Nuclear Regulation

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Future Nuclear Regulatory Challenges

A Report by the NEA Committee on Nuclear Regulatory Activities

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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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 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 the 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 consists 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.

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NOUVEAUX DÉFIS POUR LES AUTORITÉS DE SÛRETÉ NUCLÉAIRE

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) is an international committee made up of senior representatives from nuclear regulatory bodies. It was created in 1989 to guide the NEA's programme concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It acts as a forum for the exchange of information and experience among regulatory organisations, and for the review of developments which could affect regulatory requirements.

In December 1996, the Committee came to the conclusion that changes resulting from economic deregulation and other recent developments affected nuclear power programmes and had consequences both for licensees and regulatory authorities. A number of potential problems and challenges for the coming decade were identified. The Committee decided to set up for one year a Working Party on Future Regulatory Challenges, composed of CNRA members, to consider issues which would present a challenge to nuclear regulatory bodies over the next ten years, to prepare a report that identified such challenges, and to propose recommendations to address any concerns. The group was placed under the chairmanship of Mr. C.R. Willby (United Kingdom).

The present report is the outcome of this Group's work and is published on the responsibility of the Secretary-General of the OECD. Recommendations made specifically to the CNRA are not included in the report. It is worth noting, however, that the Committee has already taken action in a number of these areas.

Foreword

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One of the major future challenges facing nuclear regulatory bodies in OECD countries over the next ten years will arise from changes in the nuclear industry as countries liberalise their electricity markets and open them to competitive global trading. This trend has already affected electricity supply industries by generating pressure to minimise the costs of production. It is the responsibility of nuclear regulatory authorities to ensure that, as the business environment changes, nuclear safety is not eroded.

Other future challenges stem from the continuing need to maintain and promote nuclear safety culture, maintain regulatory effectiveness, and, with pressure for greater openness, interface more effectively with the public, media and parliaments.

No major new challenges related to technological changes or the future expansion of nuclear power have been identified. However, some issues may arise from the regional variation in the prospects for new nuclear installations. This will reflect the difference between the newly industrialised countries, mainly in Asia, which are planning an expansion of their nuclear energy production and the developed countries of Western Europe and North America, which are planning to build very few new nuclear power plants in the foreseeable future. In Eastern Europe, challenges will continue to arise from the upgrading of the safety level of Soviet-designed reactors.

The NEA also believes that co-operation between national safety authorities, and assistance to safety authorities in countries where regulatory organisations need to be strengthened, will become increasingly important.

This report concludes that it is important to consider future challenges that may arise from: technical, socio-economic and political issues; organisational, management and human aspects; and international issues. The perceived challenges have been grouped into four categories and covered in four chapters.

Chapter 2 addresses those technical issues that may present significant new regulatory challenges in the future. These relate to various aspects of the ageing of nuclear plants: physical ageing of components and structures, ageing of analytical techniques and documentation, ageing of rules and standards, and ageing of technology. It examines briefly the potential consequences of an increase in operational flexibility, safety margins during more exacting operating modes, and backfitting and safety upgrading programmes for plants

Technical issues with potential regulatory impact:

- plant ageing;
- plant backfitting and requests for plant life extension;
- maximising output from existing reactors; and
- decommissioning plants.

Executive summary

that were designed to lower safety standards. It discusses decommissioning, as well as management, storage and disposal of radioactive waste and spent fuel. It concludes with a brief discussion of requirements for future plants.

Chapter 3 considers the external changes to the industry that will have an effect on regulators. These include privatisation and other issues arising from the deregulation of the energy and electricity markets and the consequences of increased competition. Next, demanning and contractorisation issues are considered that result from the operators' desire to minimise the cost of production. Other issues related to the commercialisation of the industry are considered under the headings of: research, managerial changes, and safety culture. The chapter concludes with a list of possible significant emerging issues that regulators may need to address.

Socio-economic and political issues with potential regulatory impact:

- economic deregulation of the electricity market;
- privatisation of national companies, mergers between utilities and restructuring of the electricity supply industries; and
- risk-informed/performance-based regulation.

Chapter 4 considers the internal changes that are affecting regulators, including organisational, managerial and human-resource issues that present significant future challenges to regulatory organisations. These are considered under the headings of: regulatory effectiveness; licensee responsibility; staff training and preserving a critical mass of knowledge; regulatory changes; and the interface between regulatory authorities and the public.

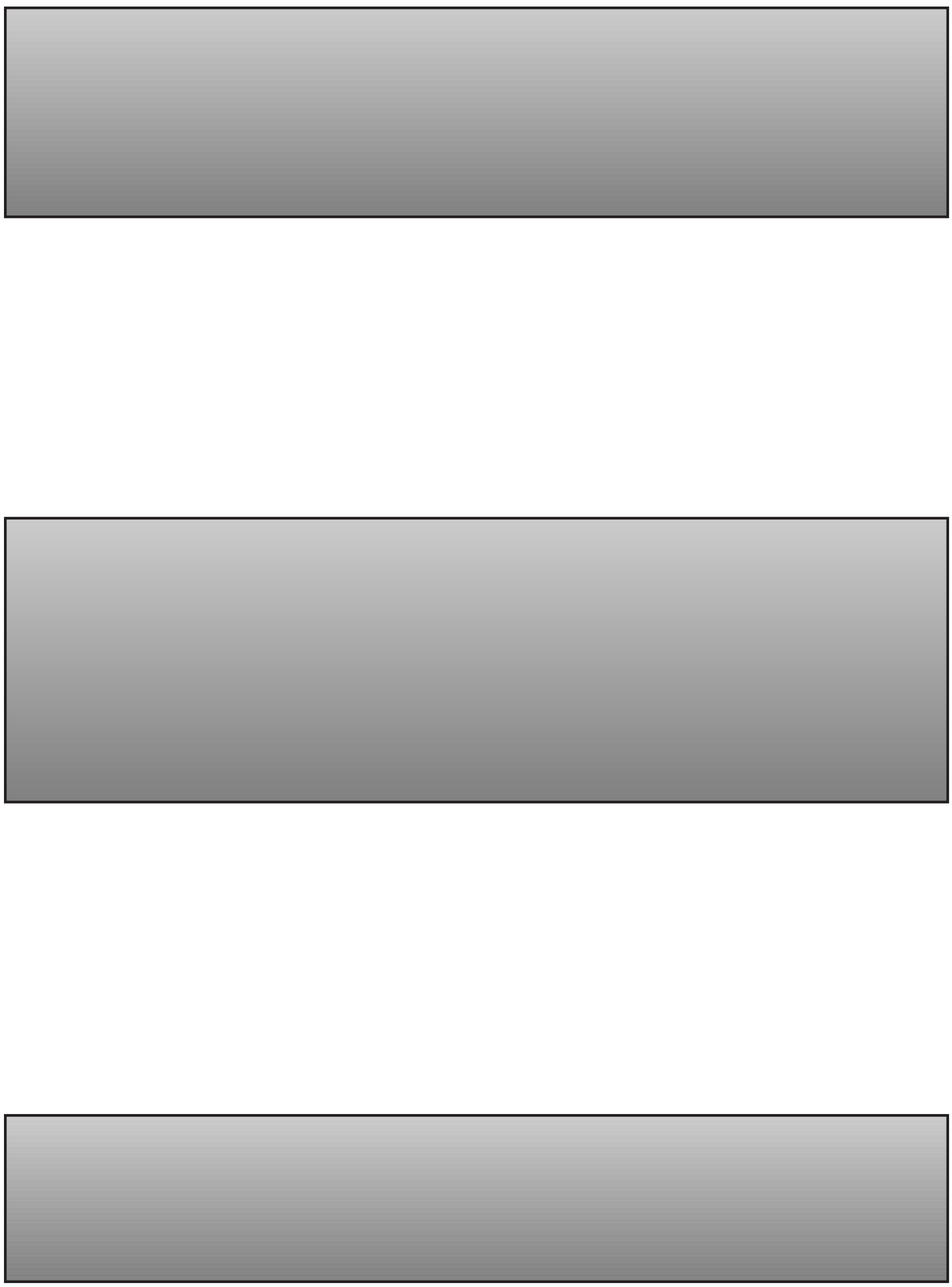
Organisational, management and human issues with potential regulatory impact:

- regulatory effectiveness;
- licensee responsibility;
- operator response and self-assessment;
- maintaining expertise; and
- the interface between regulatory authorities and the public.

Chapter 5 discusses international issues with potential regulatory impact. It stresses the international dimension of the nuclear industry, in particular that of nuclear safety. It identifies several issues where co-operation among safety authorities would be beneficial: producing common technical standards and guides, reaching consensus on technical issues, human resources within regulatory agencies, and communication with the public. It also discusses briefly

International issues with potential regulatory impact:

- development of co-operation between safety authorities; and
- co-operation with, and assistance to, safety authorities in countries where regulatory organisations need to be strengthened.



the possibility, in the framework of the CNRA, of co-operation with and assistance to safety authorities in countries where regulatory organisations need to be strengthened.

The CNRA agreed that the following major challenges had the potential to affect the majority of regulators:

- ageing – particularly of analytical techniques and documentation, and the definition of the analyses needed to support plant life extensions and the demonstration that the plant will still operate within its design basis;
- safety margins during more exacting operating modes;
- safety culture;
- regulatory effectiveness;
- licensee responsibility; and
- staff training and preserving a critical mass of knowledge.

Last, but not least, the CNRA found that the management, storage and disposal of high-level radioactive waste and spent fuel and, more generally, fuel cycle closure, are pre-requisites to the general acceptance of the continued and future use of nuclear power and therefore deserve top priority. It was recognised, however, that this area requires a cross-sectorial approach within the NEA.

