Unclassified **NEA/CNRA/R(2001)1**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

OLIS : 15-Jan-2001
Dist. : 16-Jan-2001

English text only

NUCLEAR ENERGY AGENCY
COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

NEA/CNRA/R(2001)1
Unclassified

REGULATORY ASPECTS OF LIFE EXTENSION AND UPGRADING OF NPPs

CNRA Special Issue's Meeting 2000 - Report

English text only

99064

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

– to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
– to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
– to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter; Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consist of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

– *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
– *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
– *developing exchanges of scientific and technical information particularly through participation in common services;*
– *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) is an international committee made up primarily of senior nuclear regulators. It was set up in 1989 as a forum for the exchange of information and experience among regulatory organisations and for the review of developments which could affect regulatory requirements.

The Committee is responsible for the programme of the NEA, concerning the regulation, licensing and inspection of nuclear installations. The Committee reviews developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them or avoid disparities among Member Countries. In particular, the Committee reviews current practices and operating experience.

The Committee focuses primarily on power reactors and other nuclear installations currently being built and operated. It also may consider the regulatory implications of new designs of power reactors and other types of nuclear installations.

In implementing its programme, CNRA establishes co-operative mechanisms with NEA's Committee on the Safety of Nuclear Installations (CSNI), responsible for co-ordinating the activities of the Agency concerning the technical aspects of design, construction and operation of nuclear installations insofar as they affect the safety of such installations. It also co-operates with NEA's Committee on Radiation Protection and Public Health (CRPPH) and NEA's Radioactive Waste Management Committee (RWMC) on matters of common interest.

ABSTRACT

At its annual meeting in June 1999, the Committee on Nuclear Regulatory Activities (CNRA) agreed to hold a Special Issue Meeting in June 2000 on the topic of "Life Extension and Upgrading". This report includes the synthesis of the responses received from Member countries and the results and conclusions of the CNRA discussions. The detailed responses from Member countries are contained in the report NEA/CNRA/R(2001)2.

FOREWORD

Following the recommendations made in the report on Future Nuclear Regulatory Challenges, CNRA Members agreed to set Life Extension and Upgrading as the topic for the 2000 Special Issues meeting. Many of the factors and issues discussed in the report draw attention to the need for regulators to address requests by licensees for plant life extension. As noted in the publication, "For plant life extensions, analysis must show that the plant will continue to operate within its design basis". Corresponding regulatory challenges listed in the report included:

- To have an adequate knowledge of the current design basis of the plant,
- To have a correct picture of the actual state of the plant, and
- To define the analysis needed to support life extensions and demonstrate that the plant will still operate within its design basis.

An organising committee was set-up to prepare for the meeting. Relevant information was collected through a questionnaire and the responses were analysed and presented at the meeting to initiate the CNRA discussions. In discussing the special issues topic, Life Extension and Upgrading, the organising committee reflected on how to define the terms, 'life extension' and 'upgrading'. The differences in terminology used both nationally and culturally make this a difficult task. A general consensus was obtained on using the following terms to identify the issues, although they should not be considered as definitions:

- Life Extension: Where applicable, continuous operation maintaining an acceptable level of safety of a facility beyond an established licensed term or period established by a safety evaluation. It was noted by members of the committee that the term life extension was not used widely, the term long term operation is more commonly utilised.
- Upgrading: Applying measures to enhance the safety level of the plant.

The members of the organising committee, who developed the questionnaire and were involved in compiling the synthesis of the national responses, were: Xavier Bravo, DSIN, France; Len Creswell, NII, United Kingdom; Rudolf Gortz, BfS, Germany; Lars Gunsell, SKI, Sweden; Masakuni Koyama, JAPEIC, Japan; Pao-Tsin Kuo and Robert Prato, NRC, United States; Pekka Salminen, STUK, Finland; and Andras Toth, HAEA, Hungary. The project was managed by B. Kaufer, NEA. The group wishes to acknowledge Dr. S. A. Harbison who as an expert consultant provided the technical analysis provided throughout the report and the synthesis of the national responses to the questionnaire contained in the appendix to this report.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION

At its annual meeting in June 1999, the Committee on Nuclear Regulatory Activities (CNRA) agreed to hold a Special Issue Meeting in June 2000 on the topic of "Life Extension and Upgrading". A Working Group made up of staff from the Member Countries and members of the Secretariat was established to undertake the necessary work in support of the Special Issue Meeting. The Working Group developed and issued a Questionnaire that was used to gather information from the Member Countries; this information was analysed and synthesised with the help of a consultant, Dr. S. A. Harbison and forms the basis of this Report. CNRA Members discussed the Report, in draft form, at the Special Issues Meeting and the Conclusions and Recommendations reflect the outcome of those discussions.

In the Introduction to the Report the scope and objectives of the special issue are discussed, followed by a review of the Questionnaire approach. After that there is a discussion of how the concepts of "life extension" and "upgrading" are viewed by different Member States. The Report then focuses on four main topics:

- Legislative and regulatory aspects
- Key technical issues
- Key management issues
- The use of deterministic and probabilistic methods in safety evaluation

In the sections of the Report devoted to these topics, the experiences of respondents are summarised, similarities and differences noted, and any general conclusions stated.

Issues for the future are noted in Chapter 7 and the Conclusions and Recommendations of the CNRA discussions are listed in Chapter 8.

LIFE EXTENSION AND UPGRADING

Life extension and upgrading are not the same thing: "upgrading" means "applying measures to enhance the safety level of the plant" and, as such, may take place at any point in the life of the plant while "life extension" implies "continuous operation maintaining an acceptable level of safety beyond an established licensed term or period established by a safety evaluation". Essentially all respondents made the point that it is a fundamental condition of any nuclear plant licence that the licensee should carry out a continuous review of safety and respond to any changes in the state-of-the-art in science and technology that have safety implications by upgrading the plant or its operating/maintenance procedures as necessary. On the other hand, when a regulator is asked to approve or grant a life extension, the opportunity is commonly taken to review the entire design basis of the plant and decide what safety improvements the operator might reasonably be expected to make. One exception is the license renewal process used in the U.S. The U.S. license renewal process focuses its review on detrimental effects of ageing and will not re-review a plant's current licensing basis. The difference between "life extension" and "upgrading" points up the difficult regulatory issue of deciding on the correct balance between maintaining and improving safety.

The responses to the Questionnaire showed that backfitting of modern requirements to older NPPs is generally only required to the extent that is reasonably practicable, though the test of what is “reasonably practicable” appears to be particularly stringent at the time of a periodic safety review (PSR) when an integral safety assessment is made and especially when operators are seeking a substantial life extension. However, the licence renewal process in the USA does not require backfitting to modern standards per se, though the USNRC expects all US nuclear plants to comply with its full regulatory regime, including generic safety issues.

LEGISLATIVE AND REGULATORY ASPECTS

In most countries it is a basic requirement of the general atomic law, together with relevant supporting legislation and regulations, 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. Some countries also have legal requirements that refer to maintaining the plant in line with the “state-of-the-art” in science and technology. These requirements provoke regulatory assessments and utility action to upgrade as appropriate.

Some countries issue fixed-term licences for some or all of their nuclear plants (USA, Mexico, Finland and Switzerland). Other countries that don’t have fixed term licences generally control long-term operation by means of continuous monitoring of operational performance plus comprehensive periodic safety reviews (PSRs), usually every ten years. The objectives of these PSRs may be summarised 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 rules and regulations in judging the acceptability of a licence renewal application or a PSR. Generally the responsibility for developing such rules and regulations is delegated to the Regulatory Authority, though there is an increasing tendency in most countries to involve the operating utilities and other stakeholders in the process. In some countries the regulatory rules are more or less mandatory while, in others, they simply indicate approaches or standards that are acceptable to the regulator. In such situations licensees are allowed the flexibility to propose alternative solutions to safety issues provided that they will achieve an equal or better level of safety to that which would result from applying the regulatory guidance.

New regulatory rules are not generally expected to apply retrospectively, in their totality, to existing plants. Most countries require licensees to assess the impact of any new rule on 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 rule. Such modifications have to be shown to be reasonably practicable in terms of the safety gains to be achieved and the costs of making the improvements. Though quantitative techniques such as cost - benefit analysis are often used to inform such decisions, the ultimate decision making process is generally based on pragmatic, deterministic criteria.

Apart from a few high-level safety goals, no country has a comprehensive suite of technical criteria for deciding when the continued operation of an NPP is no longer permitted. The fundamental regulatory criterion for continued operation is that the licensee should maintain the licensing basis of the plant throughout its life. If the plant goes outside its licensing basis, and the licensee can't take appropriate corrective actions, then it is normally required to shut down. However, to date most of the decisions to shut down older plants have been taken by the operators on the basis of financial considerations rather than safety. In some countries (such as the Netherlands, Sweden and Germany) decisions to shut down older plants and phase out nuclear power have been taken by governments as the result of adverse public perception of the industry.

KEY TECHNICAL ISSUES

PSRs give important insights into the key technical issues associated with upgrading and long-term operation that may be grouped conveniently under the following headings:

a) correcting deficiencies in the original design
b) correcting deficiencies in the original construction
c) dealing with ageing of materials and components
d) dealing with obsolescent components and procedures
e) applying modern requirements (as far as reasonably practicable)
f) other technical issues related to public perception

The detailed technical issues identified in the responses to the Questionnaire clearly depend on the design of the nuclear power plants concerned but the Working Group noted a growing awareness in most countries of the importance of accurate predictions of life-limiting ageing effects in safety-related structures and components.

