GC

International Atomic Energy Agency
GENERAL CONFERENCE

GC(XXXV)/970
16 September 1991

GENERAL Distr.
Original: ENGLISH

Thirty-fifth regular session
Sub-item 11(b) of the provisional agenda
(GC(XXXV)/952)

MEASURES TO STRENGTHEN INTERNATIONAL CO-OPERATION IN MATTERS RELATING TO NUCLEAR SAFETY AND RADIOLOGICAL PROTECTION

(b) Recommendations of the International Conference on the Safety of Nuclear Power: Strategy for the Future

Note by the Director General

1. At the Board's February 1990 session, the Member States of the European Community proposed that the Board invite the Director General "to convene a conference in 1991 to review, in the broad sense, the present situation in the field of nuclear safety and to formulate recommendations on further measures at the national and international levels." It was envisaged that the proposed conference would become "a major contribution by the Agency to the United Nations conference on the Environment and Development to be held in Rio de Janeiro, Brazil, in 1992.

2. At its June 1990 session, the Board agreed to the holding of such a conference and requested the Director General to proceed with the planning of it.

3. At its thirty-fourth regular session, in September 1990, the General Conference welcomed the agreement in the Board to convene "a high-level conference in 1991 in order to provide an opportunity to the international community to define the nuclear safety agenda for the decade".

4. The conference, entitled "International Conference on the Safety of Nuclear Power: Strategy for the Future", took place in Vienna from 2 to 6 September 1991 under the presidency of Prof. Dr. K. Töpfer, the German Federal Minister for the Environment, Nature Conservation and Nuclear Safety.

5. The "Major Findings" of the Conference are as follows:

"The **International Conference on the Safety of Nuclear Power: Strategy for the Future**, after

reviewing

- the fundamental principles for the safe use of nuclear power,
- the safety of operating plants,
- the treatment of nuclear power plants built to earlier safety standards,
- the next generation of nuclear power plants, and
- the final disposal of radioactive waste;

and

considering the discussions held on several substantive topics related to these issues,

DECLARES that:

"1. There was general agreement that safety should be primarily enforced at national levels, by conscientious application of existing safety principles, standards and good practices at each plant, and within each national regulatory body, making best use of national legal frameworks and working practices.

"2. Operating organizations and National Authorities should identify operating nuclear power plants which do not meet the high safety performance levels of the vast majority of operating plants and undertake improvements with assistance from the international community.

"3. The Governing Bodies of the IAEA are invited to develop a more vigorous overview process with the objective of achieving a high safety performance in all operating plants, inter alia by expanding and strengthening services such as ASSET and OSART'services, and by promoting the achievement of sufficient national regulatory oversight.

"4. The IAEA should initiate a process to develop a common basis on which the acceptable level of safety of all operating nuclear power plants built to earlier standards can be judged. In some cases, international co-operation and support will be necessary to ensure the completeness of safety reviews and the adequacy of implementation of measures to achieve that acceptable level of safety.

"5. International organizations should enhance mechanisms to improve the quality and timely exchange of findings and conclusions of systematic analysis of operating experience, in particular relating to human and organizational performance. This could be achieved in part through regular use of the Incident Reporting System available at the IAEA.

"6. The IAEA should improve its mechanisms for timely public dissemination of authoritative information on operational safety performance experience. This could be achieved in part through a regular use of the International Nuclear Event Scale of the IAEA.

"7. The IAEA should set up a small group of experts to establish safety criteria for the design of future reactors using a step-by-step approach which would begin with the development of safety principles and evolve, in the long term, into a comprehensive set of criteria. INSAG documents could provide an important input to the process.

"8. The IAEA should develop international safety objectives for use by participating Member States with regard to the implementation of waste management and disposal. The programmes should include consideration of the provision of advice on safeguards commensurate with the safety of the final disposal of spent nuclear fuel.

"9. There is a need to consider an integrated international approach to all aspects of nuclear safety, including safety objectives for radioactive wastes, which would be adopted by all Governments, and in this connection, the potential value of a step-by-step approach to a framework convention is recognized; and, therefore the Conference requests the Governing Bodies of the IAEA that they organize the preparation of a proposal on the necessary elements of such a formalized international approach, examining the merits of various options and taking into account the activities and roles of relevant international and intergovernmental bodies and using the guidance and mechanisms already established in the IAEA.

"10. Member States of the IAEA are reminded that appropriate budgetary resources must be made available if the objectives of these findings are to be achieved."

6. On 13 September 1991, the Board of Governors took note, with appreciation, of the proceedings of the "International Conference on the Safety of Nuclear Power: Strategy for the Future" and requested the Director General to transmit them to the General Conference, drawing the General Conference's attention to the "Major Findings".1/

7. The Board requested the Secretariat to analyse the conclusions, recommendations and "Major Findings" of the International Conference, taking into account the comments made on them in the Board and in the General Conference and also the outcome of further consultations with Member States, and to formulate proposals for consideration within the framework of the 1993-94 programme development exercise and the Medium-Term Plan and also proposals for additional actions to be taken under the Agency's approved 1992 programme.

8. Also, the Board (i) reconfirmed the recognition of the primary responsibility of individual States in the field of nuclear safety, this responsibility carrying with it the right to take decisions on nuclear safety within their territories but also placing on States an obligation to the international community to exercise their safety responsibilities using the best knowledge available in the world; and (ii) concluded that the Director General, and subsequently the Board, would consider all other findings of the International Conference for enhancing international co-operation in order to achieve and maintain the highest level of safety and for contributing to optimum international co-ordination.

1/ The proceedings are attached to this Note by the Director General.

RECOMMENDED ACTION BY THE GENERAL CONFERENCE

9. The Board recommends to the General Conference that it invite the Director General to prepare, for the Board's consideration in February, an outline of the possible contents of a nuclear safety convention, drawing on the advice of standing groups like INSAG, NUSSAG and INWAG and on expertise made available by Member States (e.g. through the convening of an ad hoc expert group), thus enabling the Board to study the problem in greater depth and detail.

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ATTACHMENT

PROCEEDINGS OF THE
INTERNATIONAL CONFERENCE ON THE
SAFETY OF NUCLEAR POWER:
STRATEGY FOR THE FUTURE

VIENNA, 2nd. to 6th SEPTEMBER 1991

PROCEEDINGS OF THE

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER; STRATEGY FOR THE FUTURE

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CHAPTER I

INTRODUCTION

INTRODUCTION BY THE IAEA DIRECTOR GENERAL

I should like to welcome you all to this conference on the safety of nuclear power, which is to devote itself to the strategy for the future.

The future of nuclear power, in my view, depends essentially on two factors: how well and how safely it actually performs and how well and how safely nuclear power is perceived to perform. In these safety issues I also include the safe disposal of nuclear waste.

The IAEA has a long tradition of being the central international instrument through which governments contribute to the good and safe functioning of nuclear power, and this conference deals primarily with that subject. The IAEA has much less experience in influencing the perceptions of how well and safely nuclear power functions and it is not involved much in the public information sector, except in the sense that it seeks persistently to carry out and arrange for scientific analyses of nuclear events and matters with the hope and the assumption not only that something important will be learnt from these analyses but also that they will sooner or later influence the perceptions of the public which, in turn, influence the policies of governments. In the past year the IAEA has played a major role in two conferences which performed such analyses. The first was the Helsinki Symposium on the impact on health and the environment of different ways of generating electricity. The second was a meeting in Vienna to examine the results of the International Chernobyl Project set up to study the health and environmental consequences of the 1986 Chernobyl accident in the affected areas of the USSR and the protective measures taken.

In both these subjects, public perceptions are often at great variance with the picture obtained in a dispassionate scientific analysis. It is our hope that the availability of this analysis will be of importance to the public and the policy makers.

The present conference is action oriented. It will examine past and present international measures in the field of nuclear power safety, but only in order to determine how such measures can be improved, strengthened and supplemented. The initiative was taken by some governments of the European Community which felt that, five years after the Chernobyl accident and the expanded nuclear safety programme which was adopted by the IAEA in 1986 and other safety programmes in Member States, it was time to take stock of what has been achieved in this period and to work out an international strategy for nuclear safety for the years ahead, and subsequently the whole nuclear community stood behind this initiative.

This is thus a conference of policy makers, and we are happy that so many have been able to come. We trust that, on the basis of the considerable preparatory work which they have followed and influenced from their capitals, they will be able to reach practical conclusions which will guide work in the IAEA, in other organizations and in Member countries in the future. We hope that, in addition, the public will see that nuclear safety is continuously being strengthened, and - just as important - that this is happening everywhere in the world. The vast majority of our Member Governments consider the nuclear power option to be of vital importance for the world's future energy supply. To keep it alive and to relaunch it requires above all that nuclear power works well and safely everywhere and is seen to do so. The measures you consider and adopt should be geared to this goal. The United Nations Conference on Environment and Development in Rio de Janeiro next year and other conferences where the energy needs of the world are in focus must be made aware that those responsible for nuclear power safety nationally and internationally are moving in a very determined way to create a reliable international nuclear safety regime.

The Helsinki Symposium to which I referred a moment ago stated that

> "the results of comparative risk assessments of the different energy systems indicate, under routine operating conditions, nuclear power and renewable energy systems tend to be in the lower spectrum of health risk and that energy systems based on coal and oil are in the higher spectrum of health risk."

and it stated further that

> "rough estimates suggest that the human health risks from severe accidents from nuclear, oil and natural gas are of the same magnitude and two orders of magnitude smaller than those from the hydroelectric option".

While these assessments are encouraging, they give absolutely no ground for complacency. We are clearly faced with the need for the safety level in the nuclear power industry to be higher than in other electricity generating industries. The nuclear industry is not alone in such a situation. The aviation industry must also strive - and does strive - for a much higher level of safety than what is deemed acceptable in, say, road traffic. We know that the nuclear industry accepts the challenge and is confident about its ability to meet it. The major scene of action is no doubt at the national level: the operators, the owners, the regulators. Nothing should be done internationally to relieve them of their responsibility. But much can be done internationally to assist them and to make their tasks easier, and to ensure that safety is high in all countries operating nuclear reactors.

We are not starting from scratch. For many years the IAEA has served as a useful mechanism for the international exchange of experience in the field of nuclear safety. The IAEA's nuclear safety standards, or NUSS, were essentially derived jointly and internationally from national safety standards - a pragmatic amalgamation of national experiences. Such efforts remain useful, but it is clear that Member States are gradually demanding an increase in the intensity and a broadening of the scope of the international measures they wish to pursue through the IAEA. While this development started well before 1986, the Chernobyl accident led the Board of Governors of the IAEA almost immediately to discuss an expanded nuclear safety programme for the IAEA. During the summer of that year, 1986, recommendatory guidelines which had existed regarding the notification of nuclear accidents and emergency assistance were amplified, modified and transformed into binding conventions with unprecedented speed.