Around the world, barriers to trade are being reduced and countries are developing market-driven economies with open, competitive, global trading. One effect of this is that there is pressure in some countries for reductions in the burden imposed by governments and regulators on industry so that economic efficiency, adaptability to change, competitiveness and innovation capabilities can be improved. A growing number of governments have initiated programmes to reform regulatory regimes, with a view toward reducing or eliminating regulatory impediments, streamlining formalities, and improving the quality and cost-effectiveness of regulations that remain. This trend is also seen in countries' electricity supply industries. Governments are pursuing policies of liberalisation of their energy sector as a whole and drawing back from direct involvement in the energy markets. In some countries monolithic, often state-owned, electricity companies are being broken up and separate generation, transmission and retail companies created. In some cases, this restructuring has resulted in the privatisation of profitable nuclear power stations, with the state only retaining control of older, less economic ones. It is likely that in the future there will be further changes to the structure of the industry, for example, by take-overs between utilities which may result in foreign ownership.

A result of liberalising electricity supply is that nuclear operators are having to compete with other less capital intensive generators[1], and hence need to improve performance and reduce costs to electricity consumers. In particular, the availability of cheap natural gas over the next 20 to 30 years in North America, and in European countries via pipelines from Algeria, Norway and Russia, is having an effect on the economics of the nuclear industry. However, there are large uncertainties regarding the future price and availability of natural gas and, after this period, the finite reserves of natural gas and price of production pressures from diminishing supplies could work in favour of the nuclear industry. In addition, the possible consequences of the recognition of greenhouse effects and the imposition of a carbon tax could both act to improve the future prospects for nuclear power generation.

Also, future complicated commercial considerations could have significant impacts on how nuclear stations are operated (e.g. the effects of "pool pricing", base-load or load-following operation, frequency correction, etc.). Pool pricing is used in some countries to provide a market price for bulk electricity. It is determined several times each day, e.g. each half hour, using electricity generators' bids based on the availability and source of supply (gas, nuclear or other generating capacity) within an agreed algorithm for cost minimisation. Some countries are even agreeing to open their energy markets to other countries' electricity generators. For example, the European Union is seeking to open up its Member states' electricity markets to inter-state competition.

1 Recent analysis by the IEA [IEA/SLT (98)8] points to a number of factors, notably the expectation of greatly increased OECD imports of gas, that could lead to increased uncertainties in its price. If such uncertainties persist, the strategic economic case for nuclear energy would be strengthened.

I. Introduction

A changing industry

A growing number of governments have initiated programmes to reform regulatory regimes, with a view toward reducing or eliminating regulatory impediments, streamlining formalities, and improving the quality and cost-effectiveness of regulations that remain.

The energy market this creates can make the economics of nuclear stations look relatively poor due to their high fixed costs, particularly when the uncertainties related to liabilities for decommissioning, and especially radioactive waste management and ever-increasing environmental concerns are put into the equation. In the western world, particularly in Europe and North America, it therefore looks unlikely that there will be many new nuclear power stations built in the foreseeable future. (This outlook could change if global warming became a major political and economic issue or other fuels became increasingly expensive.) Consequently, every effort will be made to maximise the lives and output of the existing nuclear stations.

Development of advanced nuclear power plant concepts is underway. A number of countries needing further nuclear power, particularly in eastern Asia, will probably install these advanced systems in the next few years. Regulatory authorities will therefore have to be prepared to license these plants when the time comes. In other countries, they will be faced with the certification of new advanced designs with a view to reaching consensus on reference systems.

Dr. S.A. Jackson, Chairman of the US Nuclear Regulatory Commission (NRC), said recently:

> *The changes associated with economic deregulation and restructuring of the electric utility industry have operational, economic, and ownership aspects that are important to the NRC... Our focus is on ensuring that, as the business environment changes, economic pressures do not erode nuclear safety. That means that nuclear electric generators must continue to maintain high safety standards, with sufficient attention and resources devoted to nuclear operations, and with decommissioning funding secure.*

Addressing the Nuclear Energy Institute's Fuel Cycle '97 Conference in Atlanta at the beginning of April 1997, she said: "What is essential is that those responsible for economic deregulation recognise the safety implications of change, and that those of you in the nuclear energy industry recognise that there are no economic shortcuts to safely operated, economically viable nuclear generation". Dr. Jackson has expressed concern about the financial condition of electric utilities and named three areas for special attention: performance assessment (financial pressures to cut costs can degrade safety), electrical grid reliability (nuclear plants are vulnerable to loss of offsite power incidents), and decommissioning funding (current rules could be rendered obsolete by business restructuring). Mr. L.J. Callan, NRC Executive Director for Operations, has also said that his biggest concern in protecting the public health and safety is the challenge of economic deregulation and all the changes it will bring about in the nuclear industry.

The Advisory Committee on Reactor Safeguards (ACRS) has warned the US Congress that research may be needed to cope with the changes brought by the financial pressure of economic deregulation of the electric power industry, but that funding for research activities has fallen by a factor of three over the last ten years.

At the end of 1996, the European Commission published a Directive promoting progressive opening of the electricity market, adding that public

Possible new regulatory challenges

service obligations in the general economic interest should be maintained. These public service characteristics are security and regularity of supply, quality and price of the service provided, equal rights of access to electricity, and environment protection.

It is not clear, though, from past and current experience with the primary energy and raw materials fields, that market forces will always automatically react positively to any demand. What will be the construction and delivery timescale delays before supply can meet demand if there is a shortfall in available capacity? What will be the incentives to install sufficient reserve capacity to meet peak demands?

Disruption to electricity supplies has not only economic impacts on production: electricity blackouts can endanger the health of workers and the public because of the total reliance on the use of electricity in modern societies. In such an environment, there will inevitably be pressures on the safe operation of nuclear power plants.

Indeed, commercial pressures and increased competition are causing all aspects of nuclear generation to be re-examined. Consider the following pressures on the industry:

- Balancing the budget and giving priority to short-term interests are now the primary tasks.
- Countries that in the past priced nuclear-generated electricity below the production cost are moving towards profitable, or at least sustainable, pricing.
- The search for savings is resulting in fewer safety upgrades being affordable, and relations between utilities and regulatory authorities may be more confrontational.
- Co-operation among utilities may diminish, as competition intensifies, though early indications are that this could be offset by the formation of co-operative agreements and alliances in some areas.
- Cost-cutting will result in staff reductions and resistance to implementing safety modifications, and perhaps also in the streamlining of training programmes.
- There will be an increasing tendency to use contractors for everyday maintenance and during outages; this could have an impact on safety as the qualification of contracting companies is sometimes insufficient.

In the UK, the privatisation of the Central Electricity Generating Board has led to massive reductions of staff, many of whom were in research posts. Many of the transmission companies created in the process are now owned by foreign companies; this situation has raised a number of new regulatory and legal issues. Elsewhere, international ownership of nuclear companies has led to the moving abroad, at least temporarily, of many of the most competent and experienced staff members. Companies are considering the financial implications of reprocessing rather than using long-term storage for their spent nuclear fuel. Different fuel management programmes are being assessed including the use of mixed-oxide fuel. Provision of funds to cover end-of-life costs is being examined to see if there is scope to reduce the future burden of decommissioning redundant plants. Regulators view these funds as a guarantee that decommissioning costs will be covered. Licensees may see this as a “cap” on liabilities, putting a limit on their ultimate financial burden. The availability of final waste repositories, and their timing, will figure strongly in the commercial decisions and balance sheets of companies.

Commercial pressures and increased competition are causing all aspects of nuclear generation to be re-examined.

All these developments will present new challenges to regulators, at a time when in several OECD Member countries the funding levels of national government programmes, both in nuclear regulation and in nuclear safety research programmes, continue to be reduced. Care is needed to ensure that it will be possible for government agencies to fulfil effectively their safety responsibilities in the new economic and regulatory environment, all the more so as sometimes the immediate interests of other parts of the government may not coincide with those of the nuclear safety authorities.

The availability of higher education courses in nuclear engineering is declining in many countries with nuclear industries. If this continues, where will future nuclear engineers receive their grounding in the subject? How will the industry and regulators continue to attract high-calibre, qualified recruits?

There are deregulation initiatives in some countries, as well as suggestions that the nuclear industry should move towards self-regulation. As a result, there are more and more pressures on regulatory bodies to examine how they work, with a view to reducing the burden on industry. The unavoidable disruptions which accompany regulatory reform have to be addressed by complementary policies and actions.

Other challenges are related to the need to maintain and promote nuclear safety culture, in particular at all levels of utility personnel, and with pressure for greater openness, to interface more effectively with the public, media and parliaments. In addition, co-operation between national safety authorities, and assistance to safety authorities in countries where regulatory organisations need to be strengthened, will become increasingly important.

The perceived challenges were multiple, ranging from technical issues to socio-economic and political issues; organisational, management and human aspects; and international issues. Aspects to be considered included:

- plant ageing (e.g. physical ageing of components and structures, including steam generators; replacement of hardware and software of computer-based systems important to safety; ageing of analytical techniques and documentation; ageing of rules and standards; ageing of technology); requests for plant life extension; backfitting of plants;
- increase of operational flexibility; maximising output from existing reactors by optimising fuel cycles and minimising outages;
- safety margins during more exacting operating modes; adoption of acceptable fuel safety margins and regulation of the use of high burn-up fuel; possible safety consequences of other increased economic pressures (e.g. power upratings);
- backfitting and safety upgrading programmes for plants designed to lower safety standards;
- decommissioning of plants (including availability of adequate funding for decommissioning);
- management, storage and disposal of high-level radioactive waste and spent fuel; and
- requirements for future plants.