KEY MANAGEMENT ISSUES

A number of respondents remarked on the major changes that have taken place, or are taking place in the electricity supply markets in their countries. In some countries the re-structuring and privatisation of nuclear generating companies have been accompanied by decisions not to build any new nuclear plants, at least for the time being. Under these circumstances there is considerable pressure on the operator's Safety Culture and management of safety. Some of the resulting issues are common to all NPPs, irrespective of their age, though the problems tend to be more critical for older plants. Some of the key management issues that relate specifically to older NPPs include:

- The role that the regulator should play in helping to ensure there is a continuing supply of competent personnel to operate and maintain older plants where the design details, technical limits etc. may be less well documented than for modern ones.
- The steps the regulator needs to take to ensure that economic pressures are not allowed to compromise the long-term maintenance of materials, components, infrastructures or processes on ageing NPPs.
- The steps the regulator needs to take to ensure that the facilities make proper plans to anticipate the possible replacement of major components subject to ageing degradation.
- Taking appropriate regulatory action, as required by national laws and policies, to ensure that the licensees make adequate financial provisions for decommissioning, dismantling and disposing of the waste from ageing NPPs.

Respondents also noted the importance of the regulator's own management systems and ways of working in the more commercially orientated environments that now existed for nuclear power in many countries.

THE USE OF DETERMINISTIC AND PROBABILISTIC METHODS IN SAFETY EVALUATION

In all countries the regulation of NPPs is still largely based on deterministic engineering criteria and methods with probabilistic safety assessment (PSA) as a complimentary tool. In PSRs and licence renewals, regulators expect the operators to make robust deterministic cases, based on a realistic evaluation of design basis events and likely normal and abnormal operating conditions using conservative assumptions. In addition, however, there is a growing awareness of the importance of plant-specific PSAs that incorporate relevant operating experience feedback. With the growing interest in risk-informed regulations the importance of PSA, as a formal regulatory tool, seems likely to increase. However, most regulators seem unwilling to accept that PSA arguments alone should be sufficient to reverse any licensing decision taken on deterministic, engineering grounds. This may become increasingly contentious as licensees strive to make arguments, on the basis of probabilistic assessments and time-at-risk, about what it is reasonably practicable for them to do by way of up-grading older plants.

ISSUES FOR THE FUTURE

The main issues that respondents identified as likely to be important in the future for upgrading and long-term operation fall into three general categories:

- Organisation and management issues, especially in the increasingly difficult environment for nuclear power.
- Technical issues, particularly those associated with ageing and the incorporation of new technologies.
- The role of PSA in risk-informed regulation and the strategies needed to ensure that it is properly integrated with the traditional deterministic approach.

1. INTRODUCTION

Following the recommendations made in the report on Future Nuclear Regulatory Challenges, CNRA Members agreed to set Life Extension and Upgrading as the topic for the 2000 Special Issues Meeting. An organising committee was appointed to prepare for the meeting.

1.1 Scope and Objectives

Many of the factors and issues discussed in the above Report draw attention to the need for regulators to address requests by licensees for plant life extension. As noted in the publication, “For plant life extensions, analysis must show that the plant will continue to operate within its design basis”. The consequential regulatory challenges include the need:

- to have an adequate knowledge of the current design basis of the plant;
- to have a correct picture of the actual state of the plant; and
- to define the analysis needed to support life extensions and demonstrate that the plant will still operate within its design basis.

In discussing the special issues topic, Life Extension and Upgrading, the Committee reflected on the meaning of the terms “life extension” and “upgrading”. Differences in the terminology used, both nationally and internationally, make any definitions difficult but the Committee reached a general consensus on using the following terms to identify the issues:

- Life Extension: Where applicable, continuous operation maintaining an acceptable level of safety of a facility beyond an established licensed term or period established by a safety evaluation.
- Upgrading: Applying measures to enhance the safety level of the plant.

It should be noted that the above are not to be considered as definitions. Members of the Committee also noted that the term “life extension” was not used widely, the term “long term operation” being more commonly utilised.

1.2 Approach

Current information and views on life extension and upgrading were obtained from the regulators by means of a questionnaire. The ten questions on the questionnaire were:

1. Describe the key elements of your legislation (i.e. rules and regulations) relevant to upgrading and continued long-term operation.
2. Do you have a term licence (licences for a fixed period)? If yes, how long and what is the legal basis?

3. If you have a limited term licence, can it be extended and what are the criteria? If you do not have limited term licences, what are the relevant regulatory measures in place to control long-term operation (i.e. periodic reviews, limitations on long-term operation)?

4. Do you perform a periodic evaluation of overall plant design? If yes, describe what is included; if no, how do you justify long-term operation?

5. How do you develop and update your rules and regulations (i.e. standards, requirements, etc.)? How do you apply these on existing plants? What criteria are used to evaluate and/or justify the current level of safety in comparison to modern safety standards?

6. Are there any specific regulatory criteria where continued operation would not be allowed? Identify any additional criteria (i.e. considered financial, public perception).

7. Describe what are the key technical issues related to upgrading and long-term operation you are addressing or plan to address.

8. Describe what key management issues you are addressing (i.e. organisation, economic deregulation, maintaining competence, use of subcontractors, etc.) to justify long-term operation.

9. Describe how you apply deterministic and probabilistic methods in your evaluation.

10. Identify additional regulatory issues or concerns that you believe need to be performed (either within your country or internationally) but are not yet actively planned for upgrading and long-term operation.

In response to the questionnaire, reports were eventually received from fourteen regulators. The reports were discussed at a meeting of the Organising Committee in April 2000, which led to certain adjustments and clarifications. Further adjustments were made in finalising this report.

1.3 Reporting

The work of the Organising Committee has resulted in the following reports:

- This report, providing a summary of the findings of the Committee. It is aimed primarily at initiating the CNRA discussions.

- National responses, forming the basis of the information summarised in this report. The reports received from Belgium, Canada, Czech Republic, Finland, France, Germany, Hungary, Japan, Mexico, Netherlands, Spain, Sweden, Switzerland, UK and USA are contained in a separate CNRA report [NEA/CNRA/R(2000)2].

- A synthesis of the information contained in the national reports, in order to facilitate overview, which is provided as an Appendix in this report

This report attempts to deal with the issue of Life Extension and Upgrading in general terms so it does not cover specific national programmes or achievements. These can be found in the compilation of the national responses to the questionnaire.

The CNRA would also like to draw attention to the report "The Periodic Safety Review of Nuclear Power Plants - Practices in OECD Countries"(1992), which resulted from a decision taken at its first meeting in

1989. Much of the information contained in that Report is still valid, including the observation in the Conclusions that “The countries that have already performed PSRs, or intend to do so, generally regard them as overall reviews of the safety status of plants, in addition to, but not as a substitute for, ongoing surveillance and review”. The relationship between PSRs and the normal, ongoing regulation of NPPs is discussed later. The two most noticeable changes that appear to have occurred in PSRs in the decade since the above Report was compiled are: the increased attention to ageing of systems and components, and the very significant attention that is now given to safety culture and management issues.

A recent NEA report entitled “Status Report on Nuclear Power Plant Life Management” (NEA/SEN/NDC(2000)6) provides a comprehensive summary of the current status of industry programmes and government policies for nuclear power plant life management in OECD Member countries. It provides much useful information to complement the discussions in the present report.

2. THE CONCEPTS OF LIFE EXTENSION AND UPGRADING

It is clearly important to recognise that "life extension" and "upgrading" are not the same thing although they may present themselves to the regulator as complementary issues in certain, rather special circumstances. The term "upgrading" is taken to mean, "applying measures to enhance the safety level of the plant" and, as such, may take place at any point in the life of a plant. Essentially all respondents made the point that it is a fundamental condition of any licence for a nuclear plant that the licensee should carry out a continuous review of safety and respond to any changes in the state-of-the-art in science or technology which have safety implications. The regulator has the responsibility to monitor and regulate the licensee's activities to ensure that this ongoing responsibility is met.

"Life extension", on the other hand, implies "continuous operation maintaining an acceptable level of safety beyond an established licensed term or period established by a safety evaluation". When a regulator is asked to approve or grant a life extension of a plant, the opportunity is commonly taken to review the entire design basis of the plant and decide what safety improvements the operator might reasonably be expected to make in the light of modern safety requirements and the state-of-the-art in science and technology. The extension period requested (2, 5, 10 or 20 years), the operating history of the plant, the ageing and in-service inspection histories of important safety-related components, the currently acceptable levels of risk and the degree of certainty about the long-term performance of safety components are all important considerations in deciding what is "reasonable" in this context. In addition, public perception, political pressures and the structure of the electricity supply market may have a major impact on decisions about life extensions and the extent of the safety upgrades that may be required as a prerequisite for such extensions.