In the five years that have passed since then, there has been a remarkable development in the IAEA's nuclear safety activities. One important element in this development - and, indeed, one tool for pursuing it - is the International Nuclear Safety Advisory Group (INSAG) which is heavily involved in many of the IAEA's nuclear safety activities.

On the standards side, the NUSS programme, which represents the most comprehensive set of nuclear safety standards existing today, is being continuously updated to reflect safety advances. In addition to the Codes and Guides of NUSS, a set of Basic Safety Principles covering nuclear power plants has been worked out. The question is now being asked with increasing frequency whether the time has come to make some international standards mandatory.

It is interesting to note that in another technical international organization - the International Civil Aviation Organization (ICAO) - members agree to "co-operate to secure the highest practicable degree of uniformity in regulations, standards and procedures". ICAO "standards" are binding - but such standards are only developed in areas where uniform application is deemed necessary. In other areas of ICAO there are recommendatory guidelines. It is evident that uniformity is a more compelling need where you have aeroplanes and crews constantly moving between countries than it is for nuclear power stations, which admittedly are conspicuously sedentary. Yet, the need for a universal respect for some nuclear safety standards may become so strong that governments may wish to make them binding. The idea of a binding convention on safety matters, comprising a set of fundamental nuclear safety principles and having annexes that could be continuously reviewed and updated, may be worth considering. Such a convention need not take away responsibility from national regulators, but might strengthen their hand. It might constitute a visible sign of the nascent International Nuclear Safety Regime. I know that Minister Topfer, who will chair this conference, will discuss the idea of a convention on nuclear safety and I welcome this.

In yet another aspect of nuclear safety, binding undertakings might be desirable. I have in mind the reporting of nuclear incidents and accidents. The present system which is operated by the IAEA and the NEA, and in which most States with power reactors participate, is not obligatory. Again, a development of our system might seek inspiration in the ICAO incident reporting system. An obligation to report, enabling others to learn, is one thing; international inquiries into accidents are another and should be reserved for the most serious cases. This, in fact, has been the practice of the IAEA.

The nuclear safety related activities which have expanded the most in the IAEA in the five years since 1986 are the wide array of services. First, of course, are the Operational Safety Review Team, or OSART, missions, of which there have now been 48, to 28 different countries. The continued high demand for these missions demonstrates their usefulness, but we must at all times be aware that this usefulness depends entirely on Member States' seconding truly excellent experts to such missions. A continuous review of OSART work methods and results is needed to obtain the maximum use of them.

I shall not tire you with lengthy descriptions of the many services which are now offered by the IAEA under acronyms like ASSETs (Assessment of Safety Significant Event Teams) and IPERs (International Peer Reviews). A division of labour must be maintained between the IAEA and other international organizations like the World Association of Nuclear Operators (WANO), and the IAEA should not pursue activities which can be undertaken effectively by others. At the same time, the IAEA's unique character of being a tool of governments and of having a worldwide membership must be made use of. It can have much contact and co-operation with industry, with regional organizations and non-governmental organizations, but, as suggested by INSAG, its closest partners in the nuclear safety field should be the national governmental nuclear regulatory organs.

Experience will tell us which of the present services are the most useful ones and how they may need to be modified and supplemented. It has also been suggested by INSAG - and I agree with the suggestion - that in some situations the IAEA should insist that its services be accepted, e.g. an OSART mission to a troubled power plant or an ASSET mission to a plant which has faced accidents.

In practice I do not think much insistence will be needed. Member States have so far accepted the IAEA's suggestions for what they are, namely assistance to strengthen nuclear safety. Cases in point are the safety programme organized by the IAEA concerning the VVER 440 model 230 nuclear power plants and recent activities to rally interested parties able to assist the Bulgarian authorities regarding the nuclear power plants in Kozloduy.

I think the IAEA and its nuclear safety division can be proud of the speedy and unbureaucratic manner in which they offer services and meet challenges. However, insecure financing is a severe handicap, and even this conference should be aware of this. To have maximum effect, international nuclear safety projects - like any other - need stable financing. A contingency fund for or an authorization to use the Working Capital Fund in cases like the International Chernobyl Project or the VVER 440 project would give our work a less improvised character.

This conference is invited to take stock of the present level of safety of nuclear power installations, to assess what improvements have been made over the last five years and to identify areas and modalities for further international co-operation. Its function is also to identify existing and foreseeable trends which may call for further national and international measures to achieve the highest levels of safety.

With the advice of the Conference Steering Committee under the chairmanship of Prof. Adolf Birkhofer of Germany, the present conference structure and content have been developed. Our deliberations this week will revolve around five issues:

(i) Fundamental principles for the safe use of nuclear power;

(ii) Ensuring and enhancing safety of operating plants;

(iii) Treatment of nuclear power plants built to earlier safety standards;

(iv) The next generation of nuclear power plants;

(v) The final disposal of radioactive waste.

That is not to say that there are not other matters which could be addressed when discussing nuclear safety, e.g. the question of liability, which is treated elsewhere in the organization. However, in the opinion of the Secretariat and the Steering Committee these five issues encompass the main technical questions facing the nuclear safety community today.

I have deliberately been general in my remarks and I have made comments relating to only three of the five issues on your agenda. Let me add that all of the five issues, in my view, are of equal importance. Although we consider the operational safety of the world's currently existing nuclear plants of vital importance, we must not be so engaged in the present that we neglect the future. The public and the political world might perhaps be more willing to take a fresh and unbiased look at new power reactors than to revise ambivalent views on some of the currently operating ones. We need to promote the emergence of the new generation.

Let me also underline that the issue of final disposal of radioactive waste remains of fundamental importance. The civilian nuclear industry has always accepted that it must dispose of its wastes in a manner that is fully responsible vis-à-vis present and future generations. It has also developed the necessary concepts for this. It is not waste from the nuclear electricity industry that poses regional and global environmental threats. But I cannot escape the impression that agreement on international standards for the safe disposal of nuclear waste would both give guidance to the national authorities and give reassurance to the public. More attention needs to be given, in my view, to, for example, the development of the IAEA's Radioactive Waste Management Safety Standards (RADWASS) programme.

For each of the issues on your agenda Background Papers were prepared and distributed to Member States and international organizations. The comments received have been incorporated into the revised Background Papers. While not wishing to preclude discussions on other topics, I would urge you to concentrate on the topics identified. Our goal this week is not to just exchange views but to develop a consensus on recommendations and conclusions for both national and international authorities for the further strengthening of nuclear power safety, thereby hopefully maintaining nuclear power as an important contributor to the world's energy needs in the future.

It is sometimes suggested that there is a contradiction between the IAEA's role in promoting the use of nuclear energy and its role in controlling such use. This comment misses an essential point which is appreciated and understood by Member Governments, namely that control is an important, perhaps the most important, element of promotion. The vast majority of the IAEA's Member Governments wish to promote the use of nuclear power as one source of the world's energy supply and they know that a key to such promotion is the development and maintenance of an international nuclear safety regime. It is not enough that States individually secure such a culture. It must be done worldwide. On this all our Member States agree - whether or not they favour the use of nuclear power. That is why this conference is meeting today.

May I welcome you all once more to the conference. It is now my honour to introduce Prof. Dr. Klaus Topfer, the Federal Minister for Environment, Nature Conservation and Nuclear Safety of Germany. He has graciously agreed to our request that he serve as President of this conference and Chairman of today's session.

PRESIDENT'S OPENING ADDRESS

KLAUS TOEPFER

German Federal Minister for the Environment,
Nature Conservation and Nuclear Safety

Ladies and gentlemen,

Although this conference will focus only on the area of joint international activities specific to nuclear safety, it nevertheless plays an integral contributory role as we enter a new age of co-operation between nations. The world community has accepted the global challenge of taking joint responsibility for its future.

We have begun to establish a world partnership, a relationship founded on shared values of freedom and democracy which demands that rights and obligations are distributed fairly and conflicts resolved in a peaceful way.

We have already experienced the set-backs that threaten this progression to a new world order and may jeopardize it again in future. However, we also witnessed the way in which people and the international community stood up for their shared values and successfully countered these threats.

The new chances and opportunities for co-operation between nations are manifesting themselves at a time when, together, we are confronted by major tasks and risks as regards future economic, ecological and political developments. Without a sound environment and thoughtful utilization of our natural resources it will be impossible to sustain economic progress. We need new bases and forms of international co-operation if we are to meet these challenges with a common approach. Among other things, this necessitates an intensification and further expansion of the system of the United Nations, particularly in the fields of environment and development.

International co-operation as regards development and the environment

Environmental issues have been on the international agenda since the first United Nations environmental conference in 1972. Now in the run-up to the second United Nations Conference on Environment and Development in Brazil in July 1992, our primary concern is to make environmental protection and conservation of resources the principal components of the further economic, social and cultural development of the industrialized nations and developing countries. This involves a joint effort to tackle almost the entire spectrum of current environmental problems. This also concerns our shared rights and obligations as regards environmental protection and development, and possible methods of incorporating these in conventions, declarations or other legal instruments.

Conference objectives

In this process of tackling our common problems and formulating concrete strategies and measures, we must also redefine the bases and strategies for the future development of the peaceful use of nuclear power. Our common task at this conference is to make a significant, progressive contribution in this context.

In particular, this conference must confront the questions that have been raised in the process of international co-operation: in Toronto in 1988, for example, in Helsinki in June of this year, and by the UN world commission for the environment and development - Our Common Future. A number of issues relating to the peaceful utilization of nuclear power require uniform rulings on an international level.

Overall this review process has to be conducted in an open and unbiased way. Only if the challenges of protection against nuclear hazards and the safe management and final disposal of waste can be solved in a satisfactory way can nuclear power contribute to world energy supply in the future as well.

We are well prepared to make sound contributions to increased international co-operation in the fields of nuclear safety and radiation protection and of other global environmental problems.

The preparatory committee and a large number of experts have done excellent work leading up to this conference. They deserve our thanks.

We are able to contribute experience dating back over more than three decades thanks to our co-operation under the auspices of the IAEA.

Joint codes and guides as well as procedures have already been established in many areas, pointing the way for other sectors within the sphere of environmental protection and technical safety. Nuclear power has to make essential contributions to the implementation of an industrial safety culture.

1. FURTHER DEVELOPMENT AND REDEFINITION OF THE STRATEGY FOR THE FUTURE PEACEFUL USE OF NUCLEAR POWER

Following the Second World War and the experience it provided of the military potential of nuclear technology, international co-operation focused on stemming the risk of a wider proliferation of nuclear weapons in order to prevent hostilities involving nuclear weapons. At the same time, efforts were made to promote the peaceful use of nuclear power, regarded in those days as a potential miracle-worker for the future, and to make it accessible also to non-nuclear-weapons states.