All these developments will present new challenges to regulators, at a time when in several OECD Member countries the funding levels of national government programmes, both in nuclear regulation and in nuclear safety research programmes, continue to be reduced.

The issues at hand

Technical issues with potential regulatory impact:

- economic deregulation of the electricity market and change of emphasis to short-term aspects (and possible neglect of long-term considerations);
- potential consequences of the privatisation of national companies, mergers between utilities and restructuring of the electric utility industry (e.g. staff reductions with possible negative effects on operational safety, loss of technical competence as a result of rapid turnover and qualified personnel moving to other industries, contractorisation, possible threats to safety culture and reduced co-operation between utilities as a result of intensified competition, defensive attitude of utilities towards regulatory authorities, etc.);
- level and scope of safety research; independence of the regulatory body;
- managerial changes in the operation of nuclear plants;
- foreign ownership of nuclear utilities; and
- safety culture.

- regulatory effectiveness;
- adequate operator response; operator responsibility; operator self-assessment and self-regulation;
- preserving a "critical mass" of knowledge (nationally or through international collaboration) in areas where national research and development programmes are reduced to such a point that the formation of independent regulatory opinions may be in jeopardy;
- monitoring (if necessary, ensuring) the level of education and training of young nuclear staff in the face of increasing lack of interest in nuclear power in several countries; and
- interface between regulatory authorities and the public (parliaments, media).

- development of the co-operation between safety authorities; and
- co-operation with, and assistance to, safety authorities in countries where regulatory organisations need to be strengthened.

The CNRA was of the opinion that these challenges would have an impact on future regulatory activities, to be undertaken by the CNRA or other groups.

Socio-economic and political issues with potential regulatory impact:

Organisational, management and human issues with potential regulatory impact:

International issues with potential regulatory impact:

There are a number of technical issues that may present significant regulatory issues in the future. With the increasing emphasis on competition in the energy markets, technical challenges and the way they are addressed could have serious consequences for the level of profitability of a nuclear utility. This is in contrast to the past when the output from nuclear power stations had a guaranteed buyer at a stable price, and technical problems requiring large financial investment or long unscheduled outage periods to resolve them did not present the same problems. The utility would, with the agreement of the regulator, produce a programme to resolve the issues and remedy the problem, for example, by replacing old steam generators, obsolete instrumentation and control or protection systems. There was relatively little difficulty for the utility and the regulator to agree a timescale for completing such work.

In a deregulated environment where nuclear power has to compete with other forms of electricity generation the financial return on technical expenditure is less certain. This could result in delays in replacing degraded equipment until programmed outage periods. As a result, there is likely to be greater difficulty in reaching agreements between the operator and the regulator on how and when important safety work is to be undertaken. Co-operation may decrease.

There are other important technical issues relevant to the future profitability of a utility that could adversely affect safety. Such issues will clearly be of importance to regulators. Many will be linked to the operators' desire to maximise output or decrease operational and maintenance costs, or to reduce the cost of waste management and other "backend" costs. As a result, it will be important to consider the following issues in the future:

- ageing of plants and requests for plant life extension;
- increasing operational flexibility;
- maintaining adequate safety margins with respect to power upratings, higher burn-ups, mixed cores;
- backfitting and safety upgrading programmes for plants designed to lower safety standards;
- decommissioning of plants;
- management, storage and disposal of high-level radioactive waste and spent fuel; and
- requirements for future plants.

The technical issues considered in this chapter are already the subject of discussion between the licensees and their regulatory bodies, but they will become more difficult to resolve because of the liberalisation of the energy

II. Technical issues with potential regulatory impact

There is likely to be greater difficulty in reaching agreements between the operator and the regulator on how and when important safety work is to be undertaken.

markets and the consequent push for cutting costs and achieving greater competitiveness.

Ageing manifests itself under various forms:

- physical ageing of components and structures;
- ageing of analytical techniques and documentation;
- ageing of rules and standards; and
- ageing of technology.

At the design stage, the properties of materials and components are selected taking into account the anticipated lifetime of the plant, the environmental conditions (normal and accidental) and the known degradation mechanisms. Periodic inspection programmes are defined to follow the evolution during operation and to monitor the ageing process where possible (e.g. pressure vessel embrittlement, weld inspections, etc.). If components cannot be qualified for the anticipated lifetime, a shorter qualified life is defined and the components are replaced at the end of this period (batteries, elastomers, etc.).

The physical ageing of components can also take place due to degradation mechanisms unknown or not taken properly into account at the design stage. Such mechanisms can appear during operation at the plant or at other plants using similar materials, via failures, incidents, or detected during periodic tests and in-service inspection. These findings clearly underline the importance of periodic inspection programmes and of feedback of operating experience, both nationally and internationally. The information gleaned by these programmes should be reflected in the reliability data used in probabilistic safety assessment (PSA) studies.

Where ageing is detected, corrective actions must be taken in order to maintain the level of safety defined in the plant's safety case, such as repair and replacement. Examples arise from: wear, erosion, corrosion, cable degradation, steam generators problems, reactor internals in boiling water reactors, cracks in welded penetrations, swelling of boron-containing plates in spent fuel pools, etc. If quick repair or replacement cannot be done, increasing the defence in depth and mitigating the possible consequences may provide temporary solutions in order to avoid plant shutdown. In some cases procedures can be used to reverse the effects of ageing. For example, for very large components such as pressure vessels of pressurised water reactors, repair mechanisms for embrittlement have been developed, like “in-situ” annealing.

For plant life extensions, analysis must show that the plant will continue to operate within its design basis. Where a change in operation is desired there will be a need for safety analyses to cover the new operational conditions.

The corresponding regulatory challenges are thus:

- 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, through periodic tests, in-service inspection and feedback of operating

Plant ageing

Physical ageing of components and structures

Where ageing is detected, corrective actions must be taken in order to maintain the level of safety defined in the plant's safety case.

experience, in order to repair or replace aged components and maintain the design basis; and

- to define the analyses needed to support life extensions and demonstrate that the plant will still operate within its design basis.

When older plants were designed, the analytical techniques used to assess their safety were not so sophisticated as they are today: simplified assumptions and conservative values were used in predicting safety margins. A detailed assessment of these margins requires knowledge of many plant parameters which are not always available. This can be considered as the phenomenon of ageing of the documentary support. In some countries it seems there are no detailed requirements for keeping up to date the safety analysis documentary support (e.g. the Final Safety Analysis Report) when modifications were made during operation of the plant. Such sloppiness makes it difficult to know precisely what the current licensing basis is.

In many eastern European countries, the original design data are missing, the equipment qualification is incomplete or unknown, and information cannot be obtained from the original supplier.

There is also the ageing of the inspection methods used during the original construction and commissioning of the plants. Since the plants have been built, there have been significant improvements in the quality of non-destructive examination methods. These methods are now capable of detecting much smaller defects and sizing them with far greater accuracy. A diagnostic on defect growth is nearly impossible since it is difficult to determine if any defects found now have existed since the construction of the plant or not. This is because in many cases systematic data acquisition and ageing management were introduced later, if at all. Some defects found now may be unacceptable under modern codes and standards.

A great evolution in computational methods has also taken place, linked to the rapid development in recent years of computer technology: multidimensional calculations are now possible in neutronics, thermal-hydraulics, mechanics, etc. R&D programmes have also provided better knowledge of the physical phenomena involved. These new methods most often demonstrate the conservatism of the simplified methods used in the past.

Verification and validation of new methodologies and of computer codes, through benchmarking by large-scale experiments, are not always available and efforts are still needed to improve confidence in the quality of the software. The use of best-estimate methodology also implies knowledge of the uncertainties involved and mastery of the users' effect for sophisticated computer codes.

In most countries, the original safety analysis was based on deterministic rules and criteria only. Probabilistic safety analysis is now being used as a complement to the deterministic approach, in order to: discover design weaknesses; consider multiple failures whose probability and consequences can not be discounted; assess the relative importance of modifications; and optimise operational parameters like allowed outage times, periodic testing intervals, etc., and where applicable to compare the risks against regulatory criteria.

The relative weight of deterministic or probabilistic criteria in the regulatory decision process is still being debated.

Ageing of analytical techniques and documentation

When older plants were designed, the analytical techniques used to assess their safety were not so sophisticated as they are today: simplified assumptions and conservative values were used in predicting safety margins.

The main corresponding regulatory challenges are thus:

- how to ensure that complete documentation exists to describe the current plant design;
- to make sure that safety analysis is up-to-date, reflecting the actual plant in use and all modifications made to it;
- how to interpret results of advanced inspection techniques (are old defects being rediscovered or are they more recent ones) and what to do with defects unacceptable to modern standards; and
- how to use probabilistic safety analysis (PSA) to complement the original deterministic analysis.

In the sixties and early seventies the rules and standards applied to the design of nuclear power plants were mostly of a general nature. Their number and the level of detail has increased with the development of technology. The number of systems to which they are applied has also increased with time. Examples of broader implementation include physical separation or segregation criteria; diversity or redundancy; single failure criterion applied not only to engineered safety systems but also to their support systems; type and size of breaks to consider in primary and secondary circuits and in high energy lines; earthquakes and other natural phenomena; fire hazards and risks; and man-made hazards like an aircraft crash.

The notion of design basis accidents has also been extended, not only to cover the whole range of break dimensions and shapes, but also to consider breaks in more circuits (e.g. the feedwater system) or to introduce anticipated transients without scram (ATWS) scenarios.

When backfitting standards are requested by the safety authorities in some countries, the magnitude of the postulated event must be defined very precisely (intensity of the earthquake, mass and speed of the crashing aircraft, fire characteristics, etc.). The outcome of the assessment will determine if the safety of the plant can be improved and the costs involved in achieving the improvement. Alternatively, the new assessment could indicate that plant closure may be unavoidable.

