

Current important activities which require an in-depth analysis to evaluate the possible safety impact are applications to increase the power output of plants which make it necessary to verify the influence of the plant's behaviour during normal operation as well as during an accident. Another important item is the tendency to turn to higher fuel burnup and to use mixed oxide fuel. The analyses of such modifications have to consider all consequences of the plant modifications with respect to the margins existing under normal plant operation and design basis accidents. The analyses must consider the core characteristics and plant behaviour, taking into account the capability of safety systems and the reactor protection system set points.

There are also examples which illustrate that the increase of safety margins by improving analytical methods was offset by additional requirements due to a gain of knowledge. One example has already been mentioned here: the verifications for a loss of coolant accident concerning the problem of sump clogging by insulation material. On the one hand, improved analyses have revealed margins in the capacity of the emergency core cooling system. On the other hand, new experiments and operating experience relating to the debris from insulation material during a loss of coolant accident have enhanced the requirements for the emergency core cooling system.

6. CONCLUSION AND OUTLOOK

The different examples give an impression of the challenges which have been discussed in recent years within the nuclear safety community in Germany and in other countries. There are, of course, more aspects which could be mentioned here: some new challenges, such as the replacement of instrumentation and control equipment by new software based equipment, the need for knowledge management, or the revision of the German nuclear regulations, will be the topics of interest in the future. Some of the examples presented will also be under ongoing discussion. Even though the major requirements for a safety management system have been regulated now, the monitoring of the implementation of safety management systems in the plants has to be supervised by the authorities.

Further impulses for the continuous enhancement of nuclear safety will be given by the improved evaluation of operating experience and by ongoing safety research.

In summary, it can be concluded, therefore, that to maintain safety under changing boundary conditions, progress is necessary.

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STUDY ON THE INSPECTION CAPABILITY OF ULTRASONIC TESTING FOR FATIGUE CRACKS IN PIPING

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Abstract

The ultrasonic testing (UT) technique is widely used as an in-service inspection (ISI) method, to ensure the integrity of nuclear safety power plant components. It is understood that detection and sizing are the key roles of inspections, because evaluation of the components necessitates such data as flaw size and distribution of flaws. Therefore, reliability or accuracy of the inspection is most important. However, data on inspection capability in terms of detection and sizing had not been necessarily sufficient. In Japan, a comprehensive research programme has been carried out, in order to verify UT performance in both detection and sizing since 1995. In this programme, various types of specimens with realistic flaws were manufactured to be used in a UT trial for detection and sizing with multiple inspection teams. They were eventually destructed for flaws to be investigated, and detectability and sizing accuracy of UT were evaluated. In the paper, results of UT verification test regarding carbon steel pipe specimens with fatigue cracks are presented. The results of the tests verified that UT had relatively high performance in flaw detection and sizing for fatigue cracks.

1. INTRODUCTION

It is necessary to detect flaws, to measure the flaw sizes accurately and to conduct the quantitative evaluation of the crack propagation, by the method of the fracture mechanics, considering the plant operating conditions; to ensure the integrity of the structure through the plant life.

The new regulation on nuclear power plants, the JSME Codes on fitness for service for nuclear power plants, on nuclear power plants was instituted in Japan in October 2003. The concept of an allowable flaw size was introduced in the Codes. Therefore, it is important to detect and to size the flaws, especially flaws that are larger than the allowable flaw size. In Japan, a comprehensive research programme has been carried out, in order to verify UT performance in both detection and sizing for the specimens simulating components (piping, pressure vessel, a nozzle corner, etc.) to be inspected by ISI. The specimens have fatigue cracks and SCC. The objective of this programme is to give guidelines that may enable the Japanese regulatory body, MITI, to make a proper judgement on inspection results.

In this paper, the results are reported about the detectability and the accuracy of the sizing (the flaw length, the flaw height) by ultrasonic testing (UT) for the fatigue cracks located in the vicinity of welds in carbon steel piping.

2. VERIFICATION TEST

2.1. Preparation of specimens

The configuration of specimens is shown in Fig. 1 and Table 1.

All the specimens were fabricated by applying TIG and SMAW welding. The flaws were mechanically induced fatigue cracks located at the inner surface of the specimen. The real sizes of fatigue cracks were investigated in a destructive test after UT measurements had been completed (Table 1).

2.2. UT measurement

The UT tests for detection and sizing were carried out by multiple inspection teams with blind test conditions. UT was performed with the direct contact technique using a 45° transducer.

Flaw length was measured based on echo height, with a cut-off level of 20, 50 and 100% distance amplitude compensation (DAC).

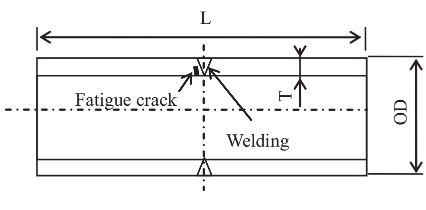

FIG. 1. Carbon steel pipe mock-up with fatigue cracks.

TABLE 1. FLAWS IN SPECIMENS

Specimen size		Number of flaws		Flaw size	
OD (mm)	T (mm)	> allowable flaw size	< allowable flaw size	Length (mm)	Height (mm)
165.2	10	7	2	4.3~24.3	0.9~7.5
355.6	25	5	7	3.1~60.4	0.3~12.2
508.0	35	4	5	8.9~20.4	1.0~6.5
609.6	50	8	3	11.3~70.6	1.8~18.2

Tip echo techniques and time of flight diffraction (TOFD) techniques were used for flaw height measurement.

3. RESULTS AND DISCUSSION

3.1. Detectability of flaws by UT

We investigated the detectability of UT for the fatigue cracks. The detection rate for the cut-off level (20% DAC, 50% DAC and 100% DAC) by UT is shown in Table 2. It was found that all the flaws larger than the allowable flaw size are detected by the cut-off level of 20% DAC.