Various ways of resolving these difficult problems were discussed at the end of the 1940s and beginning of the 1950s. The solution finally adopted, namely the formation of the IAEA, represented a co-operative approach based on partnership and one which I believe has also generally been vindicated.

As far as the non-proliferation of nuclear weapons is concerned, recent experience - violations by Iraq of its commitments under the Safeguards Agreement - has indicated the importance of an enforceable and effective non-proliferation regime and illustrated the difficulties besetting its implementation in practice. At the same time, the ultimate success of the work done by the IAEA in this field over more than thirty years has been revealed. This special role of international co-operation in protecting against the military use of nuclear power must continue to be strengthened. It enjoys broad international support, most recently, for instance, at the world economic summit in London.

It has equally become clear that the non-proliferation issue will persist and require resolution independently of the nature and scope of the contribution of nuclear power to the energy supply.

However, three decades of development and experience with the peaceful use of nuclear energy have produced fundamental changes, giving rise to new approaches and strategies: The vision of "atoms for peace" has been replaced by sober realism. The special role of nuclear power utilization, derived from the high expectations of the early years, has been overtaken. The strategy for the future no longer comprises a joint international exploration of an exceptionally promising technological territory, but seeks jointly to accomplish the safety and protective tasks associated with the peaceful use of nuclear power.

The approach underlying a strategy for the future, therefore, must be to report and review the opportunities, risks, options and necessities of the future use of nuclear power according to the systematic framework and goals of this increasingly wide reaching process of international co-operation. As the theme of this conference demonstrates, the question of safety is currently assuming primary importance.

Accordingly, then, in my view the strategy for the future which we must formulate in concrete terms during this conference encompasses three primary elements:

- Realization of a safety partnership by creating an international safety regime;
- Solution of urgent actual radiological protection and safety tasks, especially in the area of nuclear waste;
- Orientation of the further development of the peaceful use of nuclear power according to comprehensive requirement profiles for the power technologies of the next century.

2. CREATION OF AN INTERNATIONAL REGIME FOR NUCLEAR SAFETY (BASIS OF A SAFETY PARTNERSHIP)

The preparations for this conference have shown that international agreement exists on the safety objectives and on the procedures, methods and safety requirements by which these objectives can be attained. If these principles were applied strictly and uniformly, a high level of safety would be achieved. The object of our deliberations at this conference is rightly to give these fundamental and abstract principles greater transparency and clarity to promote public discussion.

Our joint interest here goes beyond protection against transboundary consequences: Even if the consequences are not felt beyond the national boundaries, a serious accident in any country represents a set-back for us all and will call into question the very future of using nuclear power.

For this reason we need more than a joint commitment to safety and more than harmonization down to the lowest common denominator: we need an international regime of nuclear safety. And the IAEA provides us with both an opportunity and an instrument for bringing such a regime into being.

The IAEA is an instrument of its Member States and its effectiveness depends on the intensity and quality of their collaboration.

International experts and the staff of the International Atomic Energy Agency have accomplished effective work over the years and in so doing have created three mainstays of an effective international regime for nuclear safety:

1. Fundamental safety requirements for radiological protection, known as the Basic Safety Standards, and for the safety of nuclear plants under the NUSS programme, as well as the Basic Safety Principles of INSAG, have been compiled and are being kept up to date.

2. IAEA services and missions provide support to Member States in implementing progressive requirements and ensure further enhancement and transparency in the practical provision of protective and precautionary measures.

3. The IAEA and the working parties it employs, INSAG for example, are proven forums for the dynamic further development of precautionary measures according to exemplary practice and new findings and experience.

Together we now have an opportunity beginning with this conference of endowing these elements with a new quality by merging them on the basis of voluntary commitment and open collaboration to form an effective international safety regime.

2.1. Internationally accepted safety requirements

A key function is assigned to the revised NUSS safety standards of 1988. These contain requirements and procedures which current experience and the latest scientific and technological findings indicate must be fulfilled in order to ensure an acceptable level of safety.

Implementing the resolutions of the General Conference, the Director General, Mr. Blix, asked the Member States to answer two questions:

1. Are the revised codes suitable for international safety standards which can be used by the individual Member States as the basis for developing and introducing national safety standards?

2. Are the relevant requirements contained in the valid national regulations and official safety standards consistent with the stipulations of the revised codes?

Almost all countries with a nuclear power programme replied. Their answers:

- The revised codes are suitable for the development and revision of safety standards.

- Current safety practices are generally consistent with the requirements of the codes.

The revised NUSS codes ought, therefore, to be recognized voluntarily by the States utilizing nuclear power as a binding basis for their regulatory requirements and safety practices.

One way of turning these commitments into binding international safety requirements is by means of a convention. Conventions are the mainstay of international relations in the modern age. As a partner to the Member States, the IAEA has already been instrumental in formulating and implementing such conventions. With its support, the Member States have been able to create important legal requirements. Examples include:

- The Convention on Early Notification of a Nuclear Accident;
- The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency;
- The Convention on the Physical Protection of Nuclear Material;
- The Vienna Convention on Civil Liability for Nuclear Damage;
- The London Dumping Convention.

We should now set a process in motion to create a similar convention in the area of nuclear safety as well. The necessary preconditions are already fulfilled. Equally, I am fully aware that this will be a difficult process. Nevertheless, I believe we should have the courage to start here and now.

For this reason, I propose to commission a group at the IAEA to devise a draft convention. The convention should allow the Member States to commit themselves legally to observe the safety fundamentals and safety standards.

I would like to re-emphasize that my objective is not to create an international regulatory authority with appropriate rights and obligations. The responsibility for safety at nuclear installations lies first and foremost with the relevant operator. In practice this responsibility must be, and can only be, discharged locally. This process must be subject to the permanent supervision of the responsible national regulatory authority. National authorities must have the capacities, procedural channels and competence at their disposal to draw up detailed regulations and monitor their practical implementation, also taking national peculiarities and structures into account. This distribution of responsibility should not be changed.

2.2. Implementation and verification

Fulfilling its defined role, by convention initially international standards are translated into domestic law on the basis of a voluntary undertaking. Vital importance then accrues to how these regulations are then actually observed and fulfilled at national level. The question of possible verification mechanisms arises.

We have both reason and new scope to follow up these questions. Although closer international co-operation has confirmed the general willingness to implement uniformly high safety standards, it has also revealed several cases of procedural and technical safety inadequacies resulting from the past.

Thus the States of central and eastern Europe, for instance, have asked the international community for concrete assistance in improving the worrying safety situation at their nuclear power stations. Tackling this challenge provides us with an opportunity:

- To highlight and implement common principles;
- To put verification instruments to the test in practice.

This collaboration has already got off to a successful start.

The IAEA has taken over laudable pioneering functions. The OSART and ASSET missions, for instance, are today widely acknowledged examples for efficient services which allow the Member States to provide each other with practical assistance when implementing advanced safety practices.

Co-operation in the field of regulatory practice is increasing as a result of IAEA surveys and the results of the 1988 international conference in Munich. The "peer reviews" in small groups have already established themselves as an important aid in verifying and further developing regulatory practice at national level. Even if these services are made use of on a voluntary basis in each case, they are a means of disclosing technical safety and regulatory practices and having them examined by experts from other countries.

Experience with these instruments has been positive so far. Such instruments are attractive as they are developed on the basis of partnership and take effect pragmatically on the spot. I regard them as containing constituent elements of a future safety culture with which an international safety partnership can be practised in the field of nuclear safety and radiological protection.

Discussions should consider if Member States on a voluntary basis should commit themselves to publish the relevant mission reports and to respond in a specific way.

Ladies and gentlemen, these are the bases on which the first major element for a strategy for the future, an international safety regime, can be created.

3. SOLUTION OF ACTUAL CHALLENGES IN THE FIELD OF NUCLEAR SAFETY AND RADIATION PROTECTION

A strategy for the future must prove its merit by solving today's problems first. This is the second key element. The current problems of using nuclear power strongly influence public controversy and political decisions and thus decisively determine the conditions and scope of all actions possible.

Managing the consequences and risks derived from past and present utilization of nuclear power is primarily a national responsibility. In this connection, we must examine how we can assist each other at an international level:

- As regards concrete progress in the practical realization of safe disposal of waste products from using nuclear power;

- In tackling contemporary tasks relating to radiological protection of the population;

- In ensuring accident free reactor operation.

3.1. Safe treatment and final disposal of residues of nuclear power utilization

Whereas safety requirements for the transport of radioactive materials were compiled very early on by the IAEA, the significance of waste management was initially underestimated at both national and international levels.

As a result of intensive national and international efforts, today's experts are of the opinion that all the technologies required for safe waste treatment and disposal are available, that they can be evaluated with sufficient accuracy, and that appropriate facilities and storage sites can be safely constructed.

Although waste disposal sites are in operation in certain countries for special types of waste and numerous disposal projects have been initiated, the implementation level in the disposal sector remains unsatisfactory and gives cause for the public to refer to waste management as an unresolved problem.

The preparatory documents for this conference concentrate on questions of the ultimate disposal in particular of high level long lived radioactive material. This is the most demanding task both technically and as regards the safety assessment. A strategy for the future must, however, have as its objective the creation of a practical formula for the safe use, interim disposal or ultimate disposal of radioactive materials in general. Such a strategy must embrace:

1. Concrete elucidation and evaluation of the entire spectrum of possible options for complete chains for recycling or disposing of radioactive residues;

2. Planning as required and operation of those installations which are needed for environmentally sound handling of existing and anticipated radioactive waste and residues.

Tackling the growing mountains of waste is not a problem exclusive to the nuclear industry. Consequently, devising a concept for pro-environmental waste disposal in general that protects resources will be a main topic of the 1992 United Nations Conference on Environment and Development to be held in Brazil. Key objectives are as follows:

- To grant priority to measures that avoid or minimize the occurrence of waste;

- To consider the relevant material flows as a whole throughout the entire life cycle;

- To harmonize criteria and strengthen the regulatory monitoring authorities in order to carry out proper enforcement;

- To monitor the transboundary transport of dangerous residues and waste materials.

In the run-up to the 1992 conference, contributions are expected from the IAEA in particular on the further evolution of transport regulations as well as in the form of information on procedures and technologies for the treatment and disposal of radioactive materials. Within this context, the question of the international ban on exporting radioactive waste to developing countries will also have to be addressed.

Here too, I consider it appropriate to present the options, strategies and measures of nuclear disposal using the objectives and concepts found in the international discussion of the waste disposal problem as a whole, and to incorporate these in a jointly created information base.