The difference between "life extension" and "upgrading" also points up the difficult issue that faces all regulators, namely the balance to be struck between maintaining safety and improving safety. This is demonstrated most clearly in the responses to the question about the criteria used to evaluate and/or justify the current level of safety in comparison to modern safety standards. By and large, backfitting of modern requirements to older NPPs is only required to the extent that is reasonably practicable, though the test of what is "reasonably practicable" appears to be particularly stringent when operators are seeking a substantial life extension (perhaps for a further 10 years). However, the licence renewal process in the USA (defined by 10 CFR Part 54 and 10 CFR Part 51) does not require backfitting of modern standards per se, though the USNRC expects all US nuclear plants to comply with its full regulatory regime, including generic issues. The US licence renewal process applies essentially to passive, long-lived components and is intended to give assurance that such components will be capable of giving satisfactory service for a further 20 years. The continued satisfactory performance of active components is controlled by the routine regulatory process. PSRs, on the other hand, seem to be viewed, in most of the countries that use them, as comprehensive, integral assessments of safety that complement the normal regulatory process. They allow the operator and regulator to carry out a searching review of the operating, inspection and maintenance history of the plant and ensure that all the records are complete and up-to-date. In addition:

- they give the regulator the opportunity to ensure that the operator has a comprehensive programme for resolving all outstanding safety issues; and

- they allow the operator and the regulator to take a long-term, strategic overview of which safety improvements are likely to be cost-effective in the context of a possible further 10 years of operation.

3. LEGISLATIVE AND REGULATORY ASPECTS

3.1 Legislation and regulatory approaches

In most countries it is a basic requirement of the general atomic law, together with supporting legislation and regulations, that the licensees (operators) should carry out a continuous review of the safety of their plants and make whatever safety upgrades are necessary, on a timely basis. It is normally the responsibility of the operators, under the terms of their operating licences, to propose the safety upgrades that they deem to be reasonably practicable, taking account of various factors, including the safety standards that would be applied to new nuclear plants. The regulatory authority then assesses the licensee's proposals, which are often contained in a safety case for the item of plant or procedure concerned, and reaches a decision about their adequacy or otherwise. When the regulatory authority is satisfied that the proposal is acceptable and the best that is reasonably practicable (or fulfils the requirements of a specific Rule or other requirement), formal approval is given for the licensee to proceed with the upgrade. In most countries there is an increasing awareness, on the part of both the licensees and the regulatory authority, of the need for adequate quality systems to ensure that all safety upgrades are properly recorded and their impacts on the overall safety case of the plant assessed. Some countries (such as Switzerland) have legal requirements that refer to maintaining the plant in line with the "state-of-the-art" in science and technology. These requirements provoke regulatory assessments and utility action to upgrade as appropriate. Generally, existing plants have to be upgraded to the extent reasonably practicable.

In most countries the requirement for comprehensive safety review as a prerequisite for continued long-term operation is found within the operating licence of the plant, either in the licence itself or in one of the attached conditions. In Hungary it is contained in a Government Decree and in Sweden, in SKI Regulations. All countries, apart from Canada, Japan and the USA, perform a periodic evaluation of the overall plant design, usually every ten years, for continued long-term operation or formal licence renewal (as in Finland). In Canada, long-term operation is based on periodic review and update of the safety analysis (about every three years), taking account of the utility's operating experience, improved analytical techniques and new research findings. The licensee is also required to follow a formal configuration control process for existing plant designs. The use of ten-year periodic reviews (PSRs) is currently the subject of discussions between AECB and Canadian utilities.

In Japan, long-term operation is based on periodic inspections of safety-critical components every 13 months and PSRs about every 10 years, which are mainly concentrated on the ageing behaviour of the plant.

In the USA, long-term operation is based on the continued adequacy of the regulatory process, based on 10 CFR regulations, and maintenance of the plant-specific licensing basis during the term of any licence renewal. US operating licences are limited to a fixed term of forty years. Any renewed licence will also be issued for a fixed period, not to exceed twenty years beyond the expiry of the forty-year period. Licensing renewal will be carried out in terms of 10 CFR Part 54, which requires the licensee to demonstrate how ageing effects will be managed safely, and 10 CFR Part 51, which deals with environmental requirements.

Some other countries have term licenses, including Mexico, Finland and Switzerland (for two of its plants). In Mexico, the operating licences have been issued for 30 years and it is likely that any future license renewals will be consistent with 10 CFR 54. The term licences for the two Swiss plants (Beznau Unit 2 and Muhleberg) were issued because of uncertainties about ECCS performance at the time they were licensed. They could be extended on the basis of a Safety Evaluation Report; other Swiss plants do not have term licences. Finland has various term licences (ranging from 5 – 20 years), reflecting the Nuclear Energy Act requirement that operating licences should only be granted for a fixed period. They can be extended in accordance with criteria presented in nuclear legislation and decisions issued by the Council of State. Though Canada is not strictly regarded as having “term” licences, the operating licences for Canadian plants are granted for two years and renewed every two years. Renewal is granted in accordance with AEC Regulations, provided AECB is satisfied that the risk to health, safety and the environment has remained within the original design basis.

The other countries do not have term licences though it is understood that, following its decision to phase out nuclear power, the German Federal Government plans to amend the Atomic Energy Law by basically confining the operating period to 32 years.

As mentioned above, countries that don't have limited term licences generally control long-term operation by means of continuous monitoring of operational performance plus comprehensive periodic reviews, usually every 10 years. The objectives of these PSRs may be summarised as follows:

- to show that the plant is as safe as originally designed,
- to show that it will still be safe for the next 10 years, and
- to compare it against the most recent safety standards and determine which safety improvements are reasonably practicable.

Generally, it addresses most of the topics covered in the Final Safety Analysis Report (FSAR), using state-of-the-art codes, operational performance information and the latest information on component performance and ageing. Most regulators also expect the licensee to provide a full comparison with modern safety requirements and give a justification for continued operation, including plant modifications or improvements that are reasonably practicable on safety grounds. Probabilistic safety assessment (PSA) is incorporated into many PSRs as a complementary tool to the deterministic analyses that still form the fundamental basis for most regulatory decisions concerning long-term operation (see section 6).

3.2 Developing and updating rules and regulations

In most countries the Regulatory Authority is delegated the authority, either explicitly or implicitly, to develop rules or regulations in support of the statutory licensing function that it carries out. There is an increasing tendency in most countries to involve the operating utilities and other stakeholders in the development of such rules and regulations. Some countries (such as Germany with respect to the KTA nuclear safety standards and Hungary) consider whether their rules and regulations need to be updated on a five-yearly basis but most countries make updating decisions on the basis of operating experience and changes in the state-of-the-art in science and technology.

The USNRC has always sought comments from industry and the public as part of its rule-making process, in order to ensure that all questions about reasonably practicability are explored and settled before the Rule is made. Strict compliance with the Rule is then expected though there is normally a feedback mechanism to identify any unforeseen issues that may require the Rule to be modified or expanded. Thus the licence renewal rule (10 CFR 54) was first issued in December 1991 and reissued in May 1995 on the basis of comments and operating experience. Countries (such as Belgium and Mexico) which make use of USNRC rules, as well as other international rules, update their rules in line with the US rule-making situation.

In some countries the regulatory rules are more-or-less mandatory while, in others, they simply indicate approaches or standards that are acceptable to the regulator (and are often thought of as regulatory guidance). In such countries (e.g. Canada and the UK) the licensees use the regulatory guidance to develop their own design and/or operating documents which are then incorporated into binding licence conditions. Licensees are allowed the flexibility to propose alternative solutions to safety issues but they have to show that they will achieve an equal or better level of safety to that which would result from applying the regulatory guidance. In other words, questions about reasonable practicability are settled on a case-by-case basis between the regulator and the operator, taking account of a number of factors including the detailed design of the plant in question.

3.3 Backfitting new rules to existing plants

Few, if any, countries require a new rule to be applied retrospectively, in its totality, to existing plants. Generally licensees are expected to assess the impact of the rule on their 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 rule. In some countries the regulator takes the lead in assessing the impact of new rules on existing plants. Either way, most regulators accept that the safety improvements to existing plants should be those that are reasonably practicable in terms of the safety gains to be achieved and the costs of making the improvements. Though quantitative techniques such as cost – benefit analysis are often used to inform such decisions, the ultimate decision – making process is generally based on pragmatic, deterministic criteria.

Many countries take the opportunities of PSRs to carry out a thorough evaluation of the extent to which existing plants conform to modern standards. Generally, the acceptability of any deviations of existing plants from modern standards is judged by the regulator on a pragmatic, case-by-case basis and few countries have specific criteria for evaluating and/or justifying the current level of safety in comparison to such modern safety standards. In the UK, the NII's Safety Assessment Principles (SAPs) contain a number of numerical limits (BSLs) and objectives (BSOs) which guide the assessors but, as these are meant for new plants, the assessor still has to exercise judgement in deciding how close an older plant has to come to the appropriate BSO in order to be considered acceptable. Generally, it seems that in most countries the most severe tests of acceptability are applied to any systems or procedures that have a direct impact on accident prevention or mitigation. In a few countries (such as the Netherlands, Switzerland and the UK) risk-informed decision making is taken into account for such systems, sometimes with specific numerical criteria of acceptability (Netherlands, core damage frequency > 10-4/ year not permissible; UK, basic safety limits for core degradation and large radioactive releases must not be exceeded).

3.4 Specific criteria that prevent continued operation

In all countries the fundamental regulatory criterion for continued operation is that the licensee should maintain the licensing basis of the plant throughout its life. If the plant goes outside its licensing basis, and the licensee can't take appropriate corrective actions, then regulators are generally delegated the authority to require it to shut down. In some countries this would be done by legal orders issued by the appropriate Government authorities.

A few countries (such as Switzerland) have the additional, explicit requirement that nuclear plants should conform to the state-of-the-art in science and technology. This is also implicit in the regulatory approach of many other countries. Such a criterion is potentially very onerous and the extent to which it is reasonably practicable for older plants to meet it is a difficult judgement for the regulatory authorities.