Seismic issues and segregation problems are difficult to solve through improvements to existing systems. However, the addition of a completely independent dedicated system able to bring the plant to a safe shutdown condition is being adopted in several countries.

Some rules and standards should also be revisited when they have been defined and are based on experimental results of the early seventies, like the emergency core-cooling system (ECCS) criteria or the steam generator tubes plugging criteria. Their validity should be checked for the designs and materials used at the present time.

In order to better evaluate which improvements can be reasonably achieved, cost-benefit analysis has been used to various extents. It can be done using simple relationships like core damage frequency reduction versus cost. Alternatively, more refined techniques can be used based on PSA calculations using the so-called “risk informed regulation” which is at present under development. However, these techniques are only suited to address well-defined localised modifications. They are much more difficult to apply to severe accident

Ageing of rules and standards

Some rules and standards should also be revisited when they have been defined and are based on experimental results of the early seventies.

analysis and indicate what further modifications are needed to further decrease the core damage frequency.

From the above considerations, the main regulatory challenge is likely to be:

- applying current rules and standards to existing plants, deciding which criteria should be applied, hence determining the extent of backfitting necessary. The crucial decision is defining the criteria beyond which operation will no longer be allowed, and the difficulties involved in implementing such criteria; and
- checking if criteria, rules and standards developed for past technological applications remain valid for present technology.

Instrumentation and control is the best-known example of a technology where components become rapidly obsolete or are no longer available.

Analogue systems are being replaced by digital ones. But when modern software is introduced, compatibility problems may arise.

With a shrinking nuclear market in some countries, manufacturers of components qualified according to specific rules have disappeared or are no longer interested in supplying a small number of spare parts. It is thus necessary to find alternate suppliers and sometimes to adapt qualification requirements.

The potential impact of these changes on safety must be carefully assessed by the operator and by the regulatory body.

The regulatory challenges are thus:

- to qualify new technologies, like the use of specific software in safety critical applications or off-the-shelf software for less critical ones; and
- to adapt qualification requirements without impacting on safety.

There is a general tendency among nuclear power plant operators to try to increase operational flexibility by widening the operation domain. This implies reductions in the level of conservatism in safety case assumptions and extending the operational limits closer to the safety limits (for example by using higher pressure or temperature rate changes, faster load increase, etc.).

In order to reduce the fuel cycle costs, utilities are trying to increase the time of operation between refuelling outages, striving for 18 to 24 months of operation. This operational mode requires higher fuel enrichments and usually the introduction of burnable poisons to keep the characteristics of the core within the limits of the safety analysis. It is necessary for the regulatory body to review such new modes of operation and to request additional evaluations if the bounding character of previous safety analyses is not evident. Uncertainties in the calculation methods and in the behaviour of components must be duly taken into account in such a process.

Utilities also want to reduce the length of the outage period, for example, by having a first, short outage devoted only to refuelling and the next outage devoted to both refuelling and to required periodic inspections.

The lengthening of the operation period and the reduction of the outage period both have as consequences a tendency to reduce the extent of periodic

Ageing of technology

Instrumentation and control is the best-known example of a technology where components become rapidly obsolete or are no longer available.

Increasing operational flexibility

In order to reduce fuel cycle costs, utilities are trying to increase the time of operation between refuelling outages, striving for 18 to 24 months of operation.

inspections and maintenance programmes to the minimum required by the regulations. Such behaviour might induce a slow and at first undetectable degradation of the installation, e.g. when components are inspected once every three years instead of once a year.

The push to avoid unplanned outages and to keep refuelling outages as short as possible can result in:

- more tests and maintenance during power operation, resulting in higher doses to personnel and thus in contradiction with the "as low as reasonably achievable" (ALARA) principle;
- repair of defective equipment being delayed until the next long outage;
- pressure on operators to return the plant to power operation as soon as possible, and possibly preventing an in-depth, root cause analysis of an incident; and
- reducing the number of modifications and safety upgradings proposed by the operator.

The main regulatory challenge is:

- to determine when increased operational flexibility might have consequential effects detrimental to safety.

Trying to maximise outputs of the operating plants could result in changes to the main parameters of the core (like power uprating, going to much higher burn-up, use of mixed-oxide (MOX) fuel or using mixed cores). Modifications such as these require an in-depth safety analysis to evaluate the possible safety impact. The analysis must consider the new core characteristics and include an accident analysis, and review the reactor protection system setpoints. It must also assess the radiological releases in normal and accident conditions, and the capability of the systems (for example, electric power, cooling systems, alternate heat sink, etc.).

In the original design, characteristics were usually chosen with some degree of conservatism. These margins can be used to allow some power uprating without changing the assessment methodologies, but this process is limited. Utilities tend to use more realistic analyses, or to extrapolate properties of the materials into new operational ranges with no increase of corresponding uncertainty. The use of best-estimate methodologies is acceptable when it has been fully qualified on the basis of experiments, R&D results, and benchmarking the computer codes, and when it takes into account the remaining uncertainties in the data and in the models. Such a qualifying process is a lengthy one. It should be discussed with the regulatory body before being used in safety analyses in order to ensure the conservatisms still considered as necessary by the regulatory body are incorporated into the plant safety parameters.

How to combine uncertainties and choose conservative or best-estimate values in the calculations has also evolved in time, going from the addition of absolute values of uncertainties to a statistical combination of these uncertainties. This way of proceeding must be thoroughly investigated, as it makes numerous implicit assumptions, like random variables being independent. It corresponds in reality to the decrease of the conservatism of the earlier methodologies, while it is not based on a more refined knowledge of the

Safety margins during more exacting operating modes

phenomena being modelled. In this respect, the collaboration between regulatory bodies confronted by the assessment of methodologies proposed by an operator could be enhanced.

The same cautiousness must be applied when utilities want to use fuel assemblies with higher performance or higher burn-ups or switch to MOX fuel. The characteristics of such fuels must be demonstrated by a full experimental programme and a step-by-step approach must be followed, building up in-pile experience before allowing unrestricted use in nuclear power plants.

The push towards using higher performance fuel from different suppliers and the use of MOX fuel will lead to the coexistence in the same core of fuel assemblies of different designs or with different fuels. Such cores must be fully analysed to establish the compatibility of the fuel assemblies in the core. Attention will have to be given to factors like: mechanical interferences; power and hot points factors distribution from beginning of life to end of life; flow distribution and hot channel factors when fuel assemblies have different hydraulic resistance; evolution of core parameters used in transient and accident analysis, etc.

Due to the complexity of the phenomena involved and the possible interactions between different fuel assemblies, the extrapolation of an existing safety case to cover an increase in performance expected in the future is not straightforward. This stresses the importance of a very detailed analysis of operating experience and the feedback of the results to assess future performance.

The corresponding regulatory challenges are:

- to identify cumulative, small design changes which are not individually fully tested: their effect can produce significant differences to the original design and require a comprehensive assessment;
- to review best estimate methodologies and define the corresponding acceptance criteria, taking uncertainties into account. Collaboration between regulatory bodies should be enhanced in order to come to common positions; and
- to assess the impact on plant safety of the use of fuel assemblies of different designs in the same core.

In the first section of this chapter the various types of ageing were illustrated. Sooner or later the operator and the regulator will be confronted with the safety assessment of ageing plants, the need to backfit improvements to them, and to determine the degree of upgrading which is necessary. For plants designed to lower safety standards, most of the problems listed above with respect to ageing phenomena will be encountered simultaneously and an overall review will be necessary. Such a safety assessment can be made once or may be made periodically. Many countries have already introduced periodic safety reviews into their regulations.

The objectives of such safety reassessments are:

- to compare the present status of the plant with that originally licensed, checking that modifications made during operation have not had an adverse effect on safety;

The same cautiousness must be applied when utilities want to use fuel assemblies with higher performance or higher burn-ups or switch to MOX fuel.

Backfitting and safety upgrading programmes for plants designed to lower safety standards

- to examine, and foresee the wear-out and ageing phenomena which might develop during the next operation period and to take preventive measures to avoid foreseeable safety problems; and
- to assess the safety of the plant against the most recent safety rules and criteria and to judge what improvements can reasonably be achieved.

An overall and integrated safety review is recommended, as there may be backfitting measures which solve various problems at the same time. This is preferable to trying to find a solution to each specific problem, a process which might generate contradictory proposals. Much experience is now available world-wide on such safety reassessments.

When the regulatory body and the operator have agreed on which safety improvements are required, it is up to the operator to assess the economic viability of the plant and to choose between its further operation or its closure.

However with regard to the needed backfitting measures, there is the danger that commercially driven operators challenge more and more the decisions and requirements of the regulatory body. The operators will put priorities on where to spend extra money, balancing safety versus operability and availability.

The main regulatory challenges are:

- to agree on which safety improvements are required; and
- to conduct an integrated safety review to optimise backfitting by addressing all issues at once rather than using a piecemeal approach.

When many plants operating now were designed and built, little consideration was given to decommissioning them. There is a need to maintain design basis information to enable decommissioning to be undertaken safely, e.g. cranes' capacity.

In the periodic safety reviews and more generally during operation, future decommissioning of the plant should not be forgotten. Where changes are made to the plant, the aim should be to select options which do not make decommissioning more difficult or, preferably, which make it easier. A survey of the technological developments useful for decommissioning tasks should be updated periodically with particular emphasis on those which minimise the radiation doses to workers.

In order to provide for decommissioning, funds have been established in many countries to which yearly contributions are made so that enough money is available at the time of the closure of the plant. In the case of premature closure of a plant, the funds might not be sufficient to undertake the decommissioning work adequately. It will then be the responsibility of the government to look for and eventually to impose adequate solutions.