As a result of both the peaceful use of nuclear power and military applications, large quantities of residues and waste products have been generated and must now be dealt with. Although I in no way wish to seek to link the peaceful and the military uses of nuclear power, when it comes to the ecological and long term disposal of waste products from the use of nuclear power, then the standards that the international community considers necessary in this context must be applied across the board. In my opinion, projects by the appropriate countries can help to promote the further development of disposal technologies and would demonstrate complete, fully operational waste management chains including final disposal.

Within this context, we must also investigate the question of what to do in future with fissile material that is not needed for foreseeable utilizations.

You all know there is no lack of concrete tasks. As well as the disposal of waste from operational power stations, I would also like to draw attention to the real disposal work that must be conducted when power stations are decommissioned. The decommissioning and waste management procedures at power plants where accidents have taken place are very topical at the moment: a programme at Chernobyl 4 will be needed soon. Action to tackle the consequences of incorrectly operated uranium ore mining should also be addressed.

3.2. Tackling current radiological protection tasks

The basic requirements and practical procedures involved in radiation protection have for many years been the subject of close international work and this co-operation has generally been very successful. Strategies for the future therefore focus less on further developing the radiation protection system than on the following:

- The practical application and implementation of concrete protective and precautionary measures in contaminated areas;
- The optimum deployment of resources on precautionary measures and regaining the confidence of the affected population in the effectiveness of the measures taken;
- Verification of adequate preparedness for emergencies.

International Chernobyl Project

With the International Chernobyl Project on the radiological consequences of the accident - the results of which were presented to the public here in May and subsequently in the affected regions - the IAEA and those experts involved took on a difficult task and have emerged with great progress. Regrettably the results have still been received with great controversy. It must still be clarified how the IAEA can purposefully continue this project that it has undertaken, and how adequate support can be provided so that the actual scale of the effects of the accident can continue to be recorded and the people can receive practical assistance where it is needed.

Similar problems, albeit on a smaller scale, are arising in certain locations where uranium ore was previously mined. Here too, the focus is on how the precautionary instruments stand up to the test, and on the credibility of the actions taken by the responsible agencies.

Optimization of radiological emergency protection

The continuing improvement of technical provisions to prevent and limit damage at nuclear installations - including accident management procedures for nuclear power plants - raises the question of the extent to which planning and the practicability of emergency plans for the area surrounding the nuclear installations should still need to satisfy certain requirements.

Off-site emergency plans for nuclear power plants are indispensable. Experience and current planning show the source terms for which effective emergency protection measures are today considered possible. Further international co-operation would be beneficial to develop a common understanding on this issue, taking different site characteristics into account.

In general, tanker accidents, the burning oil wells in Kuwait or accidents such as that in Bhopal have triggered a general debate on how the international community can prepare itself to provide joint help. The proposal of an international emergency centre is currently being investigated within the framework of the United Nations.

The reactor accident in Chernobyl prompted the IAEA to draw up conventions on early notification and assistance in the case of a nuclear accident. Against this background, I therefore suggest that here, too, we conduct our further international co-operation within the framework of the general problem area of international assistance in the event of emergencies with environmental implications.

3.3. Ensuring the safe operation of nuclear power stations

Making provision for emergencies is absolutely essential. This is a fundamental obligation that we must discharge. But the future development of nuclear power's contribution to the world energy supply depends decisively on nuclear power stations being operated with a minimum of disruption and without major accidents. Joint international efforts in this connection have made great strides in recent years as regards both organization and practice.

Current challenges which call for strategic responses and practical concepts for action include:

1. Procedures at nuclear power stations whose design and operation fail to satisfy modern safety requirements;
2. The general implementation of contemporary safety concepts, more advanced requirements and newer technologies in older power stations;
3. The political and public discussion on ensuring safety and monitoring risk in response to more advanced safety concepts and different technical installation configurations.

Extrabudgetary IAEA Project on the Safety of Older Nuclear Power Plants

A request for support from the IAEA has been received from central and eastern European countries on the safety of their first generation of pressurized water reactors. Internal investigations had revealed that these reactors do not comply with international safety requirements. The condition of these installations is giving cause for concern in other States as well.

The IAEA took up the challenge with commendable speed and purpose, devised an extrabudgetary programme to assist these States within a short length of time and, in the meantime, has made considerable progress on the work involved with the assistance of several Member States.

The project is accompanied by difficult and sensitive questions:

- When must shortcomings be evaluated as being so serious that further operation is imprudent?
- When shortcomings have been established, under what circumstances can further limited operation be supported?
- How are the priorities set to remove identified shortcomings?

The public discussion which followed the findings of the IAEA mission to Kozloduy in June of this year demonstrated that various opinions are held as to the necessary follow-up measures.

Safety issues should be treated independently from the current energy situation.

This debate at least provided the impetus for the necessary action to be taken quickly and additional international aid is now taking effect. Further decisions and measures have still to be taken.

As far as the strategy for the future in the sphere of operational safety is concerned, it is of decisive importance that the experience gained from this project should be systematically evaluated and translated into common principles for future action.

Within this context, we must ask ourselves in concrete terms whether internationally binding minimum requirements for safety provisions can be established and implemented.

Adaptation of safety provisions at power stations to meet advancing standards

The revised safety standards of the IAEA, the NUSS codes, expressly state that the requirements and recommendations cannot be transferred in their entirety to older power stations. They note the need for a case by case consideration.

Our common safety principles and practice are evidence of the understanding of safety as a dynamic, not static, process.

The periodic safety reviews, at intervals of approximately ten operating years, practised or under discussion in several countries are naturally no substitute for continuous supervision and the implementation of new findings and operating experience to create improvements. Periodic safety reviews must be regarded as complementary. They make possible a complete reappraisal of the operating experience gained in a decade of operation and of plant changes that have taken place, and an overall assessment of the extent to which the current configuration and operation have proved themselves reliable and of where further improvements are practicable.

As far as the present is concerned, the current plant specific review programmes in many Member States already indicate a broad international consensus.

Plant specific probabilistic safety analyses are today being carried out in order to investigate preventive safety and the actual substance of the defence in depth concept. These allow new findings, new modelling methods and practical operating experience to be translated into a complete safety assessment with a different methodological approach.

In addition, by plant specific studies, the most recent findings regarding the occurrence and progression of the most serious imaginable accidents are used in order to investigate severe accident vulnerability and to undertake additional preventive and mitigative measures. The creation of a further line of protection within the defence in depth concept in the form of "accident management" is a focus of international co-operation and national improvement programmes.

Public debate on the status of safety provisions and risk control

Even if clear improvements are still urgently required in individual cases, we can state in this connection that continued enhancements have been achieved in nuclear safety and radiological protection at what was already a relatively high level.

In addition, together we have created new instruments for informing the public about the practical implementation of safety provisions. The severity scale for special events, the International Nuclear Event Scale (INES), devised by the IAEA provides an aid to inform the public about the success of safety provisions in a way that can be reconstructed and verified. Further instruments such as "performance indicators" or a "precursor type evaluation of safety significant events" are on trial in a number of countries and under discussion internationally.

Within this context, it should be discussed if Member States are willing to commit themselves to report more significant incidents - for example starting from category 2 on the INES - according to current reporting procedures to the IAEA and to make these reports public.

A question that remains dominant in the public discussion - and one that is raised each year on the occasion of the anniversary of the reactor accident in Chernobyl - is whether the whole system of protection to ensure nuclear safety will be truly comprehensive and adequate. Our common objective as far as safety is concerned is not to quote low risk values but to prevent actual major damage. As far as the observation periods to be taken as the basis for our evaluations are concerned, all comparative risk and environmental considerations will be fundamentally changed at a stroke with the occurrence of one catastrophe.

It is insufficient to say that the risk is tolerably low; instead we must do everything necessary at all times successfully to control the risk associated with the operation of nuclear power plants. We are grateful to INSAG for its clear formulation of what this involves in detail in its report on the safety culture.

4. PROSPECTS FOR THE FUTURE UTILIZATION OF NUCLEAR POWER

The credibility and prospects of success of a "strategy for the future" are ultimately measured by the efforts to find optimum and practical solutions to the future tasks we face in the spheres of environment and development, in particular in conjunction with the world energy supply.

The IAEA is one of the most important forums where informed discussion can take place centrally of the future options for utilizing nuclear power on the most reliable basis possible and can be translated into concrete recommendations.

The problems we must tackle are those relating to the current utilization of nuclear power that are most complex and give rise to controversy when discussed in the political and public arenas. This means a further optimization of proven technological solutions with improved potential for control and evaluation and the preservation of those specialist and industrial capacities necessary to permit optimized technological solutions in the future as well.

On the other hand, the Background Paper on the development of new reactors demonstrates that the current international trend towards improving protection consists not only of strengthening the prevention level. It is vital that severe consequences are prevented by the establishment of damage-limiting barriers. The objective must be to limit the effects of even very improbable severe accidents to the plant itself.

I would welcome it if, starting from this conference, a clear concept could be worked out of the concrete contributions the IAEA can make in future in order to ensure adequate incorporation of all questions affecting the utilization of nuclear power within the framework of the international approaches to environment and development. This includes, for instance, contributions to establishing a common international information bank on environmental safety problems, especially on the effects of all alternative energy technologies. This includes also identifying problems with a similar basis from other areas and the provision of examples illustrating how such problems are dealt with as regards safety, disposal or emergency protection. This also includes the integration of experience gained with joint safety requirements and their legal implementation and the question of effective control and verification instruments.

In this context, finally I want to repeat my most important proposal to start with the work on a convention on nuclear safety. This could become another milestone to build a world partnership for our common future.

Ladies and gentlemen, this conference is being held at exactly the right time to allow the problems of the future utilization of nuclear power to be meaningfully and purposefully included in the international discussion process. It is an opportunity to open up the discussion of the risks concerning nuclear power, too often conducted in isolation and with only polarized views being heard. Together, we must take advantage of these opportunities at this conference.

Keynote Address

PERSPECTIVES FROM THE COMMISSION OF THE EUROPEAN COMMUNITIES

L.J. BRINKHORST

Director General for Environment,
Nuclear Safety and Civil Protection,
Commission of the European Communities

Mr. Chairman, ladies and gentlemen,

On behalf of the Commission of the European Communities I am pleased to present to you our views on the current status and future perspectives of nuclear safety. But first I should like to thank the International Atomic Energy Agency and in particular the Board of Governors and the Director General Doctor Blix, for the way in which they have so quickly implemented the proposal of the Member States of the European Community to hold this international conference.

1. THE DRIVE TOWARDS AN INTERNATIONAL NUCLEAR SAFETY REGIME

No matter how essential nuclear safety is, we should not forget that it is not a value in itself. It is rather a precondition to make possible the practical applications of nuclear technology in many fields: industry, agriculture, medicine, and what is of relevance for this conference, in power generation. Furthermore, the acceptance of the nuclear industry depends upon public knowledge of its benefits and public attitudes to safety practice. Both depend upon the success of our efforts to communicate what we are doing, a matter to which I shall return later.