TABLE 2. DETECTION RATE LARGER THAN ALLOWABLE FLAW SIZE

Specimen size		Cut-off level		
OD (mm)	T (mm)	20% DAC	50% DAC	100% DAC
165.2	10	100%	86%	86%
355.6	25	100%	100%	100%
508.0	35	100%	100%	100%
609.6	50	100%	100%	100%

3.2. Sizing accuracy by UT

3.2.1. Relation between the flaw length by UT and the actual flaw length

The relationship between the flaw length by UT and the actual flaw length is shown in Fig. 2. By comparing three data, the 20% DAC method showed best performance in length sizing, of which the RMS error was 5.85 mm.

3.2.2. Relation between the flaw height by UT and the actual flaw height

Sizing accuracy of flaw height by UT for the four kinds of specimens is shown in Table 3 and Fig. 3. Sizing accuracy for all sizes of specimens is good (RMS error < 2 mm). The accuracy of measuring the flaw height by the tip echo technique was similar to that of the TOFD technique. Moreover, both techniques show a good correlation between actual and measured flaw height. The height of all the flaws larger than the allowable flaw size was measured.

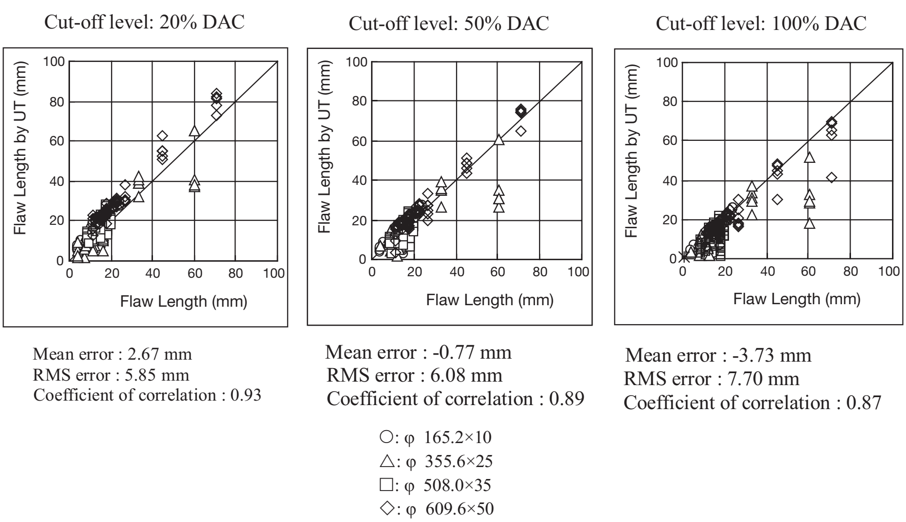

FIG. 2. Flaw length by UT for cut-off level DAC 20%, DAC 50% and DAC 100%, and the actual flaw length.

TABLE 3. MEASUREMENT ACCURACY OF FLAW HEIGHT BY UT

Specimen size		Tip echo technique			TOFD		
OD (mm)	T (mm)	Mean error	RMS error	Coefficient of correlation	Mean error	RMS error	Coefficient of correlation
165.2	10	–0.35	1.24	0.77	–0.25	0.59	0.96
355.6	25	–1.74	1.10	0.97	–1.20	1.54	0.97
508.0	35	–0.17	0.52	0.96	–0.32	0.52	0.97
609.6	50	–0.22	0.61	0.99	–0.45	0.65	1.00

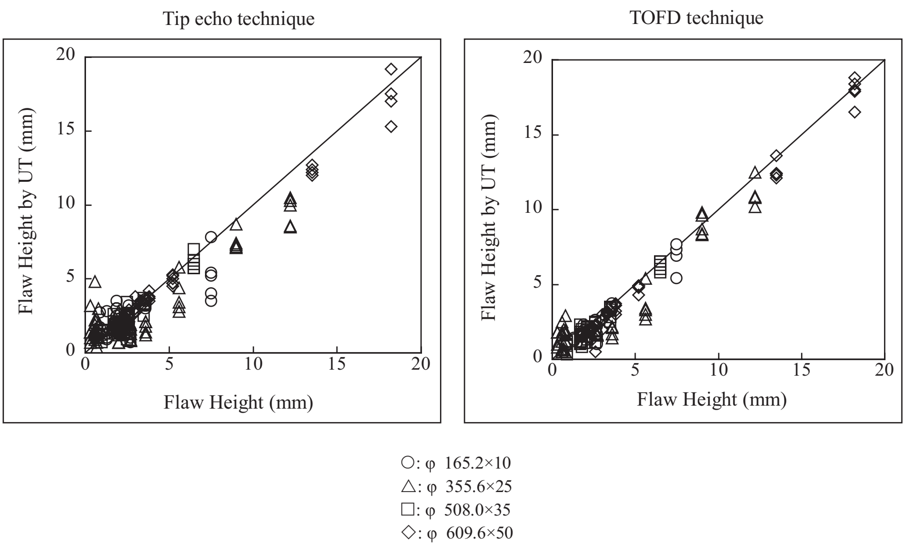

FIG. 3. Flaw height by UT and actual flaw height.

4. CONCLUSION

The results of this study examining the detectability and the sizing accuracy by UT of the fatigue cracks located in the carbon steel pipes are summarized as follows:

(1) The flaws larger than the allowable flaw size could be detected by the cut-off level of 20% DAC.

(2) The accuracy of measuring the flaw length by UT is fairly good at a cut-off level of 20% DAC (mean error: 2.67 mm, RMS error: 5.85mm).
(3) The accuracy of measuring the flaw height by the tip echo technique and the TOFD technique is relatively good (tip echo technique: mean error –0.34mm, RMS error 1.15mm; TOFD technique: mean error –0.28, RMS error 1.10mm).

We have accumulated the key data on the inspection performance, that can be the basis of regulatory decision making. We have already prepared an interim inspection guideline based on data obtained to date. In addition, to make the final guideline, additional evaluation is being carried out.

WWER DESIGN BASIS DOCUMENTATION MANAGEMENT SYSTEM

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Abstract

In the framework of the IAEA Regional Project, WWER Design Basis Documentation Management System, the Guideline for Design Basis Document Collation and Maintenance was developed. Pilot development and review of these documents for the technology system 'low pressure emergency core cooling system' of WWER-1000 and WWER-440 plants was accomplished. The paper summarizes the experience gained.