Before starting the decommissioning of its plant, the operator must clearly define the strategy to be followed and the time intervals for the different decommissioning phases, and submit this plan to the regulatory body for approval.

Decommissioning will produce various amounts of radioactive wastes, with different activity levels. Regulations on how to deal with such wastes will have to be enacted, including unconditional release thresholds and requiring traceability of how wastes have been disposed of, possibly even for very low-level waste.

Decommissioning

There is a need to maintain design basis information to enable decommissioning to be undertaken safely.

The main decommissioning regulatory challenges will likely be:

- to select solutions making future decommissioning easier at the design stage of new plants or during operation of existing plants, with the aim of dose reduction;
- to define clearly the decommissioning strategy to be followed;
- to secure appropriate funding for decommissioning activities; and
- to define a policy for the management of the different types of radioactive wastes, preferably by international consensus.

When spent fuel is removed from the reactor core, it is kept on site in spent fuel pools for a certain period, in many cases a number of years. In many countries, reprocessing was the policy chosen for the back end of the cycle, but recent political changes have reversed this decision in some. Operators must continue to exercise vigilance to ensure spent fuel pools continue to operate within their safety case.

As spent fuel accumulates and present storage capacity becomes full, operators are looking to alternative solutions, for example, re-racking (going to high-density racks) or building new storage facilities. There will be a need to maintain the integrity of the spent fuel pools over long periods of time.

If the spent fuel is kept in the pools for sufficient time it no longer generates appreciable decay heat. At this stage dry storage is a possible option, rather than wet storage in the pools. Both environments are technologically well-understood and the fuel can be stored safely for decades.

Disposal of high-level waste in geological repositories is being investigated at the laboratory level in order to study possible interactions (heat and radiation) with the host medium. As the quantities of high-level wastes generated by the civil nuclear programme are not large, the safety of interim storage can be ensured for decades, leaving time to study the problems associated with geological disposal and to gain public acceptance. These programmes also consider also the direct disposal of spent fuel.

As a producer of spent fuel, the industry must define a strategy for handling it during the next decades. This strategy will be discussed with the regulatory body and the public or even, in some instances, at the government level before implementation.

Thus, the corresponding regulatory challenges concerning high-level waste and spent fuel are:

- how to deal with the accumulating spent fuel in interim storage;
- to define a long-term strategy for dealing with spent fuel and high-level waste acceptable to all parties; and
- to identify and maintain progress in developing options for final disposal of spent fuel and high-level waste in the face of public opposition.

At the NEA, the management, storage and disposal of high-level radioactive waste and spent fuel are the responsibility of the Radioactive Waste Management Committee (RWMC).

Management, storage and disposal of high-level radioactive waste and spent fuel

As a producer of spent fuel, the industry must define a strategy for handling it during the next decades. This strategy will be discussed with the regulatory body and the public or even, in some instances, at the government level before implementation.

Many nuclear power plants began operation in the early seventies and are likely to be coming to the end of their useful life around the year 2010. If the decision is made to replace them with new nuclear facilities the designs will need finalising about ten years before the stations are required. As nuclear construction has come to a halt in many countries, a renewal programme will only be possible if enough scientific and industrial expertise is still available at that time.

In the Far East, substantial construction programmes are in place; in some, plants are being built which include advanced design features, for example, more passive safety features. These designs are based on an evolutionary approach to present reactors. In Russia, work has started on new designs and it is envisaged that there will be a need for a continuing dialogue to reach consensus on design requirements and appropriate analytical techniques.

In the US and in Europe, the utilities have published documents summarising their own requirements. These include severe accident and emergency operating procedures to be considered at the design stage. This would increase the safety level of these plants above present standards. The utilities hope that their common requirements will be agreeable to different regulatory bodies, allowing similar licensing procedures in different countries.

Hence, the corresponding regulatory challenges concerning requirements for future plants are:

- to establish close co-operation between designers and regulators of different countries to achieve a consensus on licensing requirements, in order to ensure that new designs can have a wide application around the world; and
- to maintain a level of scientific and industrial capability that is able to introduce new plants in the countries that may wish to build nuclear facilities in the future.

Requirements for future plants

The main political issue affecting many of the world's nuclear industries stems from the desire of governments to improve their country's competitiveness in the global marketplace. One way they can help to achieve this goal is to minimise the cost of electricity used by their industries. Many countries are applying market forces to achieve cost reductions in the supply of electricity. To promote this, governments are pursuing policies of liberalisation of their energy sector and drawing back from direct involvement in the energy markets. As a result, the main socio-economic issue for the nuclear industry is the desire to reduce the cost of production and in the case of new plants, to streamline the licensing process. The potential for regulatory impact as a result of the effects of the above socio-economic and political issues are considered here under the headings of:

- deregulation;
- demanning and contractorisation;
- research;
- managerial changes; and
- safety culture.

The trend towards privatisation of profitable and potentially profitable nuclear companies will continue. In addition, nuclear operators will increasingly be left to fend for themselves in the electricity market. It seems unlikely at present that governments will come to their aid by penalising other forms of electricity generation, for instance, by establishing a carbon tax. At the same time, environmental pressure groups will continue to argue for more and more safety measures with the potential to further increase nuclear costs. The result is likely to be increasing tension between commercial and safety interests in an industry which in many countries has no apparent mid-term future (except to operate existing plants to the end of their lives and to find a great deal of money to shut them down and to decommission them).

Increasingly, nuclear regulators will find themselves taking decisions which are only partly technical but which also have to take account of commercial and social pressures. They are likely to meet greater resistance to requiring improvements in safety, with operators questioning in detail the need for change and wanting justification for such expenditure measured against expected

III. Socio-economic and political issues with potential regulatory impact

Many countries are applying market forces to achieve cost reductions in the supply of electricity.

Deregulation

Increasingly, nuclear regulators will find themselves taking decisions which are only partly technical but which also have to take account of commercial and social pressures.

beneficial gains. Operators can be expected to concentrate their attention on maximising generation of electricity. Another possible effect of the new climate of competition is that regulators' requests for safety information from operators may take longer to be answered or may sometimes be ignored. Regulators must quickly learn, or acquire, new knowledge and skills to deal with possible changes in operators' attitudes towards them. Regulators also need to maintain the confidence of other stakeholders (the public, politicians and other regulators) and be appropriately tough in their response if operators default on safety matters.

The privatised companies are open to being taken over by a non-nuclear based company. Such new owners may not understand the way nuclear safety is regulated and will require additional effort from the regulators to ensure that the system of regulation is followed. This could be a particular difficulty if the new owner is based in a different country and used to a different regulatory regime.

Commercial pressures will be particularly important to privatised companies which need to answer to shareholders. In considering ways to optimise the return on investment, all aspects of nuclear generation will be re-examined. Moves towards competitive pricing for nuclear-generated electricity will require savings in the cost of production. Safety upgrades, unless seen to be absolutely essential, will have to be considered against affordability criteria, and some less significant ones will not take place. This may lead to a greater need to prioritise safety requirements and implementation programmes for safety upgrades. For others there may well be increased resistance to implementing safety modifications unless there is perceived to be an appropriate balance between costs of implementation and benefits achieved. In the search for cost savings, traditional methods of operating power stations may be challenged. For example, should the company continue to reprocess spent fuel or would it be commercially advantageous to use long-term storage followed by direct disposal when a repository is available. Similarly, different fuel management programmes are being assessed to see if savings can be achieved, including the use of mixed-oxide fuel in the reactor.

Provision of funds to cover end-of-life costs are a significant item on the balance sheet each year. These costs are being examined to see if there is scope to reduce the burden on companies. While regulators view this provision as a guarantee that funds will be available for decommissioning, operators may see this as a "cap" on liabilities, restricting their ultimate financial burden. While each provision may be for an end-of-life decommissioning strategy, commercial pressures may result in early closure of reactors for which decommissioning funds may not give full cover. Under increasing competition, it is even possible that one may see the financial failure of a company with nuclear assets and liabilities. It will pose a significant challenge to regulators to ensure that such liabilities can be safely managed, possibly in the absence of adequate financial provisions from decommissioning funds. The availability and the cost to operators of building final waste repositories, and their timing, or alternatively indefinite storage of some types of radioactive waste, will also figure strongly in commercial decisions and balance sheets of the privatised companies.

The commercialisation of the nuclear industry in many countries will present challenges to regulators, and the main issues likely to arise can be summarised as:

- the potential long-term consequences of the privatisation of national companies on regulation of the nuclear industry;
- the effect on regulation of mergers between utilities;
- the regulation of a foreign-owned or managed nuclear facility;

The privatised companies are open to being taken over by a non-nuclear based company.

Provision of funds to cover end-of-life costs are a significant item on the balance sheet each year.

- the ways to overcome operators' resistance to regulators' requirements for improvements in safety;
- the need for greater prioritisation by regulators;
- how to ensure that sufficient money is available to cover the back-end costs of nuclear power generation;
- the potential effects of early closure on decommissioning funds; and
- the effects of the financial failure of operators.

To compete with conventional electricity generators in free markets the nuclear companies need major reductions in their overheads. This is being achieved to a large extent by reductions in manpower, greater use of contractors and different approaches to the production, review and "maintenance" of safety cases. However regulators put great store on the concept that operators must have the capability to demonstrate their understanding and therefore ownership of their safety cases. Greater contracting out of safety case work with shorter contract timescales coupled with reductions in operator staff numbers and greater turnover of staff could lead to a potential loss of ownership of the case and as a result, less understanding of how to operate reactors safely.