Apart from these two general requirements, few countries have comprehensive, technical criteria for deciding when continued operation would not be allowed, though some have top-level safety goals that have to be met. In the Netherlands there are maximum allowable risk criteria, for individuals and groups as the result of potential accidents, which must be met in order for a nuclear plant to continue to operate. Similarly, the basic safety limits (BSLs) in the UK NII's Safety Assessment Principles (SAPs) are not allowed to be exceeded – otherwise the plant must shut down. Sweden has recently issued a general Regulation which defines certain classes of events (e.g. exceeding permissible limits, degradation of physical barriers, damage to primary system boundary, damage to reactor containment, management deficiency) where continued operation is not allowed until necessary measures have been taken by the licensee and approved by the inspectors. Similar classes of events appear in the NII's SAPs. Generally, however, the criteria that are applied for continued operation are deterministic ones, particularly those related to the ageing behaviour of important safety-related components.

To date most of the decisions to shut down older plants have been taken by the operators on the basis of financial considerations. In some instances it was simply that the plant was no longer economically viable while, in others, the costs of the safety upgrades required by the regulators were so great that they outweighed the potential future earnings of the plant. Public perception and pressures on Governments in some countries (such as the Netherlands, Germany and Sweden) have led to decisions to shut down older plants and phase out nuclear power. There are a range of considerations which contribute to such decisions including the ready availability of alternative sources of energy which are perceived to be cheaper, safer (particularly with regard to possible major accidents) and/or to have fewer long-term environmental problems (such as waste disposal).

In some other countries, which have not decided to phase out nuclear power, there is, nevertheless, a reluctance to allow older plants to continue to operate beyond the licensing term or period that was justified in the initial safety evaluation without the most strenuous efforts being made to upgrade the plant to modern standards. Governments and regulators are well aware of the public's perception that there is no reason to allow older, less safe plants to continue to operate when modern, safer plants are available. Part of the challenge to the operator is to show what the level of safety of older plants actually is, especially for those plants that were designed and licensed before the era of probabilistic safety assessment (PSA). PSAs are increasingly being required by regulators when PSRs are being carried out, in order to provide evidence about the significant contributors to the risk from the plant. This is complementary to the deterministic approaches that still underpin most licensing decisions. A fuller discussion of the roles of probabilistic and deterministic safety evaluations is given in Section 6.

4. KEY TECHNICAL ISSUES

4.1 General

Those countries that require PSRs use the results of the PSRs to give insights into the key technical issues related to upgrading and long-term operation. Similarly, countries with term licences use the licence renewal process for the same purpose. In both situations, the comprehensive safety evaluation that is carried out helps the operator and the regulator to identify both the current technical safety issues of importance and also those that are likely to arise (or get worse) in the time before the next periodic review (often ten years later). The importance of early identification of safety issues is well understood and the major up-grading programmes that usually accompany PSRs or licence renewals are convenient times for the operator to take preventive action to pre-empt forthcoming safety issues e.g. those related to ageing degradation or obsolescence of components.

In those countries, such as the Czech Republic, which operate WWER plants the identification of safety issues is based on safety studies conducted by the operators and by organisations dealing with those reactors, on safety missions (generally organised by the IAEA) and on information provided at various IAEA meetings. In addition, of course, all countries use on-going operating experience, national and international advances in science and technology, reports of unusual events, etc., to help define key technical issues.

The key technical issues that countries are addressing or plan to address can be divided up as follows:

1. Correcting deficiencies in the original design
2. Dealing with the ageing of materials and components
3. Dealing with obsolescent components and procedures
4. Applying modern requirements (as far as reasonably practicable)
5. Other technical issues related to public perception.

While such a division helps to clarify the reasons why different technical issues are being pursued, it is clearly not unique and a number of the issues relate to more than one of the headings.

4.2 Correcting deficiencies in the original design

With the inexorable advance of science and technology it is inevitable that any engineering plant, including nuclear power plants, will rapidly become out of date. On nuclear power plants the out of date features may be considered under three headings:

- Those that have no impact on the safety performance of the plant, either because they relate solely to its economics or because they are a matter of “fashion”.

- Those that have a modest impact on safety performance, which includes most of the on-going plant modifications and replacements that the regulator deals with day by day, often on the basis of an agreed safety classification scheme.

- Those deficiencies that have potential major significance for the safety performance of the plant and which are sometimes only identified by applying costly, modern techniques (such as PSA) at the time of a major safety review, such as a PSR or re-licensing review.

The key technical issues that relate to the latter category include:

- Problems with the layout of certain older plants (poor segregation of electrical and mechanical equipment leading to an increased potential for common-cause failures).

- The inability of some parts of the plant to meet the single failure criterion.

- The susceptibility of the plant to external events (such as earthquakes, high winds, floods etc.) and internal events (such as fire, pipe breaks, steam generator toppling etc.).

- Problems with the structural integrity of the buildings themselves (e.g. differential settling of the building).

- Lack of adequate redundancy and diversity of components and systems, and of facilities such as main and emergency control rooms.

- Inadequate systems for shutting down the reactor, cooling the core and removing decay heat.

- Inadequacy of the primary and/or secondary containment, including isolation systems, leak-tightness and hydrogen control.

- Spent fuel handling and storage systems.

- Waste management systems.

- Deficiencies in the reactor shielding systems.

4.3 Dealing with ageing of materials and components

The physical and mechanical properties of most materials and components change with age and these changes are often exacerbated by environmental factors such as heat, stress, humidity and radiation. Reactor operators and regulators have developed methods for identifying, testing and modelling the ageing mechanisms that affect materials and components important to the safety of nuclear power plants. The rate or deterioration of NPP systems and components due to ageing is kept under continuous review by the operators and is a major part of the routine inspection programmes of the regulatory authorities. Periodic outages for maintenance are used to take samples and make necessary repairs and/or replacements. In addition, however, at the time of a PSR or a license renewal the utility is normally required to carry out more extensive analyses to predict the cumulative effect of ageing on components and structures over the next period (which may range from ten to thirty years). The results of such analyses allow the utility and regulatory authority to determine which components and/or systems may be subject to life-limiting ageing effects during the next period and to decide which repairs or replacements are necessary as a consequence.

Some of the key technical issues addressed by ageing analyses carried out at the time of PSRs and license renewals include:

- The credit that can be given for existing programmes (such as in-service inspection programmes) with respect to ageing management.

- How to show that the results of ageing analysis for the first operating period (say forty years) are applicable for a further period (up to twenty years).

- The ageing of non-replaceable components (core vessel and containment building).

- The development by the operator, of replaceability studies to anticipate life-limiting ageing problems.

- The ageing of major auxiliary components such as refuelling machines and cranes.

- The validation of ageing models for extrapolation over a considerable number of years, particularly for the core vessel and primary circuit components (adequacy of knowledge about crack initiation and growth in different types of steel and weld materials).

- Accurate prediction of thermal and mechanical loads for normal and abnormal operation over the extended period.

- Predicting the ageing of electrical components especially cables.

- The possibility of enhanced embrittlement of major components or welds (e.g. RPV core zone weld) after annealing to alleviate the effects of ageing.

4.4 Dealing with obsolescent components and procedures

The rapid changes seen in instrumentation and technology over the past few decades mean that some systems and components have rapidly become obsolete. This is particularly true of instrumentation and control (I&C) systems where the extremely rapid development of computer based, digital systems has rendered many of the older, analogue I&C systems obsolete. The operator and regulatory authority are faced with a number of issues related to the replacement of obsolete I&C equipment including:

- The timing of such replacements i.e. should they be carried out piecemeal or as major one-off activities?
- Assessing the reliability of the system (either as a completely new, computer-based system or a mixed digital and analogue system).
- Ensuring that the new system is properly reflected in the safety case and operating procedures of the plant, and in the training of operating and maintenance personnel.

Another general area of obsolescence which regulators expect utilities to look at closely, at the time of PSRs and license renewals, relates to out-of-date operating and maintenance procedures. Major safety reviews provide the opportunity for updating such procedures in the light of operating experience, changed maintenance and inspection practices, insights from living PSAs, etc. Such updating is, of course, in addition to the continuous updating that is required by the regulatory authority as part of the licensing process.

4.5 Applying modern requirements

In all countries the basic licensing requirement for any plant is that it should continue to meet all the conditions that applied when it was first licensed. Beyond that, it is generally expected that older plants should conform to modern safety requirements to the extent that is reasonably practicable. Routinely, compliance with modern standards is assessed during routine and periodic inspections and the operators are required to justify deviations or take remedial actions. More specifically, PSRs and licence renewals provide major opportunities for assessing the extent of non-compliance with modern requirements. However, there is a general recognition that the backfitting of newer safety requirements should only be required to the extent that is reasonably practicable, taking account of the potential safety gains and costs involved.

Some of the key technical issues for older plants that have been identified from applying modern standards are:

- Improved systems to predict and deal with severe accidents, including severe accident management.
- Increased demand on verification and control of safety system operability.
- Increased importance of PSA, including plant-specific PSAs for directing and optimising pre-service, in-service and post-service inspections, and periodic inspections.
- Operator actions following DBAs and severe accidents.
- Implications of current radiation protection requirements, especially concerning hazard and risk assessments, and ALARA policy.
- Re-qualification of I&C equipment under accident conditions.
- Analysis of containment threats, leading to requirements for hydrogen control in the primary containments of certain water reactors.
- Isolation and leak-tightness of primary and secondary containments.
- Accident analysis to take account of operational experience and to cover both power and shutdown modes.
- Implications of state-of-the-art research information and computer modelling for existing DBA transients, core and coolant behaviour, and systems for controlling and mitigating the consequences of both DBAs and severe accidents.