1. INTRODUCTION

The IAEA Regional Project RER/9/69, WWER Design Basis Documentation Management System, was started in 2001. During the first two years of the project, the main approaches were gathering and developing IAEA guidance. Each country was forming their infrastructure to support this activity.

In 2003, a new type of work was initiated. This covers preparation of the pilot design basis document (DBD) for a selected system (low pressure emergency core cooling system — LP ECCS) and its review or verification by various organizations from different countries.

The first two years of the RER 9/069 project were primarily focused on gathering experience on different methodologies to develop DBDs. No unique approach was adopted by participating countries. Two key design and architect engineering organizations from the Russian Federation participated actively, but with no obligation to develop DBDs. At the end, they agreed to participate in the review process but only in a 'generalized' recommendations process, without any attempt to assess any documented and undocumented DB value.

After agreement that the pilot DBDs for LP ECCS will be developed, the work started with assignment roles (developer, reviewer) in early 2003 as described in the following sections.

A description of work organization and its results are presented in this paper.

2. BACKGROUND AND REASONS FOR THE IAEA GUIDELINES

The design bases for a structure, system or component is information that identifies the specific functions to be performed, and the controlling design parameters and specific values or ranges of values for these parameters. The design bases of an NPP are used by the plant staff and regulatory authority in judging the acceptability of the original design and of modifications to the NPP with respect to the safety of the NPP's personnel, public and environment.

The design bases stipulate the following:

- The function of the structures, systems and components (SSCs);
- Essential SSC parameters of the stated functions and processes;
- Basic safety margins to be included in the design;
- Interfaces with other SSCs, including mutual dependences;
- Accident, hazards and fault scenario expectations;
- Environmental considerations and impacts;
- Applicability of safety and industry codes and standards.

Some plants have the design bases information in a format that is easily retrieved and used. Other plants have difficulty obtaining the design bases information and may have some of the following characteristics:

- Documentation is dispersed, even that containing very important information;
- The main design principles are not readily available and sometimes have been lost, although functionality of the plant was approved;
- The original 'know-why' is not readily available for use by plant personnel;
- Many plant changes have been made, but the cumulative effects of these changes have not been considered;
- After several years of plant operation, modification and maintenance, management of the plant does not have a high degree of assurance that the plant documentation reflects actual plant status;
- Worldwide NPP experience has shown the value of having quality design information to support long term operation of nuclear power plants. In addition, accurate and current design basis information is necessary to make operational decisions daily.

The purpose of this guideline is to describe the various aspects that need to be considered in the development and implementation of a plant design basis programme for DBD collation and maintenance. The aspects include defining the objectives of the programme, establishing a plan to identify, collect and evaluate source documents, regeneration of the design if necessary, preparation of design basis documents, identification and resolution of discrepancies, review and validation of the documents, and ultimately including the information in a design control process within a comprehensive configuration management (CM) programme.

3. SCOPE AND STRUCTURE OF THE GUIDELINE

This guideline focuses primarily on the process of identifying and developing supporting design basis information and producing DBDs, which can be referenced and used by the plant staff. This guideline also addresses the long term maintenance of the DBDs as part of a comprehensive CM programme at nuclear power plants.

Recommendations of this guideline are offered to IAEA Member States that have nuclear power plants in current operation for their voluntary use as appropriate. The guideline is not intended to describe the only method of developing and implementing a DBD management programme. Members are encouraged to use the guidelines as a reference point from which to review their existing or planned efforts. The guidelines are structured primarily for use by the owners and operators of nuclear power plants, who are responsible for plant management processes, rather than for regulatory authorities. Regulatory authorities may wish to use aspects of this guidance related to a determination of the effectiveness of existing or improved design basis processes.

Section 2 provides definitions of relevant terms used in the guideline. Section 3 is an overview of the desired characteristics for DBD content and format. Section 4 then describes the process for developing DBDs.

Annexes are provided which contain more detailed information on these subjects. References are listed in Annex A. Annexes B and C are process flow charts for design and design change processes and for the DBD development process, respectively. Annexes D and E were extracted from NEI 97-04, Rev. 1, Design Bases Program Guidelines. Annex F provides examples of DBD software. Annex G provides an example of a DBD structure for the low pressure emergency core cooling system (LP ECCS). Annex H presents lessons learned from the pilot DBD project.

4. DEVELOPMENT AND REVIEW/VERIFICATION OF DBDs

4.1. Goals

In March 2003, the Technical Planning Meeting on Design Basis Methodology and its Application for WWER Type Nuclear Power Plants set up clear milestones, with the following deliverables to be achieved by the end of 2003:

- The IAEA document Design Basis Document (DBD) Guideline (now in final draft form), will be completed, reviewed and issued;
- Two Pilot DBDs for WWER-1000 will be completed by August–September and reviewed and verified (R&V) by November 2003;
- Meeting of Ukrainian and Czech experts at NRI Řež to further discuss details of the DBD (May 2003);
- Two Pilot DBDs for WWER-440 will be completed by October 2003 and R&V by 15 November 2003;
- Meeting of Hungarian and Czech experts at NRI Řež to further discuss details of the DBD (June and September 2003);
- Final meeting to review the pilot DBDs to be held at the end of November 2003;

The scope of participation of countries or their organizations can be seen in Table 1.

TABLE 1. SCOPE OF PARTICIPATION OF COUNTRIES OR THEIR ORGANIZATIONS

Country or organization	DBD-1000 development	DBD-1000 verification/ review	DBD-440 development	DBD-440 verification/ review
Czech Republic	D	R	D	R
Ukraine	D	R		R
Bulgaria		R		R
Hungary			D	R
Slovakia				R
Rus – OKB		Generalized recommendation		Generalized recommendation
Rus – AEP		Generalized recommendation		Generalized recommendation

4.2. DBD preparation

Pilot DBD content as well as collation procedures used were presented by particular document authors at a meeting held in Vienna in November. The most important conclusion from the discussion of the above DBDs and first reviews was that it is necessary to prepare DBDs in a more consistent format. So two sets of documents were provided for review:

— First set, presenting the different views and approaches of the involved plants (provided before the meeting of November 2003);
— Second set, developed with a more consistent approach (provided between November 2003 and February 2004).