The report Our Common Future, prepared by the World Commission on Environment and Development, chaired by the Norwegian Prime Minister Brundtland, was published in 1987 and identified three problem areas affecting the perspectives of nuclear energy, namely weapons proliferation, safety and waste disposal.

With respect to the first, the international community has laid down and implemented since the early 1960s an international safeguards regime based on the Non-Proliferation Treaty (NPT) and the Statute of the International Atomic Energy Agency. The IAEA's safeguards constitute a complex and sophisticated system with well defined objectives and goals as well as implementation procedures, including on-site verification by international inspectors. The meetings of the IAEA's policy making organs and the NPT Review Conferences held periodically provide opportunities for the international community to assess the evolution of the non-proliferation regime.

The IAEA's annual Safeguards Implementation Reports and the results of the NPT Review Conferences are precise answers to the Brundtland Report on the issue of non-proliferation. However, the regime is not satisfactory in all respects, and recent events in Iraq have shown that the safeguards agreements do not provide complete assurance against a determined effort to violate them. Nevertheless the international community has had the means, in particular via the special measures contained in UN Security Council Resolution 687, to ascertain the nature and scope of the transgressions and to deal with the weapons grade material possessed by Iraq.

On the other hand, the answers that the international community can give to the two other interrelated issues of safety and waste disposal are not so convincing. Indeed we do not yet have anything that resembles an international nuclear safety regime, that is, a system of international treaties, conventions and practices to which States could adhere.

The accidents at Three Mile Island and in particular at Chernobyl have highlighted the need for such a regime and have provided the momentum to work towards it. Western leaders, on the occasions of the summit meetings of the group of seven most industrialized States, the so-called G-7 Group, have also supported a move in this direction. Most recently at the London Summit last July it was concluded:

> "In developing nuclear power as an economic energy source, it is essential to achieve and maintain the highest available standards of safety, including waste management, and to encourage cooperation to this end throughout the world."

In some quarters the idea of an international nuclear safety regime might raise doubts and reservations. There are those that may think it is still a premature project, or even further, that such a regime is neither necessary nor convenient. They believe that national actions and guarantees suffice. But for my part I believe that the time has come to take all appropriate actions at the global level in view of the consensus that already exists. If I need to argue the case any further, I would like you to reflect on what has really jeopardized the peaceful uses of nuclear energy during the last 40 years - weapons proliferation or the fear of severe accidents. For any doubters this comparison should be an interesting exercise.

But an international nuclear safety regime would be a major undertaking in which improvisation and precipitate action could have no place. To be successful it demands solid legal and technical foundations which are not yet fully at hand.

However, some legal instruments are already available, for example in the form of the conventions relating to physical protection, rapid information and assistance in case of accident or radiological emergency. And some of the technical instruments could also be found, inter alia, in the Basic Safety Standards for radiation protection generally based on the recommendations of the International Commission on Radiological Protection as well as in the Nuclear Safety Standards of the IAEA. The nuclear safety services being offered by the IAEA to its Member States are a further element on which it would be possible to build.

In my view it would be possible to move right now towards an international nuclear safety regime if, for example, the Basic Safety Standards for radiation protection of the IAEA and other international organizations were consolidated into an International Convention on the Radiation Protection of People and the Environment. The Community would be able to adhere to such a convention based on the broad competences that are conferred upon it by the Euratom Treaty. Actually, the Community Directive on Basic Safety Standards for radiation protection was one of the first to be adopted by the Council of Ministers in 1959 and there is a continuing effort to keep it up to date with the recommendations of the ICRP and the latest scientific developments.

In addition, the safety review services offered by the IAEA could be more systematized, made mandatory at regular intervals, at least for certain types of reactors, and sanctioned by a publicized review statement.

If we think of specific problems, we see that in practice we are already not so far away from an international regime. Now it is necessary to provide coherence and a legal base.

2. NUCLEAR SAFETY AND THE INTERNAL MARKET

What could be the particular contribution of the Commission of the European Communities to the development of international nuclear safety in the perspective of a future nuclear safety regime? The Euratom Treaty of 1957, which aims to create the conditions necessary for the growth of the nuclear industry, seeks to establish uniform radiation protection safety standards throughout the Community. The Treaty itself provides the legal basis for Community regulatory, operational and research actions, and Resolutions of the Council of Ministers of July 1975 and February 1980 mandate the Commission to work towards Community harmonization of safety requirements for nuclear installations and to implement an action plan for radioactive waste.

Quite clearly the completion of the Community Internal Market in 1992 has brought a new impetus. It is expected to lead to enlarged trade, growth and specialization and this will affect, among many others, the nuclear sector. Free movement of persons, including workers, goods and capital will be accompanied by demands to maintain or even enhance the level of excellence in nuclear safety and radiation protection achieved so far in the Community. This excellence should in no way be compromised and it is therefore essential to assure compatibility with the new economic objectives.

The expectations raised by the Internal Market are already having practical consequences for nuclear energy and nuclear safety policy within the Community. Strategic decisions no longer need to be taken mainly on the basis of restricted national interests but can now be adopted with a broader European perspective in mind. A number of Community Member States, for example, have given up plans to build their own nuclear installations, including reprocessing centres, in order to take advantage of similar facilities already available inside the borders of the Community. In addition to solving difficult domestic problems of acceptance and resource allocation, the Internal Market will produce improvements by rationalization and economic efficiency which will benefit the whole nuclear industry.

Further harmonization of Community regulations and practices will, therefore, be needed if we do not want to compromise what is expected to be an important landmark in the process of European integration. There is consequently a strong link between the Internal Market and nuclear safety.

I would even go one step further and suggest that within the broader context of European unification the Internal Market concept requires a real European vision of nuclear safety, which goes beyond the particular and sometimes restricted visions of individual Member States.

In this respect the Council Resolution of July 1975 on the technological problems of nuclear safety constitutes the link between Community radiation protection and the safety of nuclear installations. The Resolution calls for the progressive harmonization of Community safety requirements and requests Member States to seek common positions extending beyond the Community.

The European Community knows that the effective protection of its population depends on the development of nuclear safety not only inside but also beyond Community borders and therefore is thoroughly committed to international efforts, especially those of the IAEA to enhance nuclear safety worldwide.

The achievement of the Internal Market should be the occasion to implement inside the Community the highest available safety levels and to contribute thereby to their international dissemination. To reach these objectives it will be necessary:

- to increase concerted efforts among Community nuclear safety authorities; and

- to progress internationally towards the incorporation of Community safety requirements into the practice of other countries.

3. *THE SOVIET UNION AND CENTRAL AND EASTERN EUROPE*

In addition to the completion of the Internal Market, another major challenge to the European Community is presented by the new relationship with the Soviet Union and the countries of central and eastern Europe. For a variety of reasons - political, geographical and historical - the European Community considers that it has special responsibilities to its continental neighbours.

The recent London Summit of the G-7 underlined the courage and determination shown by these countries in building democracy and a market economy. Although the success of reforms will depend in the first place on the efforts of those concerned, the European Community is ready to provide important technical assistance to help them overcome obstacles.

One of the areas where Community technical assistance has been requested and could be of greatest value is nuclear safety. Most countries in the region have significant nuclear programmes and nuclear generation is an essential component of their economies.

At the same time some of the reactors still in operation are of old design and do not meet current safety requirements. Following requests from the Soviet Union, Czechoslovakia and Bulgaria the Commission, in close co-operation with the IAEA, has put at the disposal of these countries important financial resources to help upgrade the safety of their nuclear power plants.

Community assistance is being allocated:

- to reinforce nuclear safety authorities;
- to strengthen co-operation with the Community at both authority and plant levels; and
- to perform safety reviews and implement internationally agreed recommendations.

The overall objective is to meet safety requirements for Europe as a whole.

Nuclear safety in central and eastern Europe is an urgent problem and it is necessary that the response not only of the European Community but also of the international community at large be comprehensive and consistent. It is therefore essential to have an effective means of co-ordinating this response. The Commission, on its side, has been in permanent contact with the IAEA and with other global institutions like the World Association of Nuclear Operators (WANO), the World Bank and the European Bank for Reconstruction and Development, as well as with the group of 24 industrial countries providing assistance to central and eastern Europe (G-24), to assure at all times co-operation and complementarity.

As a result, a number of nuclear safety projects are going to be implemented in Czechoslovakia, with particular emphasis on the VVER-230s at Bohunice.

More recently, the problems at Kozloduy in Bulgaria have required an urgent response by the Community and other international organizations. As you know, in June the IAEA reported that the plant was in very poor condition and urged the Bulgarian Government to take urgent action. The Commission immediately put at the disposal of the Bulgarian authorities 11.5 million ECU to support remedial measures. Today I can report that all the administrative arrangements are practically concluded and teams of international experts financed by the Commission are working closely with the Bulgarian authorities and the IAEA to tackle the different problems, including the possibility of alternative power supplies.

Co-operation with the Soviet Union has also developed rapidly. Ongoing negotiations are finalizing the details of a 1991 technical assistance programme of the order of 62 million ECU and negotiations have started on a standing nuclear safety co-operation agreement. All this is in addition to many other research and assistance activities directly related to Chernobyl.

4. ORGANIZATIONAL MEASURES

While the Internal Market is stimulating the drive towards harmonization of safety requirements inside the Community, the challenge posed by the assistance requests received from the Soviet Union and central and eastern Europe is providing a practical opportunity to propagate outside the Community important elements of our nuclear safety culture. It would be in my view a serious mistake if these favourable circumstances were not seized by the wider international community to lay the groundwork for an internationally accepted nuclear safety regime.

The Commission of the European Communities, together with its Member States, is ready to co-operate in this endeavour. The existing provisions of the Euratom Treaty and in particular its Chapter III on Health and Safety, as well as the previously mentioned Council Resolutions, give us the necessary legal basis for Community involvement.

But to react appropriately to the new challenges it will be necessary to restructure and to reinforce our available financial and human resources in order to address the priorities. It is particularly necessary to clearly differentiate research activities, even if they are targeted towards safety, from the specific regulatory and operational activities relevant to the implementation of our co-operation programmes.

The IAEA has been up to now the focal point for multilateral actions in nuclear safety. The Commission co-operates closely with the IAEA and is ready to reinforce this co-operation. The IAEA should in my view aspire in the future to play a nuclear safety role similar in nature and scope to the one it already plays in non-proliferation.

In addition to its regular permanent programmes, such as the Nuclear Safety Standards (NUSS), and services (OSARTs, ASSETs, RAPATs, etc.), a number of special programmes and actions, mainly of extrabudgetary character, have been launched by the IAEA in the aftermath of Chernobyl and also in view of the current concerns over the greenhouse effect. There has been a significant expansion of nuclear safety activities and services as well as an increase in advisory groups and steering committees, all the more remarkable in view of the strict budgetary limits within which the IAEA has to operate.