Hence regulators are having to address ways of exercising regulatory control over reductions in manpower. In so doing they will consider how to assess the effects of the changes on safety. The industry might consider such issues as being interference in purely commercial decisions or having the potential to compromise sensitive personnel matters. Regulators must implement systems capable of monitoring new working arrangements, staffing levels and the provision of relevant safety competencies. Such issues will have short-term and longer-term implications for safety. Regulators need to develop performance monitoring systems, including indicators, that are sensitive to changes in the effect of humans on safety, and to consider whether it is possible to encourage improvements in safety culture during the upheaval of a cost-cutting regime.

With the nuclear industry in decline in many parts of the world, one concern has to be from where the next generation of nuclear engineers (both operators and regulators) will come. How will it be possible to attract the right calibre of staff into an industry with an uncertain future? Of more immediate concern are the effects of a reduction in technical competence within operators, caused by reduced numbers and the possibility of a greater turnover of staff, with the likelihood that the more able qualified personnel will move to other industries or seek early retirement if of the right age.

As the technical capacity of the operators declines, regulators will tend to take even greater care than at present to convince themselves that an appropriate level of safety is being maintained by the operators. The industry may consider this unnecessary and strongly challenge any increase in licensing charges.

The main issues to be addressed from demanning and contractorisation challenges to regulators are:

- how to ensure the operators maintain ownership of their safety cases;
- the need to develop ways of monitoring the adequacy for safety of new working arrangements caused by staff reductions and the greater use of contractors; and

Demanning and contractorisation

To compete with conventional electricity generators in free markets the nuclear companies need major reductions in their overheads.

- how to ensure the long-term availability of staff with the appropriate skills and training in the future for safety critical work.

Like commercial nuclear activities, research facilities must be properly regulated. Wherever possible, this should be achieved using an independent regulatory body. If this is not the case, the appropriate steps should be taken to ensure the effective independence of the regulatory functions from other functions where organisations are involved in both research and in its regulation.

Short-term planning to cope with economic pressures could lead to a reduction in the level and scope of safety research. In addition, private companies are likely to be less willing to share research findings with competitors, and indeed, regulators. Such positions could be seen to be a generally increasing hard-nosed and competitive attitude between the nuclear generators where there used to be essentially unquestioning co-operation. Traditionally, research efforts have concentrated on hardware issues and the development of analytical techniques. These are under pressure as funding is reduced. In addition to these areas, there remains much research to be carried out on improving human and organisational behaviour and on the implications of change on the industry. This includes changing regulatory and financial pressures.

The main socio-economic issues for safety research are:

- the need for research activities to be regulated in such a way that the regulator maintains its independence; and
- how to ensure that the necessary research facilities are available, a stable infrastructure is maintained and an appropriate level of research covering all necessary areas is sponsored and shared by the nuclear industry to improve the knowledge base on safety issues in the future.

In the event of a severe accident with the potential for significant environment releases of radioactivity, nuclear regulators (both foreign and domestic) must be ready to mitigate quickly and effectively the risks to: public health and safety; the environment; and economies; and to assure the safety of similar facilities within their jurisdiction. Only through the effective discharge of these tasks will the socio-economic and political challenges to the regulator and the regulated industry be limited. This will include co-ordination with, and the support of, other responsible government organisations, the effective communication of risk information, necessary protection measures and the results achieved, and a critical review and conservative response to lessons learnt.

The move into a more commercial business environment has inevitably changed the functional balance of senior managers in the nuclear operators. Companies are being increasingly influenced by the needs of the shareholders

Research

Short-term planning to cope with economic pressures could lead to a reduction in the level and scope of safety research.

Emergency arrangements

Managerial changes

and the use of tighter accounting practices on how money is spent. The traditional role of engineers in senior management is changing with the inevitable danger of a loss of safety appreciation at the top, and increased potential for production versus safety disputes. A change in emphasis towards short-term planning could result in neglect of longer-term safety issues.

In the past, operators' decisions about taking ageing nuclear plant out of service were based on either straight commercial grounds or on the basis that it was not cost-effective to meet regulators' safety requirements. In future, in a more competitive environment, operators will be much less ready to take such decisions when it means both a loss of generating revenue and an immediate call on their decommissioning funds. It may lead to the industry openly challenging the regulator on the need to close a station on safety grounds, with all the associated public relations problems this will bring.

The spend profile and the time remaining before decommissioning redundant plants will be an issue as this will affect the requirement to provide funds to cover the cost of this non-profitable activity. Decommissioning programmes could also be jeopardised by the non-availability of waste disposal routes for radioactive material released by decommissioning activities. Decisions about long-term waste management and decommissioning strategies will become increasingly important but the intractability of the problem may lead nuclear regulators into conflict with governments, the operators, environmental agencies, or interest groups who will seek to express increasing public concern about the environment.

All these management issues will present challenges to regulators. The principle ones can be summarised as:

- how to ensure that commercial interests and strategy do not compromise safety; and
- how to ensure that safety risks from redundant plants are addressed, and that they are decommissioned over an appropriate timescale.

Although the definition of safety culture given by the INSAG-4 report[2] has been widely adopted, it is believed that the phrase has been over-used and might have lost its meaning and impact. Since a well-managed plant would usually have a high level of safety, the alternative phrase “safety management”, which is more all encompassing, is recommended by some. It is also believed that the true concept of safety culture can only be demonstrated when an organisation could remove and replace members of a team without significant detrimental effects on safety. The challenges of the concept of safety culture are generally related to:

- the definition itself, agreeing on what constitutes a good safety culture and how to develop one;
- how to measure safety culture (tools to be developed), how to maintain it and how to develop it further;
- the effort needed to better understand the relationship between organisational and human behaviour and nuclear safety;
- the need to develop a guide on safety culture and how to promote its implementation (it is generally felt that the issue of safety culture has not been given adequate attention by the CNRA in the past);

[2] Report by the International Atomic Energy Agency (IAEA) International Nuclear Safety Advisory Group, published in 1991.

A more competitive environment may lead to the industry openly challenging the regulator on the need to close a station on safety grounds.

Safety culture

- how to measure the effectiveness of the application of a safety culture policy at all levels of an organisation;
- the effort required to assess the effect of management attitude and practices, policies, structure, procedures and level of internal communication on nuclear safety; and
- the importance of managers' training (e.g. simulation games, case studies, etc.).

From the above considerations of socio-economic and political issues and their effects on operators and regulators, there are some significant issues that regulators must address. They are:

- the potential long-term consequences of the privatisation of national companies on regulation of the nuclear industry;
- the effect on regulation of mergers between utilities;
- moves to deregulate utilities;
- the regulation of a foreign-owned or managed nuclear facility;
- energy market deregulation and concomitant emphasis on short-term financial aspects of operation with possible neglect of longer-term safety concerns;
- ensuring that resources are available to discharge operators' long-term liabilities; and
- increasing public concern for the environment.

Each of these issues will have components that are specific to each country and regulators will have to consider their response to the issues separately. However, some of the issues will have a degree of international commonality. It will therefore be appropriate to increase the effort expended on sharing experiences in tackling regulatory concerns so that there will be a consistent minimum standard of safety achieved and maintained between regulators. Such interaction will be particularly valuable where so-called "soft sciences" are involved, since emerging conclusions would benefit from a wider perspective.

Emerging issues

As discussed in the preceding three chapters, there are significant technical, political and socio-economic challenges facing regulatory organisations in the coming years. In order for regulators to be able to respond adequately to these challenges, they have to deal simultaneously with other pressing issues relating to their own organisations, interfacing with their operators and communicating with the public. Similarly, governments are concerned with minimising any unnecessary burden they may impose on industry. One possible burden could arise from over-regulation. As a consequence regulators are investigating ways to become more effective and efficient in how they regulate, and at the same time satisfying themselves that the changes in the industry are not adversely affecting safety. These issues can be broadly classified as follows:

- Regulatory effectiveness;
- Operator responsibility;
- Staff training and preserving a critical mass of knowledge; and
- Interface between regulatory authorities and the public.

These are dealt with in more detail below.

It is evident from the discussion in Chapters 2 and 3 that as privatisation issues and cost-cutting measures (for the nuclear industry) start to dominate the international scene, the need for more effective and efficient regulatory bodies becomes more important. This could result in reductions in their capacity to inspect sites. But at the same time they can expect more challenges from operators when regulatory requirements result in costs to operators or reductions in output. There may be greater use of cost-benefit analyses in attempts to relax some existing safety requirements or to extend the lives of plants. Reductions in the technical expertise within a generating company could result in a greater burden on regulators to make sure all safety aspects are covered by the operators properly. Utilities may by default, or actively seek to, shift the responsibility for safety towards the regulators reducing informal dialogue and demanding more detailed regulations and associated guidance. Not only could this pose a threat to a regulatory system that is based on goal-setting and non-prescription, but it could also lead to unacceptable demands on regulators to maintain requirements up to date in more prescriptive regimes.

IV. Organisational, management and human issues with potential regulatory impact

Regulators are investigating ways to become more effective and efficient in how they regulate, and at the same time satisfying themselves that the changes in the industry are not adversely affecting safety.

Regulatory effectiveness and changes

As markets are liberalised it is important to ensure that financial regulators are aware of the safety and environmental implications of their requirements to ensure they do not prejudice, through requirements which they set, the legitimate interests of other regulators. Only effective liaison between regulators can lead to an avoidance of problems in this area.

As mentioned in Chapter 3, good safety culture is also important for regulators.

It is also necessary to clarify the interface between regulatory activities and operator activities (see the section below) in addition to enhancing regulatory efficiency and quality of work. One of the most significant challenges is how to judge the effectiveness of a regulatory organisation and how to justify its operating budget.