DBDs for the technology system LP ECCS of WWER-1000s are in Appendices A and B. DBDs for WWER-440 are in Appendices C and D.

5. NRI REVIEW OF THE DBD DEVELOPED AND THE REVIEW PROCESS

5.1. Review principles

From the point of view of the Nuclear Research Institute (NRI), the purposes of the DBDs are the following:

(1) To serve as a base for design modification. This implies a requirement on *completeness* of DB functions and values. Without ensured completeness of DB functions, the use of the DBD for this purpose is limited.
(2) Evaluation of safety margins. Again the *completeness* of DB functions, DB values and open items identification should be ensured. A *methodology for the margin management* should be prepared in the short term.

The following features of DBDs are desirable:

(1) The DB value of a DB function should be an envelope of values corresponding to individual operating modes relevant to DB functions. The DB value is, therefore, usually expressed as an interval or upper and lower bound functions. Nevertheless, a list of design accidents relevant to DB functions should be contained in the DBD as well.

(2) DBDs should contain, besides DB functions and DB values, also supporting information, i.e. references and DRs.
(3) DBDs should be well arranged. In the text, it should be clearly emphasized what the DB functions are, with clearly distinguished DB values and DRs. An extension of the system description should be moderate. A large description deteriorates orientation in the document and degrades prime DBD purposes.
(4) DBDs should be based on a reliable methodology ensuring completeness of DB functions, values, open items and their correctness. The correctness means, besides other items, a clear distinction between DB values and DRs that are made. The envelope of DB values corresponding to relevant operation modes is well constructed.

6. CZECH DBD

6.1. Introduction

The NRI created pilot DBDs just at the very beginning of the Temelin DB collation project. At first, the pilot LP ECCS DBD was created for Temelin NPP and then immediately the main part of the project (with an increased number of participants) was started in Czech. As a result of the pilot stage and the newly obtained experiences, the used methodology was further developed. These methodology changes have not, unfortunately, influenced the pilot DBDs; therefore, the latest changes and improvements are not part of the pilot DBDs.

7. METHODOLOGY DESCRIPTION

For a better understanding of the description of the methodology used by the NRI, some additional comments are presented.

For NPP, DB collation, a knowledge management system DART (from WEE) is used. DART enables very effective storing of prepared information, as well as using reverse failure mode and effect analysis (RFMEA) for DB collation in a very systematic way.

DB collation methodology is presented by the following list of basic steps with added comments written in italics:

— Working out the failure trees to the required extension and depth using RFMEA.

For DB collation based on analysis employing failure trees, it is necessary to create trees to a much larger extent than for the systems for which collation is carried out. The reason is that required system functions for a particular system are requested in different parts of the tree, therefore, it is not possible to limit the tree only to parts necessary for the system DB collation. This has been a disadvantage when the pilot project was performed.

Until the end of the year 2003, the NRI further developed a methodology for trees preparation. The method employs templates of typical failures updated on the base of obtained experiences and expert discussion.

— Description preparation for each gate (failure or event) from the tree.
Description gives precision and explains failures.

— Defining the functional requirements, system requirements, analyses requirements and procedure requirements for individual gates.
In this step, requirements, which could solve or moderate a problem represented by failures written in particular gates, are defined. In this step, an open minded method is used even if it is managed by templates of typical requirements, which hold authors' creativity in reasonable limits. Tables were finished during January 2004.

— DB functions can only define system requirements but for completeness or further use, all mentioned requirements are prepared.

— Working out the compliance statement for each system requirement.
Particular statements to the system requirements contain a list of SSC which fulfil required functions, plus references that prove the statement.

— Writing down the functional requirements to the working DBD version of these systems that appear in the compliance statement, as required by the system fulfilling the function required by the requiring system.

— *Requiring system failure → Requirement → Compliance statement containing the required system. For each SSC that fulfils any defined system requirement, a list of these requirements (rough DB functions) is written into their working DBD version.*

— Completing the functional requirements by additional requirements issued by the regulatory body for individual systems and components.
It is not possible to find out all these DB functional requirements — only by a purely logical way.

— The grouping of identical functional requirements generated by different failures (i.e. different parts of the tree) from the set of functional requirements collated for individual systems and components, unifying the formulations of these requirements and formulating the representative functional requirement for each group.

- Formulation of requirements for searching for DB parameters of a required system in the documentation of the requiring system.
- Based on requirements defining DB parameters formulated in the previous step, the scanning of technical documentation belonging to individual systems and components is performed, and the result of scanning is written down into the requirements compliance statements.
- Statements about found parameters are analysed and parameter intervals or open issue are defined. Based on information included in the working version or other sources, the final version of DBDs is prepared. Due to the fact that all information contained in DART *is structured and fragmented, it is possible from existing fragments to easily prepare other documents, for instance, a final version of DBD. This way it is possible to obtain different views on the same information, which is the reason why in our DB collation projects we do not put too high a concern to define the final DBD structure. All will be solved at the end of the projects, depending on information obtained, information from other databases used by DART and requirements of the NPP owner or regulatory body. Czech DBDs for the NPP Dukovany (WWER 440 type) and NPP Temelín (WWER-1000 Cz type) are at A 3.*

8. CONCLUSIONS

No further development and reviews of pilot DBDs are foreseen by the IAEA. Now it is understood that all participating countries and organizations gained enough experience to prepare their own DBD collation process. No unique methodology is foreseen, but with the developed IAEA guidance and thorough experience gained during this project, any further continuation of this effort is supposed to be ensured at the national level. Some other activities especially related to the configuration management and margin assessments are foreseen by the IAEA in the near future. For this year, however, a more detailed assessment of the review process is highly recommended.

COPING WITH A NEW LINGUISTIC ENVIRONMENT
The expanding role of English within the nuclear industry

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Abstract

The role of English as a medium of communication within the nuclear industry is expanding. The paper surveys the spread of English use and assesses the positive and negative implications, in particular, whether the use of English as a medium of communication between non-native speakers increases the probability of miscommunication. Suggestions are put forward for ensuring that communication is enhanced and not weakened in the new linguistic environment, including the use of a new occupationally tailored English course for the nuclear industry entitled 'Nuclear English'.