4.6 Other technical issues related to public perception

It is generally accepted that public and political perceptions of the nuclear industry should not feature directly or explicitly in the day-to-day regulation of NPPs though they do feature prominently in some countries during hearings into new siting proposals, licence applications and licence renewals, etc. However, in one or two key areas such perceptions do have a direct influence on the regulator's approach and are increasingly being factored into licensing requirements.

Three specific technical areas are:

- The development and application of risk-related criteria (such as the NII's BSLs and BSOs) where public perception is factored into the levels of tolerability and acceptability used, and the determination of what is reasonably practicable.

- The current situation in various countries with regards to alternative decommissioning and waste management strategies for older NPPs.

- Decisions, or sometimes lack of decisions, about the treatment of spent fuel and the treatment, handling and storage/disposal of radioactive waste.

5. KEY MANAGEMENT ISSUES

5.1 Issues

In a number of countries major changes have taken place, or are taking place in the electricity supply markets that are having significant effects on the management of NPPs. In some countries the restructuring and privatisation of nuclear generating companies has been accompanied by decisions not to build any new nuclear plants, at least for the time being. Under these circumstances there is considerable pressure to extend the lives of the existing nuclear plants as far as possible, always provided their operational safety and economics remain satisfactory. In a competitive energy market all generators, including nuclear generators, are under constant pressure to cut their costs, especially those that are not “sunk” (e.g. staff costs, training, research, maintenance). This can lead to a number of issues for the regulator related to the operator's Safety Culture and Management of Safety. Many of these are common to all NPPs, irrespective of their age, though the problems tend to be more critical for older plants. Attention is drawn to two important NEA Reports on “The Role of the Nuclear Regulator in Promoting and Evaluating Safety Culture” and “Regulatory Response Strategies for Safety Culture Problems”, which discuss the issues in general terms.

Some of the most important **general management issues** are:

- How to go about assessing the “safety culture” of nuclear utilities in order to be satisfied that it is being maintained at the required high level.

- How to recognise and deal with a management that is giving inadequate attention to safety before there is an unacceptable decline in the operating and maintenance standards.

- How to exert a proper regulatory influence over the organisational structure and staffing levels of nuclear utilities without interfering with their managerial and commercial independence.

- How to assess the impact on safety of the use of contractors for various purposes on NPPs.

The key management issues that relate specifically to **older NPPs** include:

- The role that the regulator should have in helping to ensure there is a continuing supply of competent personnel to operate and maintain all NPPs, particularly older ones where the design details, technical limits, etc., may be less well documented than for modern ones.

- Ensuring that economic pressures are not allowed to compromise the long-term maintenance of materials, components, infrastructures or processes on ageing NPPs.

- Ensuring that utilities make proper plans to anticipate the possible replacement of major components subject to ageing degradation.

- Taking appropriate steps, as required by national laws and policies, to ensure that the licensees make adequate financial provisions for decommissioning, dismantling and disposing of the waste from ageing NPPs.

Some of the above management issues are of less immediate importance in those countries that have either decided to shut down their nuclear generating stations or to retain the traditional structure of their generating industries.

Finally, there are three general management issues that relate to the **Regulatory Authority** itself:

- The need to maintain the competence, independence and economic standing of the regulatory body so that it can be a trusted point of reference in a rapidly changing scene.

- The need for the regulator to formulate and publish the criteria against which decisions about continued operation and/or upgrading will be made.

- The importance of the regulatory body employing appropriate quality systems, in line with current international standards, in order to ensure the effectiveness, efficiency and audibility of all regulatory actions.

6. THE USE OF DETERMINISTIC AND PROBABILISTIC METHODS IN SAFETY EVALUATION

6.1 Deterministic and probabilistic approach

In all countries the regulation of nuclear power plants is largely based on deterministic engineering criteria and methods, with probabilistic safety assessment (PSA) as a complementary tool. In PSRs and licence renewals, deterministic methods are used to provide continued assurance of the safety of critical systems, structures and components. Generally regulators expect the operators to make a robust deterministic case, based on a realistic evaluation of design basis events and likely normal and abnormal operating conditions using conservative assumptions. Deterministic analysis is also often expected for beyond design basis events (using best estimate values) to determine the likely consequences and to assist in the development of accident management strategies.

Though defence-in-depth remains the basic safety philosophy there is a growing awareness of the importance of operating experience feedback and its incorporation into plant-specific PSAs. Such PSAs can be used to:

- Check that the risk profile of the plant is uniform, with no extreme contributors, and that the overall risk is as low as reasonably practicable.
- Identify plant vulnerabilities and assess balance of safety concept.
- Rate different risk contributors and assist in prioritising up-grading measures.
- Evaluate the effect of proposed plant or procedural modifications.
- Provide a base line for re-evaluating the allowed outage times in Tech Specs.
- Minimise the risk associated with on-line preventative maintenance.
- Help define the optimum strategies for in-service inspection and testing.
- Help identify structures and components where vulnerability to ageing may be critical and develop appropriate management strategies.
- Assist in the cost-benefit evaluation of proposed new Rules.
- Assist with cost-benefit evaluation of the extent of implementation of existing Rules.

With the increasing interest, in many countries, in risk-informed regulations the importance of PSA, as a formal regulatory tool, seems likely to increase. In some countries it is already formally integrated into the licensing process though there still seems to be a need to develop rules and procedures for combining deterministic and probabilistic analyses. However, most regulators seem unwilling to accept that PSA arguments alone should be sufficient to reverse any licensing decision taken on deterministic, engineering grounds. This may become increasingly contentious as licensees strive to make arguments, on the basis of probabilistic assessments and time-at-risk, about what it is reasonably practicable for them to do by way of up-grading older plants.

7. ISSUES FOR THE FUTURE

The main issues that appear likely to be important in the future for up-grading and long-term operation fall under three general headings:

Organisational and management issues

These will include:

- the negative impacts of deregulation, privatisation and “stagnation” on the safety cultures of nuclear operators;
- the rapid run-down of nuclear knowledge and experience in some countries at least;
- the problems faced by inspectors in attempting to detect early indications of potential failures in safety culture or safety management.

Technical issues

These will include in particular:

- the ageing of structures and components and the strategies for ageing management;
- the incorporation of new technologies (hardware and software).

The increased use of PSA

The role of PSA in risk-informed regulatory approaches and the strategies that will be needed to ensure that it is properly integrated with the traditional deterministic approach.

8. CONCLUSIONS AND RECCOMMENDATIONS

The following conclusions and recommendations have been drawn from the discussions at the CNRA Special Issues Meeting on 20 June 2000.

- The fifteen national responses to the Questionnaire (NEA/CNRA/R(2000)x) provide a valuable snapshot of the legislative background and regulatory/industrial rationale that underlies current activities related to life extension and upgrading in NEA Member States.

- The Synthesis of the responses to the Questionnaire (see Appendix) gives clear insights into the similarities and differences of approach within NEA Member States and helps to identify a number of general issues about life extension and upgrading that regulators need to consider.

- CNRA re-iterated the conclusion of the 1992 Report that PSRs are generally to be regarded as overall reviews of the safety status of plants, in addition to, but not as a substitute for ongoing surveillance and review. They allow regulators and operators to stand back and take a view of the overall safety situation.

- Members recognised the wide diversity of legal requirements, industrial situations and regulatory approaches reflected in the responses of Member States to the Questionnaire. They, therefore, agreed that it would be impossible to identify a “standardised” approach to life extension and upgrading. Instead they emphasised the importance of concentrating on the safety outcome achieved by the overall legal/regulatory system in each country - and the extent to which the overall levels of safety achieved within NEA Member States can be considered to be in harmony. At a qualitative level, Members felt that this was probably the case and they recognised that the peer reviews required by the Nuclear Safety Convention should provide support for this judgement. However, a number of Members felt that it might be appropriate for CNRA to consider whether more quantitative studies might be carried out to provide further support. Such studies might consider:

  1. the total safety assurance system in different countries (including the contribution from licensees' self-assessment);
  2. the important variables in each such safety assurance system; and
  3. the extent to which it can be demonstrated that appropriate combined use of such variables gives the desired safety outcome.

- Members considered that the existence or otherwise of a “term” licence is largely a legal/administrative matter rather than a safety one. Some countries that don't have legally-stipulated licensing terms nevertheless regard the periodic statutory shutdowns and restarts of NPPs as equivalent to de facto term licences. Whether the licensing term is fixed or indefinite, regulators still rely fundamentally on routine surveillance and review to give continued assurance that the plant continues to operate within its licensing basis. However, there is a need for regulatory clarity about the safety standards that NPPs have to meet in order to achieve a renewal of their licence or to be allowed to re-start after a statutory shutdown or a PSR.

- One of the most difficult questions facing regulators at the time of life extension or upgrading is "how safe is safe enough?". There is no unique answer to this question; it may well be different at different times and in different locations and is ultimately for society to determine. However, regulators have to interpret what society requires by means of technically-based regulations that licensees must meet. Members agreed that, for operating NPPs, the fundamental requirement is to maintain the safety of the plant at the level on which it was granted its initial licence but safety improvements should be carried out where they are reasonably practicable or where changes in the state-of-the-art in engineering or science require it.