This challenge of credibly judging regulatory effectiveness starts with the establishment of clear criteria for success and the tools for its measurement. This in turn requires consultation with and substantial acceptance by stakeholders both within and external to the government. Because regulatory effectiveness plays a critical role in the safety, operational performance and economics of the regulated industry, the majority of measures of success involve an assessment of industry operating experience and data. As a result, programmes for assessing regulatory effectiveness and justifying operating experience and budgets must involve establishing access to a comprehensive set of industry performance information. This information should be integrated with the results of regulatory programmes for inspection and enforcement. Periodically, the combined information should be systematically analysed against the effectiveness criteria and the degree of success reported with recommendations for further improvements.

Some of the other challenges that need to be addressed are:

- how to do more work with less resources as a result of continuously shrinking regulatory budgets;
- whether operators' "self assessment" or some form of "self regulation" should be introduced and how this would affect regulatory effectiveness;
- to what extent risk-informed, performance-based regulation should be applied and how this should be related to cost-benefit considerations;
- to what extent international peer-reviews should be used to monitor regulatory effectiveness;
- how to implement effective quality programmes in regulatory organisations;
- what the rationale should be for the frequency and scope of inspections; also, whether the inspection requirements for facilities with significant passive safety features should be different;
- the need to find ways to improve the effectiveness and efficiency of the interactions between operators and regulators;
- the need to establish liaison between regulators, for example between those having safety, environmental and financial responsibilities;
- the need to recognise the importance of safety culture within the regulatory body itself, other interfacing government agencies and the need for regulatory excellence; and
- the need to avoid increased burden on regulators stemming from reduced technical expertise within the generating companies.

One of the most significant challenges is how to judge the effectiveness of a regulatory organisation and how to justify its operating budget.

In almost all countries, operators have primary responsibility for safety. With the trend towards deregulation and privatisation of the nuclear industry, there are currently pressures on regulatory bodies to examine their regulatory approaches with a view to reducing the burden on the industry in order to maintain or improve competitiveness. This can lead to the introduction of the concept of "self assessment" and "self regulation" in some countries, while encouraging maximum effectiveness from operators. A certain measure of self assessment should generally reduce the amount of regulatory effort and the number of topics regulators need to examine. However, a strong and competent regulatory presence must be maintained. This does not preclude regulators from encouraging their operators to improve operational standards and the quality of work. Regulatory strength is needed to guard against potential degradation of plant safety that could result from self-imposed, cost-cutting measures by some operators to maintain competitiveness. Challenges in this area can be summarised as follows:

- how to ensure a proper interface between regulatory activities and operator activities to maintain effectiveness on both sides;
- while permitting some measure of "self regulation" or "self assessment", what should be the standards or criteria against which operators can be assessed to quantify their success in that endeavour and at the same time ensure that a strong regulatory presence is maintained;
- to what extent regulators and operators should consult one another to agree on required R&D as well as priorities in order to minimise duplication of work and to accelerate the resolution of safety issues;
- how regulators should interact with operators to help them develop a proper framework to ensure high levels of safety without being overly prescriptive; and
- how regulators should measure operator performance and respond to different levels of performance.

The human element has been identified as one of the most critical aspects of maintaining regulatory effectiveness, efficiency and quality of work. Due to a lack of new plant licensing and/or construction in most Member countries, new staff have no experience in how to do a regulatory review. Moreover, in the absence of good corporate memory, new staff tend to ask old questions which may burden operators unnecessarily. The overall objective should be to preserve among the staff a collective knowledge in all relevant technical disciplines, with sufficient depth to permit adequate, independent assessment of safety issues.

Training regulatory staff and maintaining technical capabilities are significant challenges. Quality organisations require well-educated, well-trained and well-motivated staff. In some countries, national R&D programmes are being reduced to such a point that forming an independent regulatory position might be in jeopardy. If a significant problem occurred over the next ten years, there might not be sufficient knowledge and capability to deal with it in a timely manner if the current trend continues. Some countries require a two-year, structured training programme for new regulatory employees with restricted

Operator responsibility

Regulatory strength is needed to guard against potential degradation of plant safety that could result from self-imposed, cost-cutting measures by some operators to maintain competitiveness.

Staff training and preserving a critical mass of knowledge

tasks. Such training programmes need to be discipline-dependent to maximise the benefit (e.g. human-factors specialists may not need the same training as safety analysts). Alternatively, other countries benefit from certification or review of new designs, periodic safety reviews or periodic licence renewals by exposing their new staff to all plant safety issues. Some of the challenges to be considered to ensure appropriate staff developments are:

- how to implement structured training programmes and how to measure programme effectiveness;
- how to maintain an appropriate balance between short-term needs (pressures on staff to deal with day-to-day operational issues) and long-term needs (maintaining and upgrading staff capabilities);
- the need to develop "Standard Review Plans" and/or to maintain a framework of procedures to ensure regulatory consistency and to preserve the corporate memory;
- what is the best way to preserve the "regulators' corporate memory" in order to maintain regulatory effectiveness in the face of the imminent retirement of senior and key regulatory staff, or how to "download" senior specialist expertise in a planned and structured manner;
- the need to introduce the concept of "periodic licence renewals" and/or "Periodic Safety Reviews" which could be used for staff training and development in addition to the principal objective of assessing plant safety;
- the need for periodic review of regulatory documents and procedures to ensure that they are current and relevant;
- the need to ensure some level of staff participation in international standard problems and to encourage staff to join non-promotional, national or international professional societies to maintain and upgrade their skills;
- the need to assess the benefit of staff secondments to other national or international organisations in addition to maintaining and encouraging international links through exchange of information and/or staff;
- the need to initiate co-operation programmes with universities to develop staff knowledge and/or to run complex computer codes;
- assessing the benefit of participation in reviews or certification of new designs (even without a real project) as a means of staff development; and
- assessing the extent to which all the above aspects apply to R&D and operator organisations.

In many countries there is little or no interaction between regulatory bodies and the public for a variety of reasons (e.g. policy issues, complexity of issues, etc.). Moreover, for those countries where there is already interface with the public, public participation varies widely from one country to another. In general, it is believed that providing the public with information will require increasing resources in the future. Regulatory bodies are responsible for informing the public about their role in ensuring nuclear safety. However, they should remain neutral and refrain from the temptation to educate the public about nuclear energy, which could be misinterpreted as promotion of the industry. Major challenges in this area are summarised below:

Interface between regulatory authorities and the public

Regulatory bodies are responsible for informing the public about their role in ensuring nuclear safety.

- responding to increasing pressures on regulatory body resources in some countries to accommodate public needs to participate in deliberations as well as the decision-making process through hearings and consultations;
- meeting freedom of information requirements and the requirement in some countries to respond to all requests from the public and the media;
- responding to public demands for involvement in major decision-making; and
- how to maintain an appropriate balance between the need to inform the public and at the same time the need to encourage responsible media reporting of regulatory actions.

The need for nuclear safety is recognised globally, as is the need for adequate regulatory control. A significant event or accident at a nuclear installation in one country has the potential to affect its neighbouring countries. Today news travels rapidly around the globe. As a result, a major accident anywhere in the world will affect public opinion in every state and particularly ones with a nuclear industry.

The nuclear industry is global in other senses. The reactor built in one part of the world may well have been designed in another part, with components supplied from many countries. Each country's regulators and operators interact with their counterparts abroad. Similarly, the environmental pressure groups interact globally.

Although the industry is global in nature, the way it is regulated is not. Each country has its own regulatory regime and has significant differences in the way it regulates. No responsibilities related to nuclear safety have been delegated to international organisations or even bilateral agreements. The activities of international organisations are mainly related to: international law; co-operative research projects; standard setting; reaching technical consensus and understandings; and providing communication fora among members. However, the fact that nuclear safety regulation is a matter for each country should not prevent assistance being given to countries where regulatory practices need to be strengthened.

The public can be forgiven for wondering at times why basic concepts and regulations need different approaches and result in different technical solutions. Regulators must emphasize that the same level of safety can be achieved using different approaches. The diversity in reactor designs, technologies applied and different regulatory frameworks should provide a minimum level of safety that is recognised internationally as being adequate.

In Western Europe and North America downward pressure on the costs of the nuclear generation of electricity has brought about a need for more research co-operation and co-ordination to ensure that effectiveness is maintained. There is strong concern about the ability of Member countries to sustain an adequate level of nuclear safety research, even though there is an international consensus on research needs and objectives. In particular, there is concern about the lack of international support for important new experimental facilities at a time when existing facilities are being decommissioned and experienced teams disbanded. The NEA Committee on the Safety of Nuclear Installations (CSNI) has endorsed a review undertaken by senior experts which recognises the need to retain

V. International issues with potential regulatory impact

A global industry

A major accident anywhere in the world will affect public opinion in every state and particularly ones with a nuclear industry.

important facilities and capability within Member countries and recommends that it:

- play a proactive role in organising and implementing co-operative programmes; and
- act as a forum in which facilities threatened by closure are identified and support action initiated.

These characteristics underline relevant challenges that should be faced by nuclear regulators. These challenges can be classified into the two following categories:

- co-operation between safety authorities; and
- co-operation and assistance to safety authorities in countries where regulatory organisations need to be strengthened.

The need for increased co-operation between safety authorities raises several issues. The six most important are described below.

Defining appropriate technical standards and guides to achieve the correct minimum safety levels is a crucial element of regulators' work. This task should be assigned to the right international organisation with inputs from countries with the appropriate expertise and experience. It is important to maintain national regulators' resources in order to preserve the viability of international co-operation on standard making.