1. INTRODUCTION

To use a nuclear analogy, the number of English speakers in the world has reached a critical mass [1]. English learning is growing globally at an exponential rate. Unlike previous international languages, such as Latin, Sanskrit, French and Esperanto, English has penetrated all five continents and all levels of society. It has emerged as the world's language and will retain that role for the foreseeable future. This paper will survey the expansion of English use within the globalizing nuclear industry and assess the positive and negative implications. Recommendations for ensuring that the new linguistic environment is leading to enhanced and not weaker international communication will be made. Clear and accurate communication is vital to the nuclear industry — safety concerns must always be paramount.

2. SURVEY OF ENGLISH USE WITHIN THE NUCLEAR INDUSTRY

A survey of the global nuclear industry reveals a widespread growth in English use. Table 1 shows a selection of organizations and projects where English now serves as the common language between non-native speakers.

TABLE 1. EXAMPLES OF NON-NATIVE SPEAKER ENGLISH USE IN THE NUCLEAR INDUSTRY

Organization/project	Comments
Framatome (France)/ Siemens (Germany)	The merger of these two companies in 2000 has created a company (Framatome ANP) of approximately 14 000 non-native employees using English as a working language.
British Energy (UK)/ FMA Services (Framatome ANP, Alstec, Mitsui Babcock)	The consortium, FMA Services, is contracted by British Energy to refuel and maintain its PWR reactor at Sizewell. At the latest planned outage at Sizewell B in October 2003, FMA Services employed a team containing over 20 different nationalities to perform the work [2].
KHNP Nuclear Power Education Centre (KNPEC), Republic of Korea	KNPEC near Ulsan, Republic of Korea, is the largest single nuclear training centre in Asia. It offers nuclear operator courses in English to employees from neighbouring Asian countries.
Lingao NPP, Guangdong Province, China	The recently commissioned Lingao reactors use Framatome ANP technology. They were built through a cooperative effort between French and Chinese engineers who used English as a medium of communication.
Cogema (France)/ Sojitz Corporation (Japan)	English is the language used by the French company Cogema in its dealings with its trading company partner in Japan, Sojitz Corporation.
Japan Atomic Energy Research Institute (JAERI)	JAERI is at the centre of some of the world's most important research into nuclear safety and innovative reactors. Each year, it invites around 350 foreign researchers to participate in its programmes; most of these communicate with their Japanese counterparts in English.
IAEA	English is the working language at the IAEA.

3. POSITIVE AND NEGATIVE IMPLICATIONS

The benefits of a common language linking the world's nuclear community are clear: it facilitates the sharing of information; it leads to increased mutual cultural understanding; it can improve communication efficiency; it allows reduced expenditure on translators and interpreters.

However, the emergence of English as a global language also has negative implications. The dominance of English gives unfair advantage to native English speakers, while those without linguistic aptitude are inhibited from fully participating in meetings, debate, research, etc. Within organizations, poor English speakers may be overlooked for promotion in favour of more linguistically able colleagues, despite excellent nuclear science or engineering credentials.

To help cope with the new linguistic environment, many within the nuclear industry study English at home or in classes. However, the nuclear industry, outside Asia, has an ageing population and many of its members studied at a time when the future importance of English was not recognized. Moreover, in Eastern Europe and other parts of the world, English is a fairly recent addition to the school curriculum. According to research into second language acquisition, full competence in a foreign language can only be achieved if learning commences before a certain age, accepted to be around 16 years [3]. Therefore, many of the current generation of nuclear workers, who either were not given the opportunity to study English at school or did not take their English study seriously, can aspire only to a working knowledge of English, rather than full competence.

While communication through English between a native speaker and a non-native speaker or between two non-native speakers offers convenience, the quality of that communication may not be as high as that achieved through an interpreter or translator. There is a shortage of research in this area, however, studies conducted in Scandinavia — an area famous for its high level of proficiency in English — published in the Norwegian Medical Association Journal showed that Nordic medical doctors took in 25% more information when they read a medical article translated into their mother tongue than when the article was in the original English version [4].

Miscommunication can occur at any time — even between speakers of the same language. In analysing whether the probability of miscommunication is increased when speakers communicate through a second language, it is useful to look at the experiences of the aviation and the shipping industries. Here, English has been the default language between pilots and air traffic controllers, and between multilingual crews, for many decades. In 1976, the Aviation Safety Reporting System (ASRS) was set up by the National Aeronautics and Space Administration (NASA) to be a voluntary and anonymous reporting system for any operational incidents. Since its inception, ASRS has received 400 000 reports from aviation personnel. In 1996, following an analysis of the reports, NASA announced that 25% of the reports cited language problems as a primary cause of the foreign airspace operational incidents reported to ASRS.

Miscommunication involving non-native speakers contributed to both the fourth largest and largest air disasters in history. In 1972, a Turkish Airlines DC-10 jet crashed near Paris when the cargo door opened after take-off and the aircraft depressurized. The accident was attributed to the inability of a

French cargo handler to read a metal plate next to the door which explained, in English, the correct door closing procedure. In 1977, KLM and Pan Am jumbo jets collided at an airport in Tenerife, killing 583 people. One of the contributory factors was found to be the poor communication between the Dutch pilot and the Spanish air traffic controller. In particular, an expression used by the pilot — we are at take-off — was interpreted by the air traffic controller as meaning we are now at take-off position rather than we are taking off. The pilot's native language, Dutch, had interfered in the way the pilot had constructed an English sentence, leading to this fatal error [5].

In the shipping industry, accidents caused by poor ship-to-shore communication and misunderstandings between multilingual crews were a source of great concern in the early 1980s. It led to the development of a simplified version of English called 'Seaspeak'. The standard phraseology and vocabulary of Seaspeak were designed to help avoid the ambiguities and unclear references which lead to miscommunication [6].