- Decisions about reasonable practicability are generally made on a pragmatic basis, taking account of national and international operating experience; the most up-to-date information on the science/engineering aspects of the safety issues; and the likely costs of alternative strategies for dealing with it. Regulators are keenly aware of uncertainties that still exist in several of the inputs to formal cost/benefit analyses (particularly the evaluation of potential health detriments) and so are generally reluctant to rely on CBA as the sole determinant of decisions about reasonable practicability. However, comparative CBA is recognised as a valuable tool for highlighting the advantages and disadvantages of different possible approaches to resolving safety issues.

- Members agreed that it was helpful to divide the key technical issues associated with life extension and upgrading into the following six categories:

  1. correcting deficiencies in the original design of the plant
  2. correcting deficiencies in the original construction of the plant
  3. dealing with the ageing of materials and components
  4. dealing with obsolescent components and procedures
  5. applying modern requirements (as far as reasonably practicable)
  6. other technical issues related to public perception

  Several Members reported that licensees had identified significant safety issues arising from inspections to determine whether the original construction of the plant was in conformity with its licensing design basis.

- The rapidly-changing economic and industrial environments in many countries over the past few years had presented major challenges to both the nuclear operators and the regulators. In the privatised and deregulated situations that now existed (or were coming into being) in many countries, the operators were acutely aware of the potential lifetimes and long-term profitability of their plants when making decisions about upgrading, undertaking PSRs or applying for formal licence renewals. Plant management was under increasing pressure to find the correct balance between operating the plant safely and not spending money unnecessarily. The regulatory challenge was to find appropriate ways to check and monitor this without interfering unduly in the licensee's business. The impact of safety culture, safety management, and the competence and level of staffing on the safety of NPPs will continue to demand considerable regulatory attention.

- Another challenge to regulators, in the new environment, is to find a logical way to deal with requests from operators for relief from some of the existing regulatory constraints. This is a sensitive regulatory issue that can easily generate public and political suspicion, if not handled openly and properly. However, a selected increase in the apparent level of risk may be acceptable by some regulators if research or operating experience allow the uncertainty in the risk assessment to be reduced, to the extent that the realistic safety margins are still sufficient to cover the remaining uncertainty. The increasing use, and wider acceptability of, risk-informed regulations may help to clarify such decision-making. [It is recommended that CNRA should have an in-depth exchange of experience on this topic at a future meeting].

- Finally, Members recognised that electricity deregulation and the changing social/economic climate for nuclear power have presented many challenges to the regulators' standards and ways of working over the past few years. The challenges were particularly evident when decisions had to be taken about the upgrading and life extension of older NPPs. It was, therefore, imperative for regulators to look closely at their own business processes, to ensure that they were effective and efficient, and as open, fair and unbiased as possible. Members noted that these aspects would be investigated as part of their current discussions on Regulatory Effectiveness.

APPENDIX - SYNTHESIS OF RESPONSES TO QUESTIONNAIRE

Q1: Describe the key elements of your legislation (i.e., rules and regulations) relevant to upgrading and continued long-term operation

General atomic law, plus supporting legislation and regulations

It is a requirement in all countries with commercial nuclear power plants (NPPs) that such plants be licensed. Though the form and duration of nuclear licences varies from country to country, they all stress the fundamental responsibility for safety of the operator. They also require the operator to meet all the licence conditions and to review the safety of the plant on a continuous basis. This continuous safety review is monitored by the regulatory authority, and the operator is required to upgrade the plant when safety deficiencies or necessary improvements are identified.

- **Operating licence**

Some countries (such as the USA, Finland and Mexico) issue operating licences for a fixed period of time, at the end of which the licensee has to apply for a licence renewal or shut down the plant permanently. The licensing renewal process requires the operating utility and the regulatory authority to review the plant's operating experience to date and decide what replacements, upgrades or ageing management programmes are necessary to ensure that it can continue to operate safely for the period to be covered by the renewal. In the USA the process is defined in 10 CFR Part 54 and 10 CFR Part 51 and Mexico has indicated that it is likely to follow this Regulation as well when the Laguna Verde licence comes up for renewal.

Most other countries issue operating licences that are essentially indefinite, subject to the continued safe operation of the plant. However, there is often a regulatory requirement that the operator should shut down each NPP every second or third year for a statutory maintenance/inspection outage. At the end of such outages the operator must obtain the formal approval of the regulatory authority before re-starting the plant, though this is not generally considered to be the same as having a “term” licence. However, it is becoming increasingly common for regulators to require additional Periodic Safety Reviews (PSRs) of nuclear plants after a defined period of operation (often 10 years). The legal requirement for such PSRs is sometimes found in the Operating Licence (e.g. Belgium, Mexico, Spain and the Netherlands) or in a Condition attached to the Licence (UK). In a number of other cases, however, it is simply requested or imposed by the Regulatory Authority as part of its normal regulation of the plant, though it may be based on a specific regulation, such as the SKI Regulation in Sweden.

- **Other legislation**

Following the German Government's decision to phase out nuclear power, plans are being drawn up to amend the Atomic Energy Law by basically confining the operating period to 32 years. The Canadian AECB has started to develop a regulatory position on requirements for the management of ageing and new regulatory documents to define requirements for PSA as related to the management of ageing. Some countries (e.g. Switzerland) have legal requirements that refer to the need for NPPs to comply with the "state-of-the-art" in science and technology. This provokes regulatory assessment and appropriate utility actions to upgrade existing plants to the extent that is reasonably practicable. Other countries (e.g. Germany) have followed a policy to bring the safety level of the plants closer to modern standards by backfitting (see NEA Report on "Regulatory Aspects of Ageing Reactors").

Q2: Do you have a term licence (licences for a fixed period)? If yes, how long and what is the legal basis?

Although several countries (such as Canada and the UK) require licensees to obtain formal approval to re-start their plants after annual, biannual or triennial statutory outages, this is considered to be part of the normal regulatory control process and not the same as having a "term" licence. Term licences are considered to be those that are granted for a significant number of years (usually at least 5) and whose renewal involves a major reassessment of the entire safety case for the plant - and sometimes, as in the USA, a new round of public consultation.

YES:

USA (operating licences limited to a fixed term of forty years; any renewed licence will also be issued for a fixed period not to exceed twenty years beyond the expiry of the forty year period. The legal basis is the Atomic Energy Act (1954) and 10CFR 54).

Switzerland (for historical reasons related to ECCS issues the Beznau unit 2 has a term licence until 2004 and Muhleberg until 2012).

Mexico (the operating licence is issued for a period of thirty years and the legal basis is the operating licence itself).

Finland (the operating licences were initially for five years then ten and are now twenty for the Olkiluoto NPP. The legal basis is the Nuclear Energy Act).

NO:

UK, Sweden, Belgium, the Netherlands, France, Hungary and Spain.

Switzerland (for Beznau Unit 1, Gosgen and Leibstadt)

Germany (but the Federal Government plans to amend the Atomic Energy Act to confine the residual operation of the existing NPPs and to interdict the construction of new ones).

Japan (but NPPs are subject to periodic inspections every thirteen months).

Canada (the operating licence is granted for a period of two years and renewed every two years subject to satisfactory safety performance. The legal basis is contained in AEC Regulations).

Q3: If you have a limited term licence, can it be extended and what are the criteria? If you do not have limited term licences, what are the relevant regulatory measures in place to control long-term operation (i.e. periodic reviews, limitations on long-term operation)?

Countries with limited term licences

Finland (Yes: the criteria for licence extension were presented in nuclear legislation and decisions issued by the Council of State. Basically the same criteria apply to life extension as to new plants but, where an old plant can't meet the latest design requirements, the safety significance of deviations is assessed both deterministically and probabilistically and compensatory measures taken).

Mexico (Yes: criteria have not yet been established but are likely to follow the USNRC approach of 10CFR 54).

Switzerland (Yes: the relevant measures are based on the Safety Evaluation Report though there are no formal criteria for judging the SER).

USA (Yes: the technical requirements are set out in 10CFR 54, plus the environmental requirements set out in 10CFR 51).

Countries without term licences

Belgium (long-term operation is controlled by continuous operational monitoring plus periodic safety reviews (PSRs) every ten years).

Germany (control is achieved by continuous monitoring of performance, with complementary PSRs about every ten years. So far PSRs have been carried out on a voluntary basis but the government plans to amend the Atomic Energy Act to make them obligatory).

Hungary (Government Decree requires "nuclear safety inspections", essentially PSRs, every ten years of operation).

Japan (continued operation depends on passing periodical inspections (including the integrity of plant equipment) every thirteen months).

Netherlands (licence conditions require periodic reviews every ten years).

Sweden (control is achieved by review of operating experience and PSRs).

Switzerland (control is achieved by review of operating experience and PSRs).

UK (control is achieved by review of operating experience and PSRs).

France (at the regulator's discretion, operators are asked to perform in-depth safety assessment. In the past this has been on a ten year basis but could be different on a case by case basis).

Spain (control is achieved by continuous operational monitoring plus PSRs every ten years, which are the main basis for renewing the operating permits)

Canada (the licence can be extended provided AECB is satisfied that the risk to health, safety and the environment stays within the original licensing basis - shown by continuous monitoring of operating performance and compliance with safety/licensing requirements).