In the technical consensus area, international co-operation would benefit from:

- the sharing of information on strategic lines and priorities among regulators;
- the sharing of information on regulatory practices and processes (e.g. quality systems and information systems);
- the acknowledgement of good regulatory practices, the drawing of conclusions and the formulation of recommendations; and
- the enhancement of technical interchange on operational experience for international discussion and review, as well as the provision of feedback and good practice recommendations.

To improve the situation in terms of regulators' human resources, there should be:

- co-operation to take the necessary steps to maintain critical competencies if the industry does not continue to grow;

Co-operation between safety authorities

Producing common technical standards and guides

Technical consensus issues

Regulators' human resources

- interchange of technical staff and inspectors among regulators; and
- use of modern technology to facilitate international exchanges at minimum cost (teleconferencing, Internet, etc.).

The main issue regarding public communication is how to communicate with the public effectively. In this area, experiences and practices should be shared.

As regards research, the two following questions need to be addressed:

- how to maintain, and to enhance where appropriate, international co-operation on research; and
- how to maintain, in some cases, stable although small, research teams.

In the event of a severe nuclear emergency with the potential for environmental contamination of other countries, the domestic nuclear safety authority must provide its neighbours with the best available information on the situation. Using established networks of communication these countries should determine how each could best provide: requested assistance; assessment of the situation; monitoring and projections of the near-term effects; and mitigation of any consequences. Subsequently, and in response to requests for international assistance, safety authorities should determine the degree to which they could assist the domestic safety authorities in monitoring and remediation efforts.

Although an increase in the application of nuclear power is not expected in Western Europe and North America in the near future, this is not the case in the Far East where Japan, South Korea and China have ambitious nuclear energy development programmes. This may also occur in some other countries in the region, for example, in Chinese Taipei, Indonesia and Thailand, that do not at present have a nuclear industry. These latter countries' governmental infrastructure for regulatory control is not developed. This is also the case in certain countries in South America that may also wish to generate electricity using nuclear power in the future.

To establish an appropriate regulatory system, there is a need for countries that operate nuclear power plants and that possess adequately strong and capable regulatory systems to assist countries new to nuclear technology. The challenge for the existing nuclear states is how this assistance can be provided under conditions of decreasing financial and manpower resources.

The CNRA as an NEA Standing Committee should undertake the task to transfer all relevant information to those countries which ask for it. In addition, *Public communication*

Research

Responding to a nuclear emergency

Co-operation with, and assistance to, safety authorities in countries where regulatory organisations need to be strengthened

In the event of a severe nuclear emergency with the potential for environmental contamination of other countries, the domestic nuclear safety authority must provide its neighbours with the best available information on the situation.

countries represented on the CNRA should consider what assistance they could provide. This activity could be carried out within the framework provided by the IAEA's Nuclear Safety Standards Programme (NUSS) documentation.

The most important areas to develop initially would be:

- the legal basis;
- regulations and guides for licensing, inspection and enforcement;
- the establishment of the regulatory body;
- technical support; and
- the training of staff.

The CNRA has to be aware of the implementation processes for the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. It also has to be ready to share experience and information if deemed necessary by its members.

The CNRA should continue to provide support to the International Nuclear Regulators Association (INRA) top-level regulators' meetings. Appropriate linking mechanisms must be considered to integrate the findings from these meetings into the CNRA programme.

In this report, issues have been considered which could present challenges to nuclear regulatory bodies over the next ten years. Chapters 2 to 5 have highlighted these regulatory challenges. Some are new, others have been taxing the minds of regulators for some time and will continue to do so in the future. All have the potential to affect the way the nuclear industry is regulated over the short to medium term. Of the ninety or so issues identified, some major issues warrant urgent attention by the Committee on Nuclear Regulatory Activities (CNRA) or other groups. These include:

- ageing – in particular, ageing of analytical techniques and documentation, and the definition of the analyses needed to support life extensions and the demonstration that the plant will still operate within its design basis;
- safety margins during more exacting operating modes – which require in-depth safety analyses to evaluate their possible safety impacts;
- safety culture – further work to define good practice and how it can be evaluated. Organisations must be able to remove and replace staff without significant detrimental effects on safety;
- regulatory effectiveness – how this can be enhanced, in particular at a time when regulatory bodies are changing their structure and methods of regulating;
- operator responsibility – operators must have primary responsibility for safety regardless of competitive pressure on them; and
- staff training and preserving a critical mass of knowledge – regulators need well-educated, well-trained and well-motivated staff.

Although not treated herein as one of the future regulatory challenges, there is consensus that the management, storage and disposal of high-level radioactive waste and spent fuel and, more generally, fuel cycle closure, is a prerequisite to the general acceptance of the continued and future use of nuclear power and should therefore be put in a special, top-priority category. This is an issue which calls upon the responsibilities of a number of NEA committees and the immediate task is to follow up on the actions decided at the 1997 "Cordoba Workshop"[3], organised by the NEA Committee on Radiation Protection and Public Health (CRPPH), the NEA Radioactive Waste Management Committee (RWMC) and the CNRA. These actions must be completed, and co-ordination must be strengthened within the NEA so that a programme of work can be identified and implemented.

[3] *Regulating the Long-Term Safety of Radioactive Waste Disposal* (ISBN 84-87275-72-9).

The preceding issues have the potential to affect the majority of regulators and are particularly well-suited to international co-operation under CNRA auspices. There are a number of remaining issues, however, that would have

VI. Conclusions

greater impact on certain countries than on others, and may therefore be more appropriately addressed by individual regulators. It is also generally recognised that resources would not allow for all of the following issues to be addressed in international fora. Challenges which merit consideration by individual regulators, and for which a sharing of experience is also encouraged within the CNRA are:

- establish a correct picture of the actual state of the plant, through periodic tests, in-service inspection and feedback of operating experience, in order to repair or replace aged components and maintain the design basis.

- qualify new technologies, like the use of specific software in safety critical applications or off-the-shelf software for less critical ones.

- conduct an integrated safety review to optimise backfitting by addressing all issues at once rather than using a piecemeal approach;
- agree on which safety improvements are required; and
- examine and foresee wear and ageing phenomena, and ensure preventive measures are taken to avoid safety problems.

- define a policy for the management of the different types of radioactive waste, preferably by international consensus; and
- as all Member countries will be facing decommissioning issues for the foreseeable future, develop and compare decommissioning strategies, including funding issues.

- establish close co-operation between designers and regulators of different countries to achieve consensus on licensing requirements; and
- retain capability in countries which currently have no programmes to build new reactors in the future.

- overcome operators' resistance to regulators' requirements for improvements in safety; and
- assess the potential long-term consequences of deregulation of the electricity markets and of privatisation of national companies on the safety of the nuclear industry.

Countries that are or have been subject to privatisation policies could form a group to document lessons learnt and report back to the CNRA. Such a report could detail their experiences with privatisation including a list of the issues they faced and explaining how some or all of these issues were resolved and what is still outstanding. This would greatly assist regulators facing potential privatisation issues.

Physical ageing of components and structures:

Ageing of technology:

Backfitting and safety upgrading programmes for plant designed to lower safety standards:

Decommissioning:

Requirements for future plants:

Deregulation (privatisation):

- develop ways of monitoring the adequacy for safety of new working arrangements caused by staff reductions and the greater use of contractors; and
- find ways to ensure that staff with the appropriate skills and training for safety critical work will be available in the industry in the future.

- monitor the availability of research facilities and associated staff to ensure that an appropriate level of research is sponsored by the nuclear industry while arranging for regulators to have access to research in a way which maintains their independence.

There are different approaches to the issue of research. A report could be prepared by a working group to summarise these approaches in preparation for a CNRA special issue meeting.

- assess the potential long-term consequences and share experience on implementation.

- consider how this may be improved, recognising the different cultures and legal frameworks of the Member countries.

- produce common technical standards and guides. There are great differences in legal requirements and licensing approaches in different countries. However, it is essential to ensure that basic international standards and associated guidance documents are produced and followed. The International Atomic Energy Agency (IAEA) is recognised as having a paramount role to play in this work, based on its success in this area in the past. This must be supported. Co-operation between the NEA and the IAEA is also to be encouraged in order to minimise the impact on resources and in recognition of the technical competence within the NEA and its Member countries; and
- share information on strategic lines and priorities as well as on regulatory practices and processes. This may require additional CNRA activities in the field of inspection practices.

- as in some countries the regulatory organisations are still developing their role, assist these regulators during this process, primarily through co-ordinated programmes and bilateral exchanges. In addition, the opportunity should be taken periodically to involve representatives from such countries in specific NEA activities, either as observers or as contributors.

Demanning and contractorisation:

Research:

Regulatory effectiveness (moves towards risk-informed, performance-based regulation):

Interface between regulatory authorities and the public:

Continuing co-operation between safety authorities and international organisations:

Continue to provide assistance to safety authorities in countries where regulatory organisations need to be strengthened:

(Chairman)
Deputy Chief Inspector of Nuclear Installations
Health & Safety Executive
United Kingdom

Directeur-Général Institut de Sûreté Nucléaire
AIB-Vinçotte Nucléaire
Belgium

Director, Research and Production Facilities Division
Atomic Energy Control Board
Canada

Director, Nuclear Safety Inspectorate
Hungarian Atomic Energy Commission
Hungary

Vicepresidente
Consejo de Seguridad Nuclear
Spain

Director, Office for the Analysis and Evaluation of Operational Data
Nuclear Regulatory Commission
USA

(Secretary)
Deputy Head, Nuclear Safety Division
OECD Nuclear Energy Agency

Annex

Members of the Working Party on Future Nuclear Regulatory Challenges

Mr. Christopher R. Willby

Dr. Pierre Govaerts

Dr. Aly M. Mortada Aly

Dr. Lajos Vöröss

Dr. Anibal Martin

Dr. Thomas Martin

Dr. Jacques Royen

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