4. RECOMMENDATIONS

If the nuclear industry is to ensure that the new linguistic environment is leading to enhanced and not weaker communication, there must first of all be greater awareness on the part of native speakers for the need to model clear and accurate English. According to the authority on languages, David Crystal, native speakers need to become bilingual in their own language, that is to say, continuing to use colloquial, local language with their friends and family while employing standard English in an international setting [7]. They must also have an awareness of the increased time non-natives require to communicate. Courses in effective international communication can help native speakers understand their responsibilities in this area.

There should also be a new approach to English language training within the nuclear industry. Currently, English learners are offered general English courses supplemented with glossaries of terminology. However, over the last 30 years, the English language teaching (ELT) industry has created courses particular to the occupational needs of working adults in most major industries. These courses offer in context the lexis and skills learners require for their professions, thus helping to minimize transfer time to a working knowledge of English. Furthermore, a dedicated textbook offers students absorbing and relevant material, and thereby increases their motivation to master the language.

To meet the needs for improved English within the nuclear industry, the World Nuclear Association in 2003 commissioned Nuclear English, the first

English language textbook for the global nuclear industry. Due for publication in 2005, its central objective will be to increase student proficiency within the four skill areas of listening, speaking, reading and writing, as well as to cover grammatical features which have been shown to be useful in technical English (the passive, modal verbs, conditionals, etc.). It will consist of 12 lessons covering areas of the nuclear energy cycle, as well as important issues such as non-proliferation, safety, research and development, and the use of radioisotopes in medicine and agriculture. It will be aimed at both technical and non-technical staff who have reached an intermediate to advanced level of English. The textbook will not be a nuclear manual. Nevertheless, learners — in particular, newcomers to the industry — will enhance their knowledge of the nuclear industry through the course. Other features of the book are:

— An accompanying CD containing authentic and absorbing interviews with industry figures;
— Listening extracts will feature a wide range of accents encountered in the nuclear industry, such as Standard American, British, Indian, Australian and South African;
— A glossary covering key nuclear terms;
— Transcripts of recorded material used in the lessons;
— An answer key for the exercises;
— A guide to help teachers maximize the learning potential of the materials.

Nuclear English has been developed on the basis of a needs analysis conducted in Japan, the Republic of Korea, Germany and France. The materials are being piloted successfully on learners from Japan, the Republic of Korea, Bulgaria and Ukraine.

5. CONCLUSIONS

The role of English within the nuclear industry is expanding. English is now commonly used as a medium of communication between non-native speakers. The industry must ensure that the new linguistic environment does not lead to weaker levels of communication by promoting awareness among native speakers of the need to model correct, non-colloquial English when operating in an international setting. Occupationally tailored English courses for the nuclear industry should also be encouraged as a way of raising English levels.

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Session Summary

LONG TERM OPERATION: MAINTAINING SAFETY MARGINS WHILE EXTENDING PLANT LIFETIMES

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1. CURRENT STATUS

The initially assumed time of operation of nuclear power plants was, in most cases, based on considerations other than technical, in most cases economic or legal. From a technical point of view, it should be possible, therefore, to continue plant operation beyond the originally assumed time frame, i.e. long term operation (LTO), provided that the required safety level can be maintained or achieved in an economic way. Care should be taken to adequately treat those aspects where an economics based time of operation has been reflected in the design. The term LTO is used to accommodate the various approaches established in the Member States (such as operating licence, design lifetime, etc.) when evaluating the viability of operating a nuclear power plant beyond the originally assumed time frame.

Decisions on LTO involve the evaluation of a number of aspects, such as plant design, actual condition of plant equipment, equipment qualification, ageing, safety assessment, safety performance, maintenance, surveillance, plant modifications, configuration management, design basis information availability, spent fuel management, waste management and decommissioning, etc., including their relationships and dependences. While many of these decisions concern economic viability, all are grounded in the premise of maintaining plant safety.

While some Member States have already developed and implemented regulations that cover LTO, others have just started the planning and development of such measures.

For safe LTO of a plant, analysis must show that the plant will continue to operate within its design basis. Therefore, there is a need to:

- Have a good knowledge of the current design basis of the plant;
- Have a correct picture of the actual state of the plant;
- Define the analysis needed to support LTO and demonstrate that the plant will still operate within its design basis.

Further, mechanisms providing an effective feedback of operating experience and due consideration of advances in science and technology need to be in place.

Safe LTO of a nuclear power plant involves consideration of a number of aspects and is a rather complex challenge. A first step in addressing technical issues related to LTO should be a comprehensive safety review. A comprehensive safety review provides a sound basis for defining the physical state of the power plant. Accurate knowledge of the physical state enables an assessment of the actions required to demonstrate that the plant will still operate within its design basis and address all LTO relevant and important aspects.

2. FINDINGS AND CONCLUSIONS

- Long term viability of the nuclear industry begins with a strong focus on safe daily operations at each nuclear facility. This focus begins with the chief executive officer and extends to every operator and worker at a nuclear facility. It can be shared, but never delegated. At the end of the day, nuclear safety is a dynamic non-event.
- Some countries view LTO in terms of a continuous process as opposed to periods of prescribed operation. Despite differences in framework, there is much in common with each approach. It is important to identify both the commonalities and differences associated with each methodology.
- It was noted that the difference in approaches to normal and LTO is not too large, but the issues to be addressed are different.
- Further work and, in particular, international cooperation is needed to harmonize requirements on adequate safety levels to be achieved and maintained during long term operation.
- Special attention is required to ensure safe LTO, in particular, for older plants designed to earlier standards in connection with ageing, less well documented design bases, and the large scope of modifications required.
- Safe LTO will only be ensured if plants are managed in an appropriate manner. The most significant events within the past ten years provide good evidence that increasing effort is needed to develop and maintain effective safety management systems.

- If available, the lessons learned from similar installations in the country can be very useful to plan an adequate LTO programme. But if the type of facility should be unique (e.g. fuel fabrication plants), the experience gained in other countries will help to understand good safety practices, good safety design, etc.
- The establishment and maintenance of international databases on LTO, including related issues, such as ageing, as well as the experience gained in the LTO of nuclear facilities, and results from international research programmes, are of high importance.
- Strengthening international activities between the IAEA, regulatory authorities and utilities can bring mutual benefits to those countries that are at different stages of addressing the issue of LTO. The related IAEA activities can provide guidance on the scope and content of programmes to ensure safe LTO.
- Safety margins are changing during normal as well as LTO in connection with the development of safety requirements, safety assessment tools and plants' modifications.
- In addition to technical issues, losing competence is one of the key future challenges. Conceptual solutions need to be developed.