It seems to me that the time is now ripe for an overall examination of all the nuclear safety programmes, co-operation mechanisms, projects, services, advisory groups and so on, with a view to integrating them into a more global approach.

In relation to this it will be convenient to start thinking about nuclear safety objectives and goals that could be the basis for an international consensus. This thinking should profit from the harmonized contributions of the different communities of safety experts, in particular installation safety specialists, radiation protection specialists and experts on the management and disposal of waste. The definition of internationally acceptable nuclear safety objectives and goals will have to overcome the isolationism and fragmentation among specialists that sometimes prevent progress.

I look forward to the results of this special conference providing the IAEA not only with the necessary basis to continue with its current nuclear safety undertakings but also to take the impetus to start work towards the definition of international objectives and goals as well as implementation procedures and approaches. All this should be done on the basis of the safety services being offered now by the IAEA to its Member States.

5. PUBLIC INFORMATION AND ACCEPTANCE

As I stated in my opening remarks, the safety of nuclear power is a practical value, that is, a set of technologies, management practices and operational procedures which permit the generation of electricity demanded by consumers in a way not harmful either to the environment or to man, including future generations.

This is so because large sections of the population harbour doubts about safety. Public opinion surveys, including the Eurobarometer surveys of the Community, continue to highlight this and identify incorrect perceptions about the real risks associated with the peaceful utilization of nuclear power. As a result nuclear power has become a significant political problem both inside and outside the Community.

In democratic societies it is entirely natural that governments and oppositions take into consideration the state of public opinion when they formulate their policies and programmes. Therefore, we should not be surprised when we see that in some countries the development of nuclear power is slowed or interrupted.

The Commission has been making considerable efforts in the area of public information at both the regulatory and the operational level. These efforts are necessary because information, when it is factual and objective, always aids a more rational choice. Furthermore, an informed public should be able in case of emergencies to protect itself better and to avoid some of the negative psychological reaction that caused so much damage after Chernobyl.

It is more and more evident that with different degrees of intensity the population in Europe does not consider sufficient a nuclear safety guarantee issued by the competent authorities of the country where the power plant is situated. I believe therefore that progress towards international nuclear safety objectives and goals and towards international standards and practices can only be positive elements in improving public acceptance of nuclear energy.

6. CONCLUSION

Some final reflections: although the immediate impact of Three Mile Island and Chernobyl on the Community was relatively minor and prompted only an update of our legislation and preparedness, these accidents have been the driving force behind recent international actions in nuclear safety. This is unfortunate because the international community has a duty to act decisively before emergencies happen and not afterwards.

Since 1986 nuclear safety policy makers and specialists have had a hectic time and we continue to be busy. I know that some of the many actions and programmes prompted directly or indirectly by Chernobyl are not yet finalized. Even so I believe this conference comes at a very appropriate time. We must take a searching look at what has been accomplished and what is still missing at the global level.

To go beyond this inventory-taking exercise, we should start to integrate international nuclear safety into a coherent whole. And in order to do so we have to start thinking about medium term international nuclear safety goals as well as implementation procedures. The long term aim should be an international nuclear safety regime equivalent, but of course not exactly equal, to the one already in force for non-proliferation purposes.

In parallel to this we also should start to think about the necessary international legal instruments. International conventions on radiation protection standards and mandatory international safety reviews, at least for certain reactor types, would be two possible ways to proceed.

These are my suggestions and I wish that they could be food for thought during the coming days. Whatever the outcome of your discussions, I would like to assure you that the Commission will continue to work closely with the IAEA and the international community to ensure the positive contribution of safe nuclear power to sustainable development and a clean environment.

Keynote Address

THE OECD NUCLEAR ENERGY AGENCY -- FOCUSING ON THE ESSENTIALS

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1. HISTORICAL PERSPECTIVE

The key objective of this meeting is to seek broader international consensus between national approaches aimed at controlling the risks associated with fission energy.

To begin with, it would be interesting to reflect on why the nuclear community, after more than 40 years, is still struggling to align its principles and practices in nuclear safety, when the development of nuclear power has benefited, right from the start, from international co-operation on a scale never seen before.

The Atoms for Peace programme, which in 1953 initiated the development of nuclear power, recognized the need for safeguarding fissile material in the fuel cycle so that it might not be diverted for military purposes, and gave a key role to the IAEA in this regard. It is unfortunate that concerted international efforts in nuclear health and safety did not receive comparable attention early on and this is why we still need to meet here to accelerate our efforts for broader international consensus.

Had governments joined forces -- 35 years ago -- and created an international body dedicated to the uniform achievement of the highest safety standards in this industry and dedicated to the pooling of resources, Three Mile Island and Chernobyl might not have happened. However, these disasters taught us what we should have known before, that every country with a nuclear programme is hostage to the performance of every other nuclear programme elsewhere. In order to protect the nuclear option, governments and industry therefore have the global responsibility to do their utmost to avoid accidents.

Co-operation between nuclear utilities and across national borders and multilateral co-operation between governments could be particularly helpful here. Nevertheless, Three Mile Island had to happen before US utilities united their efforts in INPO and began the long and arduous process of collectively trying to improve the performance of nuclear power plants. It took the disaster of Chernobyl to begin co-operation, in WANO, between nuclear utilities around the world.

On the other hand, intergovernmental co-operation in nuclear health and safety began more than 30 years ago, with the formation of the IAEA, Euratom, and the OECD Nuclear Energy Agency and, in fact, long before the first accident in a nuclear power plant. However, these efforts advanced very slowly. They were not only hampered by the absence of a common will of countries to interact dynamically, but also by the growing difficulty of comparing and aligning national approaches that had developed in parallel in the meantime.

In the 1950s and 1960s, intergovernmental organizations concentrated their efforts primarily in areas different from nuclear safety, that is on the development and transfer of reactor technology and on the economics of fission energy. The accidents and growing public concern provided a modest impetus. Yet, the contribution that international co-operation could make to the credibility and the safety performance of our industry, so essential for its continued exploitation and growth, is not widely appreciated even today. Many decision makers are still not aware that the most powerful argument for our endeavours is what Rudolf Rometsch calls "the international quality assurance of thinking". International co-operation makes it possible for countries to compare and mutually vet their approaches and practices, to make sure that there are no gaps in knowledge and to bring the best expertise to bear in joint assessments and research undertakings. It thus provides an important tool to achieve a high and homogeneous level of nuclear safety. A single bad performer can discredit the entire industry!

2. THE ROLE OF THE OECD NUCLEAR ENERGY AGENCY IN INTERNATIONAL CO-OPERATION IN NUCLEAR HEALTH AND SAFETY

In general terms, the IAEA, the CEC and the Nuclear Energy Agency of the OECD cover similar ground in nuclear health and safety and it is thus incumbent on us in these organizations to avoid wasteful duplication and to render our efforts as productive and effective as possible. While the methods and objectives of the NEA differ somewhat from those of other international organizations, we nevertheless strive to pursue activities jointly with the IAEA wherever feasible or, alternatively, concentrate on different aspects. However, these endeavours would not be sufficient if we did not build on the particular strength of our Agency and develop complementary expertise so as to serve our Member countries -- which all belong also to the IAEA -- in the most effective way.

In the following, I intend to describe the way in which we assist in the search for a consensus in nuclear health and safety, and I will emphasize the contributions by the NEA which we consider unique among those made by inter-governmental organizations.

The NEA comprises 23 industrialized countries, on four continents, which share the concepts of democratic governments and market economies. Both would be unthinkable without the unrestricted flow of information. In fact, the open societies in the OECD are aware of their interdependence and thus of the notion that international co-operation can only flourish on the basis of give and take. Our Agency therefore benefits from a climate of mutual trust, which has allowed and continues to allow us to tackle thorny questions and topics in a pragmatic way and to reach consensus, even on controversial issues. Incidentally, we are in the process of incorporating eastern European countries into this manner of co-operation.

As a group, the countries which constitute the NEA are the most advanced in the nuclear field. With 80% of the world's installed nuclear capacity, they have a particular need to enjoy a high level of co-operation.

The NEA programme is guided by a number of factors which, to some extent, differ from those of other international organizations. We are, for example, by approximately a factor of 15, smaller than the IAEA, and so are the resources which we are able to deploy to different sectors. This requires us to be very selective and flexible in the choice of topics to be pursued. It assures that we deal only with those issues which are collectively judged to be most important, and which can be profitably tackled jointly. Many activities are first proposed and explored in the restricted circle of the NEA and subsequently continued either jointly with other agencies, or taken over by them. In a way, we thus provide a laboratory of ideas for international co-operation, as regards both topics and mechanisms for international interaction.

Our activities are also more closely supervised by governments. While our Steering Committee, which is comparable to the IAEA Board of Governors, determines the overall budget and thrust of our activities, the technical programmes in the various sectors are determined and directed by a range of permanent technical committees made up of nominated national experts. These long-standing bodies, which have no parallel in other organizations, have existed for more than 30 years in radiation protection, more than 25 years in nuclear safety, nearly 20 years in nuclear regulation and 15 years in radioactive waste management. Over this long time, they have grown into forums in which mutual confidence and trust permit full exchange of advanced experience and a frank assessment of controversial questions, and allow representatives from national authorities to vet their ideas and concepts in addition to undertaking joint studies and co-ordinating research activities. These committees have become authoritative sources of information and advice and make a contribution to international consensus-building in two major ways.

The safety thinking and the fundamental safety approaches for light water reactors have been developed chiefly by the major OECD countries, both as regards the design basis and, even more so, for severe accidents. The OECD countries have also been instrumental in developing the guiding principles of radiation protection and radioactive waste management. It is therefore evident that the role of the competent NEA committees is to serve as a focal point for the evolution of thinking and the setting up of directions in nuclear safety. This has been one of our major contributions and in our view we should continue to provide this advice. However, these privileged encounters and the growing consensus in a number of areas cannot and should not be restricted to the OECD community at large, and while we may be on the cutting edge of the evolving thinking, we must, and do, share our insights and disseminate our knowledge to other active members in the nuclear field, notably through the IAEA.

Another area of work that is specific to the NEA involves operational co-operation and in particular joint research ventures. The long-standing and intimate co-operation of our committees in nuclear safety technology and radioactive waste management has created a suitable climate for countries to conduct and finance jointly safety research projects and to compare their methods and practices.

In this context, it is worth recalling that the original European Member countries of the NEA saw the formation of joint undertakings as one of the principal functions of our Agency when it was established more than 30 years ago. For this purpose, they provided us with the legal means of setting up such projects with the minimum of administrative burden. The flexibility of our Statute enabled the NEA, in the late 1950s, to develop several reactor demonstration projects, and over the past decade we have increasingly turned to common undertakings in nuclear safety and radioactive waste management.