Q4: Do you perform a periodic evaluation of overall plant design? If yes, describe what is included, if no, how do you justify long-term operation?

Although many countries have introduced PSRs, there is considerable divergence in the extent of the documentation and other information that has to be supplied by the operators in different countries. There are also differences in the extent to which the regulatory authority carries out an independent evaluation of the safety case for prolonged operation. However, there is general agreement that PSRs are intended to provide a kind of integral evaluation of the safety of the plant, as part of its general regulation.

YES:

For countries that perform periodic evaluations the list of issues that are covered includes:

- Re-validation of the original design justification (often in the FSAR), with implementation of improvements in accordance with the principle of “reasonable practicability”.
- Systematic evaluation of plant and all safety-related structures and components against modern standards, again to identify any safety improvements that must be made and those which should be considered in terms of “reasonably practicability”.
- Review of past plant performance and evaluation of safety improvement measures carried out.
- Review of the results of other, relevant PSRs and of safety topics included in the licensing of recent NPPs.
- All relevant unresolved or generic safety issues.
- The implications of state-of-the-art research and knowledge in science and technology.
- Plant-specific PSAs and their relationship to the traditional deterministic methods applied to the plant.
- Review of the effects of ageing on safety-related structures and components and assessment of the validity of models for predicting future behaviour.
- Safety management and safety culture issues (a relatively recent issue).

NO:

Those countries that don't perform a periodic evaluation of overall plant design (USA, Canada and Spain) base their decisions about long-term operation on:

- The continued adequacy of the regulatory process (which they expect to pick up many of the above issues, on an on-going basis) and the maintenance of the plant-specific licensing basis of the plant.

- If formal licence renewal is required, as by 10 CFR 54, the licensee is required to demonstrate how ageing effects will be managed safely.

- In Canada, long-term operation is based on periodic review and update of the safety analysis, about every three years, taking account of the utility's operating experience, improved analytical techniques and new research findings. Licensee is also required to follow a formal configuration control process for existing plant designs. (10-year PSRs are currently being discussed between AECB and utilities).

- In Spain a special review and updating of the design bases was initiated in 1997 for all Spanish NPPs, with the intent of having in place reliable mechanisms for keeping up-to-date the design basis information and FSAR. This review is expected to be completed in 2000 for all the plants.

Q5: How do you develop and update your rules and regulations? How do you apply these to existing plants? What criteria are used to evaluate and/or justify the current level of safety in comparison to modern safety standards?

Development and updating of rules and regulations.

In most countries the Regulatory Authority is authorised, under the terms of national legislation (such as the AEC Act in Canada, the HSE/NII Acts in the UK, the Atomic Energy Act in the USA, etc.) to develop and update rules and regulations related to nuclear safety. In some countries (such as Hungary) they are issued as attachments to Government legislation or decrees.

The extent to which such rules are mandatory varies from country to country, and within individual countries. Those countries that expect strict compliance with regulatory rules and regulations (such as the USA) tend to have a very extensive consultative process before making any such rule or regulation. By involving all stakeholders, including the utilities and the public, in formulating the detailed requirements, the regulatory authority expects that all questions about what is reasonably practicable will be explored and settled before the rule is made. Strict compliance with the rule is then expected though there is normally a feedback mechanism to identify any unforeseen issues that may require the rule to be modified or expanded. In other countries (such as Canada and the UK), the regulator issues fewer mandatory rules. In those countries, the regulatory approach is to give general guidance about the level of safety to be achieved and then leave it up to the operator to propose the optimum safety solution for the particular plant in question. This usually leads to a debate between the regulator and the operator about what is reasonably practicable. Traditionally there has been less involvement of stakeholders (such as the public and utilities) in these countries in formulating the regulatory rules, though this appears to be changing.

Whatever approach is adopted, it is clearly necessary to keep detailed records of all compliance decisions and the reasons for any non-compliance, together with the regulatory actions taken. This helps to provide a baseline for deciding when updates are necessary (AECB, for example, has made modifications to the basic single/dual failure safety analysis requirements to reflect Canadian experience in applying this approach - in Consultative Document C-6).

In addition to considering the feed-back from operating experience and advances in technology or improvements in safety studies, a number of regulators also apply a formal review process to their rules and regulations (generally about every 5 - 10 years) to determine what, if any, updating is necessary. This is a growing trend that reflects the growing appreciation by regulators of the value of adopting Quality Management Systems.

Safety of operating plants assessed in the light of updated rules and regulations

The fundamental requirement on all nuclear licensees is that they should maintain the safety case on which the plant was licensed throughout its operational lifetime. Generally this means that regulators do not require updated rules to be applied in their entirety to existing plants. Unless the discrepancies are shown to be unacceptable in terms of risk or violate acceptable levels of safety, the older NPPs need only satisfy the updated rules to the extent that is reasonably practicable, taking account of the costs and safety gains that are achievable. Decisions about the backfitting of newer safety standards can be taken at any time in the life of a plant but are considered most closely at the time of PSRs or licence renewals. In the case of the USA, backfitting of any new rules or regulations to existing operating plants is subject to the backfitting rule, 10 CFR 50.109. However, for licence renewal, the requirements for ageing management of structures and components are not subject to the backfitting rule. Such comprehensive safety evaluations give the operator and regulator the opportunity to reassess the extent of previous backfitting activities, which may have been quite major. Decisions about the reasonable practicability of safety improvements are still taken largely on deterministic grounds, though PSA is increasingly used as a complementary tool. Regulators are conscious of the need to avoid unnecessary ratchetting of safety standards on older NPPs, which could occur as a direct consequence of applying modern safety requirements. Whilst it is accepted that many older NPPs are operated and maintained to standards that are more conservative than the rules and regulations strictly require, regulators are generally unwilling to accept any arguments from the operators that safety levels might be relaxed. However, such arguments are likely to be pressed more vigorously in the future as utilities are faced with ever more stringent economic pressures and NPPs enter their last few years of life.

Criteria used to evaluate and/or justify current level of safety in comparison to modern safety standards

Few countries have specific criteria to evaluate and/or justify the current safety level of older plants. Generally, the regulators make pragmatic judgements on a deterministic basis, assisted by the insights from PSAs. In some countries (such as France and Germany) the regulator's judgements are taken in many cases after formal consultations with expert groups that support them.

Several countries are moving towards applying risk-informed criteria to older plants. This implies the availability of a plant-specific PSA to help evaluate the plant's risk profile as well as numerical acceptability criteria for such older plants. The UK NII's Safety Assessment Principles, for instance, contain Basic Safety Limits (BSLs) of acceptability which no UK NPP is allowed to exceed, plus Basic Safety Objectives (BSOs) which give guidance on the level of safety that can be regarded as fully acceptable. However, the regulator still has to decide how close the older plant must come to the relevant BSO in order to be considered acceptable - which is still essentially a pragmatic decision. A further difficulty for the regulator is that many of the most important decisions about the safety of older plants involve ageing phenomena that are not easily quantifiable in risk assessment, and so the decisions have, necessarily, to be taken in a deterministic way.

It is understood that, in the USA, all future generic safety issue resolutions will have to apply to a 60-year operating period as well as to the normal 40-year period.

Q6: Are there any specific regulatory criteria where continued operation would not be allowed? Identify any other additional criteria (i.e. considered financial, public perception).

Specific criteria to cause shutdown

The basic regulatory criterion applied by all regulators is that licensees must maintain the licensing basis of any NPP throughout its life. If, at any time, the regulator decides that this is no longer the case, and the licensee is unable or unwilling to correct the situation, then the licence can be withdrawn, either temporarily or permanently. Such regulatory decisions are made on a largely deterministic basis though PSAs are increasingly being used to complement the deterministic decision-making. Some countries, such as Switzerland, also require licensees to demonstrate that their NPPs are in compliance with the state-of-the-art in science and technology.

Although no regulatory authority has defined a fully comprehensive set of technical criteria for deciding when continued operation of a nuclear plant is no longer allowed, some have devised some high-level ones. For instance, a few countries have defined quantitative criteria that are not allowed to be exceeded, such as the Basic Safety Limits (BSLs) in the UK NII's Safety Assessment Principles and the probabilistic radiation acceptance criteria and maximum allowable risk criteria (for individuals and groups as the result of accidents) in the Netherlands. Also, a Swedish Regulation (SKIFS 1998) defines certain classes of events where continued operation is not allowed until necessary measures have been taken. These appear similar to some of the engineering criteria in the NII's SAPs. To date, however, it is clear that most decisions to shut down older NPPs have been taken on the basis of deterministic criteria, or for financial or public policy reasons.

Additional criteria that could cause shutdown

Financial considerations clearly affect both the straightforward commercial viability of any NPP and decisions about when it is no longer reasonably practicable to make the required safety upgrades to meet the regulator's requirements. For example, Yankee Rowe in the USA and a number of the older Magnox reactors in the UK were shutdown because the licensees did not consider it economical to upgrade them to meet the regulatory requirements. For the licensees, such decisions are a mixture of normal commercial considerations and the costs, and likely benefits of safety improvements. Regulators are primarily concerned about the latter aspect and in many countries appropriate use is made of cost-benefit analyses, though CBA seems never to be the sole determinant of licensing decisions. Decisions to shutdown individual NPPs, or indeed entire nuclear programmes, can be taken at Governmental level for political reasons or in response to adverse public perception (e.g. in Germany, the Netherlands and Sweden). Generally this is outside the purview of the regulatory authority though HSE/NII consider that public perception is built into the levels of acceptability in the Tolerability of Risk document (ToR) - and hence into the BSLs and BSOs that are based on ToR.