CLOSING SESSION

Chairperson

J. PU
China

CLOSING COMMENTS

TOPICAL ISSUES IN NUCLEAR SAFETY

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As I stand here this morning, I look back upon the comments with which I opened this conference on Monday and I feel particularly pleased at how each and every expectation that I expressed, and each challenge that I put forth, has been recognized. This gives me a great sense of pride combined with deep gratitude — in China, in the Chinese Atomic Energy Agency (CAEA), in the National Nuclear Safety Administration (NNSA); in you, in the participants in this conference and in the staff of the IAEA. Each of you should be justly proud of your accomplishments this week.

During this week, 274 participants presented, critiqued and discussed issues related to the challenges before the world nuclear community as it moves into an environment of change and globalization. These participants represented 37 countries, five international and private organizations, and all aspects of the nuclear power community. There were 10 observers to our proceedings and 10 members of the press. Approximately two-thirds of us came to China from foreign lands, while one-third came from all over this wonderful country.

I must take this opportunity to recognize the contributions of several individuals, in particular. First, my thanks and congratulations to Messrs Zhang Huazhu, Chairman of CAEA, and Li Ganji, Assistant Administrator of NNSA. Their staff has served them well. Mr. Guo Lingquan, the NNSA Conference Coordinator, and Mr. Zhang Chi and their staffs worked especially hard to make this event the success it has been.

Next, I would like to thank Mr. Pang for the assistance he provided to all of us as for the PowerPoint presentation. Mr. Chen and Ms. Zhang were essential to our microphone communications throughout the week. Ms. Zhang O', Mr. Fred and Ms. Xu ran our Information Desk with charming, smiling faces. And then there was an innumerable number of 'hidden faces', members of the Hotel Xiyuan staff who attended to all of the little details so well.

Finally, I would like to express special thanks to the President of the Conference, Mr. R.A. Meserve, for his excellent leadership and foresight in the preparation and conduct of this successful conference. I would also like to thank the IAEA staff members that have worked so hard behind the scenes for the past nine months to make this conference a success: M. Lipar, our Scientific Secretary; R. Perricos, E. Janisch and B. Amir, our Conference Administrative Coordinators, and J. Stuller (Department of Technical Cooperation), who assisted in coordinating and supporting the participation of so many of the non-nuclear power plant participants who have been here this week.

Please join me in expressing our thanks to each and every one of these persons.

Now that we have recognized those that have made this conference such a success, I would like to share some thoughts on what it accomplished.

As I mentioned at the beginning of this presentation, on Monday, I posed about a dozen questions that we should keep in mind during the various sessions. These questions ranged from “How could we establish a global safety regime that could adequately respond to the trend towards globalization?” to “How could the industry and intergovernmental information sharing networks become mutually supportive?” to “How do we establish an adequate level of safety for long term operations?” Our deliberations considered each point — some robustly and some less fully — but all were addressed.

Additionally, I stressed five broad points that we should consider throughout the week. These included the role of the IAEA’s safety standards and the approaches in the IAEA’s assistance and services to better meet the ever changing environment, network knowledge and management, safety and security synergy, and views on future activities and meetings of the IAEA. Throughout our discussions, these points rose time and again.

I agree with our Conference Chairperson that the findings can be grouped into a few common themes and I would not challenge his characterization. However, as I look upon our results, I focus my thoughts on what actions the IAEA should pursue as a result of this week’s activities. Four actions seem particularly worthy of mention.

First, how should the IAEA further its efforts in the development and application of its safety standards? The need for international standards, as the global reference of a high level of safety, was recognized in each of our four sessions, and the IAEA is the only international organization with the statutory mandate to serve this role. We must continue our efforts at developing standards for all safety thematic areas and for all types of nuclear installations, and at keeping them current and user friendly by actively incorporating feedback to meet the changes in technology and the needs of our Member

States; likewise, we will continue to seek ways to ensure that the standards are applied effectively and universally throughout the world.

Second, we must seek out ways to share lessons learned in as deep and wide a manner as possible. Self-sustaining networks within and between Member States, based on strategic knowledge management, is a key vehicle to achieve this objective. The Asian Nuclear Safety Network, supported in China by the Beijing Institute of Nuclear Engineering, CAEA and NNSA (among others), is the flagship of the IAEA's safety networks. The proceedings and results of this conference will be a key input to this network.

Further enhancement of the IAEA peer reviews, OSART and IRRT in particular, was also widely perceived to be another very effective way to promote the sharing of lessons more in-depth.

Third, it is essential that international legal instruments, such as the Convention on Nuclear Safety, are incorporated into the improvement suggestions on the global safety regime that have been proposed. The IAEA will share the insights of this conference with the contracting parties and will work to engage them, as appropriate.

Finally, all the valuable suggestions and insights of this conference regarding the future activities of the IAEA will be duly reflected in the planning and implementation of the IAEA's future programmes. We also plan to organize the next topical issues conference in 2007. We appreciate your continued support and insightful suggestions to make those conferences as successful and meaningful as this conference.

In closing, I congratulate you again on this conference. You have provided it with the vision, energy and sustenance that ensured its success. Thank you very much! I wish each and every one of you the safest of travels home and declare this conference closed.

PRESIDENT'S CLOSING COMMENTS

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It gives me great pleasure to have served this week as the Chairperson for this conference on Topical Issues in Nuclear Installation Safety. We have now come to that part of the conference where each Chairperson has to earn his or her pay. Up to now, it has been you, the individual presenters and the participants in this conference, who have made it a success. You, the presenters, have provided the thought and insights for each of our individual topics. You, the participants, have raised the questions and engaged in the discussions that have taken this conference beyond the individual papers. For this, I give each and every one my heartiest congratulations and thanks.