2.1 Nuclear safety

The fundamental principles of operating nuclear plant safety have been formally summarized by INSAG. Two aspects deserve particular consideration. The first and foremost necessity is to put in place and maintain a high degree of safety culture at all stages of the design, construction, operation, maintenance and inspection of nuclear power plants. Safety culture is everybody's business in the nuclear industry. Related to the need for a high degree of safety culture is the need for a high quality of human performance. Quality of training for normal operation and abnormal situations, including accidents, is obviously of utmost importance. Better understanding of what is generally called human factors and how to deal with them in nuclear plant safety is another important element.

One of the key ways to integrate those factors in the day-to-day life of the nuclear industry is the sharing of operating experience among the nuclear community. The NEA played a pioneering role in this area when it set up its international Incident Reporting System (IRS) in 1980. The system has since developed to include information from non-OECD countries and will soon be merged with that of the IAEA. Fifteen hundred reports have been disseminated so far. The detailed analysis of significant incidents indicated where priority efforts should be made, especially in the human factors area. It has also contributed to the prevention of incidents and accidents.

Accident prevention includes all the aspects mentioned before. It covers also the detailed study of accident initiation, progression and possible development into accident situations exceeding the design basis of the plant. These severe accidents deserve special investigation and adequate operator training, as they cannot be handled through the conventional, prescriptive methods of accident management. The NEA has sponsored information exchanges covering all relevant aspects, has conducted international standard problem exercises to compare and to assess national approaches, and has described the emerging consensus in a number of state of the art reports. Materials issues will be viewed as increasingly important. One of the best ways to avoid accidents is to manufacture and build plants to standards and to examine and test their components adequately and regularly, especially those affected by ageing phenomena. The NEA has a number of programmes which address issues concerning the integrity of the primary and secondary circuits of water reactors, non-destructive testing, structural integrity and safety assessment of flawed structures.

Should an accident nevertheless happen, two other key elements of nuclear plant safety will be called upon. The first one is the reactor containment. This ultimate barrier must provide an effective protection against all reasonably conceivable accidents. Let me recall that, as far as public opinion is concerned, the containment is the most vital single item of nuclear plant safety. It will need to be improved further. The NEA has been actively exchanging information on containment performance for many years and it is also discussing new containment concepts. However, the containment must be protected in order to limit the severity of the test to which it will be put, and accident progression must be stopped in such a way that a controllable and stable situation can be reached again. Accident management, in particular severe accident management, is the key element where major efforts have been made in these areas in recent years and where the NEA has played a special role.

A Senior Group of Experts was set up soon after the Three Mile Island accident to exchange views on severe accidents. Starting from a situation where opinions regarding the prevention and mitigation of severe accidents were extremely divergent, this small group managed, through very frank and highly competent discussions, to arrive at a technical consensus which has strongly influenced the national positions adopted by OECD countries. Controversial issues such as filtered containment venting and intentional coolant system depressurization were discussed in that group for the first time internationally. A similar treatment is being applied to severe accident management issues, where progress is being made towards a technical consensus.

It is clear that all the fundamental safety principles must also be applied to nuclear power plants built to earlier safety standards. Assuming that such plants meet safety requirements, either through their design or adequate backfittings, it is unavoidable that specific inspection methods will have to be developed for the ageing plants, in particular for inspecting pressure vessels, steam generators and pipes, and that the inspection frequency will also have to increase. The NEA has a number of programmes in this field, covering information exchanges as well as international intercomparisons.

Reflecting on the older plants brings us naturally to reflection on the next generation of nuclear power plants. It is obvious that operating experience plays a fundamental role in identifying areas where improvements are needed and in defining and designing improved systems. As a consequence, authorities and industry alike will turn their efforts, in priority, towards the development of 'evolutionary' plants, integrating past experience, rather than towards designs based on new concepts that are remote from current expertise. There will be greater difficulty with these revolutionary designs in convincing safety authorities that the designs effectively meet safety criteria, both for design basis and for beyond design basis situations; industry will also have to be convinced that they can be licensed without major problems and can perform with a real economic advantage over current types of plant. The time has come to exchange information on safety aspects of evolutionary designs, and the NEA is beginning to be engaged in that process. Views must also be exchanged on the safety features of systems which might be built in the more distant future.

2.2 Radiation protection

In the field of radiation protection, we see two major challenges for the years to come. The first concerns the recent revision of the radiation risk factors recommended by the ICRP, which lead to more stringent individual dose limitations for workers. The nuclear community is thus confronted with the need to assess the implications of these lower limits for regulatory and operational practices. Difficulties may arise in the maintenance of nuclear facilities, in certain underground uranium mines and in some other operations in the fuel cycle, especially those involving uranium oxides and plutonium oxides. In this respect, international organizations, including the NEA, are called upon to translate the ICRP concepts into applicable regulatory guidance and operational requirements.

The second challenge comes from the attempt by the ICRP to introduce an integrated approach to the management of risks, by extending the scope of the radiation protection system to cover potential exposures with a probability of less than 1, such as nuclear and radiological accidents. This new approach is now being confronted with the philosophy and techniques used in nuclear safety in analysing and preventing nuclear accidents. Mutual understanding and reconciliation of policies and methodologies between radiation protection and nuclear safety in the treatment of probabilistic exposures will thus require our attention in the near future and we intend to continue to contribute to the evolving debate, notably through our seminars on interface questions in nuclear health and safety.

The first and elementary step here is to identify concepts and terms which have a different meaning in nuclear safety and radiation protection and to propose a unified terminology. A second and more important question which we are also beginning to tackle is how to constrain the range in which risks are assessed by treating differently, and perhaps even excluding, extremely unlikely nuclear accidents and large numbers of small individual exposures in the calculation of collective detriments. A widely accepted approach, which is extremely difficult to define, could help focus the nuclear debate on that range of probabilities which is more meaningful and which could be properly assessed with the scientific tools available to us.

2.3 Radioactive waste management

The principle of dilute and disperse, which many industries use for their waste products, cannot be applied to the waste arising from nuclear power plants, except for very small quantities of slightly contaminated effluents. Therefore confinement and isolation are the only practical means available for the disposal of most radioactive waste. Predicting and judging the long term safety of high level and long lived radioactive waste, together with the identification and characterization of potential disposal sites, is one of the major challenges confronting the nuclear community.

Disposal systems based on containment usually rely both on a multibarrier engineered design and on a site on land with favourable hydrogeological conditions. For long lived radionuclides, very long containment periods are required and the disposal system must be essentially passive and must not rely on man's action to maintain its long term integrity. In addition to inherent safety features such as the stability of deep geological formations, hosting repositories should have little or no water circulation. Repository siting should also be such that it minimizes the risk of human intrusion and therefore avoids areas presenting a potential interest to future generations. The ambitious objective is to ensure that the radioisotopes will not pose a problem to man or the environment, even in the very far future. This puts extraordinary demands on the assessment of the long term performance of geological repositories, which has considerably progressed over the past decade.

The very long time-scale, which far exceeds what has been considered in technology hereto, requires particular efforts in integrating the accrued knowledge and in imparting this information to others. To this end, the NEA has led the international activities which have culminated in the recently published international Collective Opinion entitled: Disposal of Radioactive Waste: Can Long Term Safety Be Evaluated? This document was supported by the relevant bodies of the IAEA and the CEC. It is the considered view of the entity of professionals in radioactive waste management that safety assessment methods are available today to evaluate adequately the potential long term radiological impacts of a carefully designed radioactive waste disposal system. The Collective Opinion states that proper use of safety assessment methods, coupled with sufficient information on proposed disposal sites, can provide the technical basis to decide whether specific disposal systems would offer a satisfactory level of safety for both current and future generations.

The many international studies and research projects which support the Collective Opinion have been performed jointly by developers of waste disposal systems and regulators. In the foreseeable future, we see a gradual shifting from the development and refinement of assessment methods to the identification and characterization of potential disposal sites, as well as to the conduct of site specific assessments to be used in the licensing process. For the time being, we believe that the experts developing the knowledge for these sites and representatives of regulatory organizations should continue their joint efforts to develop tools and data, which are necessary to ensure that the public is properly protected, before each of them plays its specific and independent role. In this respect, it is worth recalling that the beginning of construction of the first high level radioactive waste repository will be in about 20 years from now and that the subsequent operational life of a repository will be somewhere between 20 and 40 years. There are therefore about 50 years during which safety studies will continue and thus the possibility will exist to retrieve waste canisters, before closure of a repository, in case a better disposal solution becomes available. This should militate for concerted efforts for some time.

Finally, there are a number of alternatives to the geological disposal on land. Placement into geological formations under the seabed has been studied for more than ten years under the sponsorship of our Agency. In practice it has the major advantage over the land based option of limiting considerably the risk of human intrusion. However, this interesting option would have a future only if there were public and international political agreement to utilize the seabed for this purpose, which is not the case today.

Another concept consists of the separation and concentration of a substantial fraction of the long lived elements and their subsequent transmutation into shorter lived or even stable elements. This is a very attractive concept but its technical complexity makes it difficult for the time being to establish whether its potential and theoretical advantages outweigh its disadvantages. It nevertheless holds sufficient promise for research to be continued; this, however, must be clearly distanced from efforts for the geological disposal of radioactive waste, because of the unrealistic hopes it may raise in the public and the damage it may inflict on the current activities to isolate the waste.

2.4 Operational co-operation and international projects

As mentioned earlier, operational ventures and international projects are one of the major contributions of the NEA to the consensus-building in nuclear health and safety. These activities cover a wide range between fully fledged projects and focused intercomparisons, known as international standard problem exercises (ISPs). The NEA has developed a series of mechanisms which allow countries to integrate their safety R&D for nuclear power plants and radioactive waste repositories. The most important concerns jointly financed and directed projects, which a Member country offers for participation by others. We also co-ordinate projects in which countries share a common programme, or interlink national projects with similar objectives. Finally, we conduct comparative exercises, in which countries compare their procedures and practices with each other, and perform standard problem exercises, in which countries test a variety of safety assessment methods and tools, against each other or against an agreed standard, under well defined conditions.

Our international undertakings include the US $100 million OECD LOFT Project, which we successfully completed in September 1989, and which greatly contributed to improved understanding of thermohydraulics, core melt and fission product behaviour; the OECD Halden Reactor Project, which for more than 30 years has significantly improved understanding of fuel behaviour under abnormal conditions and of the man-machine interface; the TMI-2 Vessel Investigation Project, which examines the nature and extent of damage to the lower vessel structure of this ill-fated reactor; the TMI-2 Joint Core Examination Programme; the OECD Decommissioning Project, in which 11 countries exchange information, expertise and tools; the OECD Stripa Project, which was instrumental in developing techniques for the containment of radioactive waste; and the OECD Alligator Rivers Project, examining natural analogues. Several other projects concerning accident management studies and the predictive behaviour of real defects in thick steel vessels are under active consideration. We see a promising future for further projects of this kind, which are not only most cost effective for participating countries, but often lead to more imaginative solutions owing to the interaction between experts with different cultural and educational backgrounds.