Q7: Describe what are the key technical issues related to upgrading and long-term operation you are addressing or plan to address.

All countries use the results of on-going operational experience, national and international advances in science and technology, and reports of unusual events to help define key technical issues. In addition, those countries that have PSRs use them to identify and consolidate the list of key technical issues; countries with periodic licence renewals use them in much the same way.

The following is a convenient, though not unique, system for classifying key technical issues:

- Correcting deficiencies in the original design
- Dealing with the ageing of materials and components
- Dealing with obsolescent components and procedures
- Applying modern requirements
- Other technical issues related to public perception

Correcting deficiencies in the original design

Some of the key technical issues are:

- Layout problems, such as poor segregation of electrical and mechanical equipment leading to an increased potential for common-cause failures.
- Inability of some parts of the plant to meet the single failure criterion
- Susceptibility of plant to external events (such as earthquakes, high winds, floods, etc.) and internal events (such as fire, pipe breaks, S/G toppling).
- Problems with the structural integrity of the buildings themselves (e.g. differential settling of the buildings).
- Lack of adequate redundancy and diversity of components and systems, and of facilities such as main and emergency control rooms.
- Inadequate systems for shutting down the reactor, cooling the core and removing decayed heat.
- Inadequacy of primary and/or secondary containment, including isolation systems, leak tightness, hydrogen control.
- Spent fuel handling and storage systems.
- Waste management systems.
- Deficiencies in the reactor shielding systems.

Dealing with ageing of materials and components

Some of the keys ageing issues are:

- The credit that can be given for existing programmes (such as in-service inspection programmes) with respect to ageing management.
- How to show that the results of ageing analyses for the first operating period (say forty years) are applicable for a further period (10 - 20 years).
- The ageing of non-replaceable components (core vessel and containment building).

- The development, by the operator, of replacability studies to anticipate life-limiting ageing problems.
- The ageing of major auxiliary components such as refuelling machines and cranes.
- Validation of ageing models for extrapolation over a considerable number of years, particularly for the core vessel and primary circuit components.
- Accurate predictions of thermal and mechanical loads for normal and abnormal operation over the extended period.
- Predicting the ageing of electrical components, especially cables.
- Possible enhanced embrittlement after annealing major components or welds to alleviate the effects of ageing.

Dealing with obsolescent components and procedures

The issues here relate mainly to replacing obsolete I&C systems and include:

- The timing of such replacements i.e. should it be carried out piecemeal or as a major, one-off activity?
- Assessing the reliability of the system (either a completely new computer based system of a mixed digital and analogue system).
- Ensuring that the new system is properly reflected in the safety case and operating procedures of the plant, and in the training of operating and maintenance personnel.

Another general area of obsolescence which regulators give close attention to, at the time of PSRs and licence renewals, concerns out of date operating and maintenance procedures.

Applying modern requirements

Some of the key technical issues that have been identified from applying modern standards are:

- The need for improved systems for predicting and dealing with severe accidents, including severe accident management.
- The increased demand on verification and control of safety system operability.
- Increased importance of PSA, including plant specific PSAs for directing and optimising pre, in-service and post-service inspections, and periodic inspections.
- Operator actions following DBAs and severe accidents.
- Implications of current radiation protection requirements especially concerning hazard and risk assessments, and ALARA policy.
- Re-qualification of I&C equipment under accident conditions.
- Analysis of containment threats, leading to requirements for hydrogen control in the primary containment of certain water reactors.

- Isolation and leak tightness of primary and secondary containments.

- Accident analysis to take account of operational experience and to cover both power and shutdown modes.

- Implications of state of- the- art research information and computer modelling for existing DBA transients, core and coolant behaviour and systems for controlling/ mitigating the consequences of DBAs and severe accidents.

Other technical issues related to public perception

Though public perception is not seen as a regulatory criterion, there are three specific technical issues that are directly related to it:

- The application of risk-related criteria (such as the NII's BSLs and BSOs) where public perception is factored into the levels of tolerability and acceptability used, and the determination of what is reasonably practicable.

- The current situation in various countries with regard to alternative decommissioning and waste management strategies for older NPPs.

- Decisions about treatment of spent fuel and storage or disposal of waste.

Q8: Describe what key management issues you are addressing to justify long-term operation.

The key management issues depend, to some extent, on the structure of each particular country's electricity supply industry and the future of nuclear power within that structure. Many Safety Culture and Management of Safety issues are common to all NPPs, irrespective of their age, though the problems tend to be more critical for older plants. Attention is drawn to two important NEA Reports on "The Role of the Nuclear Regulator in Promoting and Evaluating Safety Culture" and "Regulatory Response Strategies for Safety Culture Problems", which discuss the issues in general terms. Some of the most important **general management issues** are:

- How to assess the safety culture of nuclear utilities in order to be satisfied that it is being maintained at the required high level. It would, of course, be expected that any utility should have in place its own systems for maintaining safety and monitoring its safety culture.

- How to exert proper regulatory influence over the organisational structure and staffing levels of nuclear utilities without interfering with their managerial and commercial independence.

- How to assess the impact on safety of the use of contractors for various purposes on NPPs (e.g. the extensive use of contractors may lead to a loss of competence within the utility.).

- How to recognise and deal with a management that is giving inadequate attention to safety before there is an unacceptable decline in the operating and maintenance standards.

The key management issues that relate specifically to **older NPPs** include:

- The role that the regulator should play in ensuring that there is a continuing supply of competent personnel to operate and maintain all NPPs, particularly older ones where the design details, technical limits, etc., may be less well documented than for modern ones.
- Ensuring that economic pressures are not allowed to compromise the long-term maintenance of materials, components, infrastructures or processes on ageing NPPs.
- Ensuring that utilities make proper plans to anticipate the possible replacement of major components subject to ageing degradation.
- Taking appropriate steps, as required by national policy and laws, to ensure that the licensees make adequate financial provisions for decommissioning, dismantling and final waste management.

Finally, there are some important management issues which relate to the **Regulatory Authority itself**, such as:

- Maintaining the competence, independence and economic standing of the regulatory body so that it can be trusted as a fixed point of reference on NPP safety.
- The need for the regulator to formulate and publish the criteria against which decisions about continued operation and/or upgrading will be made.
- The importance of the regulatory body employing appropriate quality systems that are comparable to generally-accepted international standards in order to ensure the effectiveness, efficiency and auditability of the regulatory actions.

Q9: Describe how you apply deterministic and probabilistic methods in your evaluation.

In all countries the regulation of NPPs is largely based on deterministic engineering criteria and methods, with PSA as a complementary tool. In PSRs or licence renewals, deterministic methods are used to provide assurance of the safety of critical systems, structures and components. Generally regulators expect the operators to make a robust, deterministic case, based on a realistic evaluation of design basis events and likely normal and abnormal operating conditions using conservative assumptions. Deterministic analysis is often also expected for beyond design basis events (using best estimate values) to determine the likely consequences and to assist in the development of accident management strategies.

Though defence-in-depth remains the basic safety philosophy there is a growing awareness of the importance of operating experience feedback and its incorporation into plant-specific PSAs. Such PSAs can be used to:

- Check that the risk profile of the plant is uniform and that the overall risk is as low as reasonably practicable.
- Identify plant vulnerabilities and assess balance of safety concept.
- Rate different risk contributors and assist in prioritising upgrade measures.
- Evaluate the effect of proposed plant or procedural modifications.

- Provide baseline for re-evaluating the allowed outage times in Tech Specs.
- Minimise the risk associated with on-line preventative maintenance.
- Help define the optimum strategies for in-service inspection and testing.
- Help identify structures and components where vulnerability to ageing may be critical, and develop appropriate management strategies.
- Assist in the cost-benefit evaluation of proposed new Rules.
- Assist with cost-benefit evaluation of the extent of implementation of existing Rules.

With the increased interest, in many countries, in risk-informed regulations the importance of PSA, as a formal regulatory tool, seems likely to increase. In some countries it is already formally integrated into the licensing process though there still seems to be a need to develop rules and procedures for combining deterministic and probabilistic analyses. However, most regulators seem unwilling to accept that PSA arguments alone should be sufficient to reverse any licensing decision taken on deterministic, engineering grounds. This may become increasingly contentious as licensees strive to make arguments, on the basis of probabilistic assessments and time-at-risk arguments, about what it is reasonably practicable for them to do by way of upgrading older plants.

Q10: Identify additional regulatory issues or concerns that you believe need to be performed (either within your country or internationally) but are not yet actively planned for upgrading and long-term operation.

The main issues that appear likely to be important in the future fall under three general headings: organisational and management issues; technical issues; and the increased use of PSA.

Organisational and management issues

These include:

- The negative impacts of deregulation, privatisation and general “stagnation” on the safety cultures of nuclear operators.
- The rapid rundown of nuclear knowledge and experience, in some countries at least.
- The problems for nuclear regulators to get sufficiently early indicators of potential failures in safety management and safety culture.

Technical issues

- The ageing of structures and components and the strategies for ageing management.
- The incorporation of new technologies (hardware and software).

The increased use of PSA

The role of PSA in risk-informed regulatory approaches and the strategies that will be needed to ensure that it is properly integrated with the traditional deterministic approach.