But, as I mentioned, now it is my turn. As the Chairperson for this conference, I now will attempt to summarize the major findings and recommendations that we, together, have reached during the past four and a half days. In putting my thoughts together, I have chosen not go through a detailed summary of each individual session. I leave the task of preparing the details of each session to the IAEA staff rapporteurs and the respective session chairpersons. These findings will, I am sure, be adequately captured in the final report of this meeting. (Of course, you know that this will mean that each of us will now have to buy a copy of the proceedings!)

What I am going to do is to present what I believe are the central themes that have arisen during the week's presentations and discussions. I will also share examples from the individual topical sessions that, I believe, support my thematic categories. In preparing these thoughts, you will find that my themes are closely aligned to the topical sessions. One key exception is that I believe that the regulatory implications are something that is woven throughout this concept of a changing environment. I believe that it is an inherent part of each of my thematic areas; therefore, you will not see it as a separate thought.

My first broad theme is the need to harmonize regulatory approaches:

— There is a need to build on the IAEA safety standards to provide vendors, operators and regulatory authorities with internationally accepted standards for designing, licensing, operating and regulating nuclear installations;

— The variant opinions on design certification;
— The question of how to harmonize the transition point between safety standards and industrial standards;
— Role of the IRRT to act as a vehicle to promote regulatory consistency. Emphasis on the new IRRT process that addresses self-assessment. Recognition of the generic call for all Member States with nuclear installations to consider availing themselves of this valuable peer review service;
— The need to establish the right balance in using, in a complementary manner, both deterministic and probabilistic approaches during design, operations and regulatory activities;
— Globalization and the provision of reactors to Member States with no vendor knowledge (or allowing for the new business concepts where new corporate owners or individual site managers are ‘business-oriented and experienced’ as opposed to being ‘operationally experienced’) calls into questions who ‘owns’ the design (design conscience), who is responsible for providing the necessary focus (decision making and resources) on safety (safety conscience) and security (security conscience).

My second broad theme relates to the concept of operating experience and the need to foster an environment conducive to becoming ‘learning organizations’:

— Maintaining a transparent environment is essential, with other owner–operators, with the regulatory authorities and with the public;
— Recurrent events are taking place! How do we ensure that the lessons learned in the past are not forgotten during the present and lost in the future?
— The process for identifying low level and near miss events must be stimulated and serve as a repository of lessons learned for all members of the nuclear community;
— Artificial barriers to sharing safety related information need to be breached. This includes addressing proprietary, technical and political factors that stand in the way of information sharing;
— Information technology methods, such as self-sustaining networks, must be pursued to ensure that resources are leveraged to the maximum degree possible;
— Lessons learned are not unique to any specific period in the life cycle of a nuclear installation or any particular type of nuclear installation. Knowledge must be shared during the design, construction, operation

and decommissioning phases of all facilities (power plants, research reactor and fuel cycle facilities);
— Likewise, lessons learned are not unique to any particular industry. All sources of lessons relative to material and process safety insights must be pursued.

My final theme relates to the concept of extended operation:

— The first point that comes to mind is the extended discussions we had concerning the term ‘long term operation’. Not sure if we ever reached an agreed definition, but for this morning I propose ‘continued operation of nuclear installations that have been in operation for periods beyond their design assumptions’;
— What safety standards are needed, if any, for the transition from ‘normal operation’ to ‘long term operation’;
— Some countries view long term operation as a continuous process and others as something that is tied to their licensing process;
— It was accepted that for safe long term operation of an installation, the safety analysis must show that the plant will continue to operate within its design envelope. Thus, there is a need for:
  - Sound knowledge of the current design basis;
  - Accurate knowledge of the actual state of the plant;
  - Verification that adequate safety margins will be maintained;
— Long term operation must consider the concept of ageing management in its broadest context, addressing both material (pumps, valves, etc.) and personnel (knowledge) issues.

Finally, in closing I would like to make a couple of personal observations. If you looked at the list of participants of this conference, you will notice that the attendance was dominated by regulators, and the participating countries were mostly those with nuclear power plants. There were reasons for this, such as the fact that just last year there was an international conference that was specifically focused on research reactor safety; however, I would encourage the Secretariat to actively pursue the widest possible participation in future conferences. All stakeholders interested in nuclear installation operational safety should be actively pursued.

Second, as the current Chairperson of the International Nuclear Safety Group (INSAG), I must say that I am quite proud that the four areas that we have identified related closely with the findings of this conference: the need for a global safety regime; what should be the safety principles upon which nuclear installations are grounded; what the operational safety considerations are that are driving nuclear safety; and how information should be shared throughout the entire nuclear community (public outreach). The shared focus seems, to me, to add credence to each other's deliberations and conclusions.

Again, I thank you for your active and thoughtful participation. You have made my job this week a pleasure. And, I most especially thank our Chinese hosts, the China Atomic Energy Authority and the National Nuclear Safety Administration, for their hospitality and professionalism. Your attention to detail and your warmth and friendliness have made this week one that, I am sure, all of us will long remember.

CHAIRPERSONS OF SESSIONS

Opening Session	K. BROCKMAN	IAEA
Topical Issue 1	L. WILLIAMS	United Kingdom
Topical Issue 2	L. ECHÁVARRI	OECD Nuclear Energy Agency
	G. SERVIÈRE	France
Topical Issue 3	E.W. MERSCHOFF	United States of America
	A.-C. LACOSTE	France
Topical Issue 4	S.M. BERG	World Association of Nuclear Operators
	J.A. AZUARA	Spain
Closing Session	J. PU	China

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AUTHOR INDEX

Events at nuclear installations continue to be reported whose root causes call into question the effectiveness of safety at those facilities. These events all have common issues that contribute to non-conservative decisions being taken or omissions in the decision process. More importantly, these events have highlighted issues within both the regulatory authorities and the operating organizations. In the light of these developments, it was considered appropriate to convene an international conference on Topical Issues in Nuclear Installation Safety: Continuous Improvement of Nuclear Safety in a Changing World. Its objective was to foster the exchange of information about topical issues in nuclear safety, including changing environments, operating experience, regulatory management systems and long term operation. These proceedings contain the conference summary, the opening addresses and invited papers. The contributed papers are provided on a CD-ROM attached to the inside back cover of this volume.

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