Finally, the 40 comparative exercises and ISPs have provided confidence in the reliability and accuracy of these often complex assessment tools; such confidence could not be attained in a purely national context. These intercomparisons cover, for instance, assessment methods predicting the accident behaviour of reactor systems and the efficacy of safety provisions, accident consequence calculations, computer codes estimating the evolution of severe accidents and criticality accidents in spent fuel containers. The most notable exercise of this kind, the PISC programme, which we conduct jointly with the CEC, assesses the capability of different non-destructive test methods for reactor pressure vessels. Much remains to be done, particularly in the area of materials and of severe accidents, where our understanding is insufficient. Most of the projects and intercomparisons are open to non-OECD countries and a number of eastern European countries have already joined some of these joint undertakings.

2.5 Nuclear regulation

An important element, which is rapidly gaining ground, concerns international co-operation in nuclear regulation. In contrast to co-operation in science and technology, regulatory aspects require a more gradual approach since national practices are strongly influenced by the respective legal systems, traditions and habits which, to a certain degree, escape harmonization. For these reasons the competent NEA committee provides a forum for the exchange of views between national regulatory organizations. One particular aim of this committee is to share the substance and the rationale of anticipated regulatory measures. As an example, an issue which we have recently examined is the regulatory approach to low power operation and shutdown, which is universally considered to be inadequate. These efforts are bound to increase mutual understanding and constitute an important step towards the ultimate alignment of regulatory practices.

2.6 Conclusion

In concluding, I should like to summarize the message which I wish to leave with you.

It is regrettable that countries did not, from the start, treat international co-operation in nuclear health and safety with the same urgency as the safeguarding of nuclear fuel, even though nuclear development benefited greatly from international interaction. Thus, safety principles and practices evolved in parallel early on. We are now making progress in recovering lost ground, yet more could and needs to be done.

There exist a great number of bilateral and multilateral links involving both governments and industry. It is essential that the various channels be as productive and as complementary as possible.

Given its membership, its small size and thus versatility, its Statute and its working methods, the OECD Nuclear Energy Agency is in the unique position to quickly and efficiently provide the nuclear community with advanced reflections on a broad range of key safety issues; to explore and test novel mechanisms for international interaction; and to assist Member countries in integrating efforts in safety technology and safety assessment to the maximum extent feasible.

The OECD Nuclear Energy Agency is therefore well suited to be in the forefront of international co-operation in nuclear health and safety, acting on behalf of and in concert with the international community as a whole. To this end we intend to increasingly open our specialized activities to the participation of countries who are not members of the OECD.

Keynote Address

AN INTERNATIONAL SAFETY AGENDA

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Many of you in this audience are the policy makers guiding national and international nuclear safety activities. My remarks are directed principally to you, who at this time carry a heavy responsibility. You must above all promote policies to assure the safety of today's nuclear power plants and, along with this, you must also actively pursue measures to preserve the nuclear option in energy planning for tomorrow. Preserving the nuclear option will depend not only on effective national nuclear safety programmes but also, and more importantly, on public confidence in a convincing record of safety in every country with nuclear power.

Many in this audience were instrumental in calling for this conference. You undoubtedly recognize that building trust in global nuclear safety is today's real and difficult task. I wish to focus solely on this task of securing the public's confidence. This week's conference provides an opportunity to actively promote the necessary confidence in global nuclear safety by considering very visible and persuasive international measures, which, supported by national efforts, will maintain an adequate level of nuclear safety worldwide.

Building Public Trust

What specifically can this safety conference do to assist in the task of gaining public trust? The end result cannot be solely a series of recommendations to national and international bodies to enhance safety. Improvements in regulatory oversight, better analysis and feedback of operational experience, and encouraging a broader information exchange are not by themselves sufficient. To be most useful, the outcome should also embrace a course of visible actions which can convince the public that there are strengthened international mechanisms to assure that all nuclear installations worldwide are continuously being operated and being maintained at internationally recognized levels of safety. In today's world of increased transparency, the public is demanding this. We should not ignore their appeal.

What could these strengthened international mechanisms be? We may be able to learn from another field which greatly depends on public confidence. The Director General has already referred to the aviation industry, which has succeeded in demonstrating to the public that through national efforts and an array of international arrangements, an adequate level of international air transport safety exists. The public readily accepts new aircraft designs and willingly flies from one country to another, perhaps with varying degrees of anxiety, but with an underlying belief that an acceptable level of safety exists.

The nuclear community has not succeeded in achieving such a level of public confidence. It has perhaps neglected the wider concerns generated by nuclear power's international implications. Here in Austria, the public is not comfortable solely with having prevented indigenous nuclear power. It remains very concerned with the safety of its neighbours' facilities. There would perhaps be a higher level of comfort in Austria, and elsewhere, if there were more public confidence in an established and verifiable international level of safety.

International Civil Aviation

Some of the reasons for the different public perceptions of safety in the aircraft and nuclear industries can possibly be found in their mechanisms for international collaboration. It is interesting to compare the International Atomic Energy Agency (IAEA) with its aviation counterpart, the

International Civil Aviation Organization (ICAO), a specialized agency of the United Nations. Both bodies deal with promotional and safety activities. The international nature of civil aviation safety is clear. Safe operation in international flight requires the support of involved countries. Nuclear power plant operational safety, on the other hand, has until today depended almost solely on national requirements. Nevertheless, the design and construction of nuclear facilities, as with aircraft, have continuously involved multiple international aspects.

The safety objectives of the ICAO are in its founding Convention. They require the organization:

> to meet the needs of the peoples of the world for safe, regular, efficient and economical air transport, and to promote safety of flight in international air navigation.

The IAEA's Statute similarly calls for:

> the development of atomic energy for peaceful uses throughout the world along with the establishment and adoption of standards of safety.

In the ICAO Convention the Member States agree to "co-operate to secure the highest practicable degree of uniformity in regulations, standards and procedures." ICAO Standards must be applied and the word "shall" is used. There are also Recommended Practices which are agreed to be desirable but not indispensable and the word "should" is used. Both the Standards and the Recommended Practices are binding unless a contracting state provides notification that compliance is impractical. There is a sensible recognition that in certain areas obligatory Standards are not needed. The basic consideration is whether a uniform application by all Member States is necessary. In the aircraft design area, uniform application was deemed not necessary, and therefore only guidelines have been prepared to assist Member States in developing their own detailed national standards for safe design.

The IAEA has also developed a series of standards in the form of codes and guides, although these serve only as recommendations. Contrary to the ICAO, the IAEA has no standards which must be applied. Although Member States have endorsed them, their principal use has been as guidelines to assist in the development of national standards.

In the operational safety area, the ICAO has established technical requirements for aircraft crews. A pilot's licence that is in accord with these standards is accepted throughout the world. The ICAO maintains an obligatory incident reporting system and is also involved in accident investigations.

The IAEA has of course also been very active in the operational safety area. It too has developed guidelines for operating personnel, but here again only in the form of recommendations so that there are notable variations in national operator requirements. In co-operation with the Nuclear Energy Agency of the OECD (OECD/NEA), the IAEA operates an Incident Reporting System in which participation is general but not obligatory. The IAEA also has well developed operational safety review services which are undertaken, however, only on request.

What we can see in these comparisons between the intergovernmental organization dealing with air transport and the intergovernmental agency dealing with nuclear energy are similar objectives, but significant differences in the formality and authority of measures to achieve them.

A More Demanding International Approach

With international concerns and activities now in the forefront, it would seem an opportune time to consider implementing a more demanding international approach to nuclear safety. This could be an essential ingredient in building public confidence by demonstrating that, as with air transport, key international measures exist which ensure safety excellence worldwide.

As Director of the IAEA's Division of Nuclear Safety I would like to speak to only a few of the recommendations which this conference could direct to the IAEA. With the IAEA's future safety activities on the agenda of its Board of Governors as well as its General Conference, which both meet later this month, this conference's proposals can influence the course of international nuclear safety for the remainder of this decade. This safety conference, which is framing a strategy for the future, has a rare opportunity and a real responsibility.

The IAEA Programme

Many of your proposals may build on and be a logical extension of ongoing efforts at the IAEA, but with an added thrust to strengthen and broaden them. The 1980s already saw increasing nuclear safety co-operation with the formulation and recognition of a set of international safety codes and guides as well as the forward looking Basic Safety Principles for nuclear power plants. The past decade also saw the development of a number of widely used safety advisory services at the IAEA, particularly in the operations area, along with formalized incident reporting procedures.

Both the standards and operational activities lend themselves to further international attention.

It may be the proper time to bring about an international accord on a comprehensive and up-to-date set of fundamental nuclear safety principles covering the many aspects leading to safe operation, including the necessary regulatory oversight. These principles would contain well defined and clear safety ambitions. They need not be overly prescriptive and should allow for varying approaches. The already revised codes of the Nuclear Safety Standards (NUSS) programme and the Basic Safety Principles demonstrate that consensus will be readily achievable. These fundamental principles, embodying a united approach to nuclear safety, could be adopted for universal application. They would demonstrate to the public that an international consensus and determination exist to assure that nuclear power facilities worldwide are built and operated to recognized safety levels.

On the basis of their broad acceptance and use, it may be an opportune time to strengthen the IAEA's operational safety services, particularly the Operational Safety Review Team (OSART) and the Assessment of Safety Significant Events Team (ASSET) services, through perhaps a non-compulsory but markedly increased regular and periodic use. OSART missions have already visited almost 50 plants in 25 countries, while use of the ASSET service has grown remarkably in the past two years. Their advice has not only strengthened nuclear safety but these international peer reviews have demonstrated to the public a growing openness in nuclear safety matters.

It would also be beneficial in the operations area to encourage standardized intergovernmental systems for nuclear event reporting and communication, both for technical as well as for public information purposes. The IAEA's Incident Reporting System's (IRS) technical database has grown and since last year also includes all reports from NEA countries. If the foreseen annual publication of lessons learned from the IRS activities is to be of maximum value, it will require a further commitment from governments to completeness and accuracy of event reports. As to public information, the International Nuclear Event Scale (INES), designed for improved communication, has been employed on a trial basis since March 1990 to provide rapid and clear information about the safety significance of reported events. There has been a generally positive reaction to its use and the worldwide adoption of the scale could lessen public misunderstandings about events at nuclear facilities.

Undoubtedly, other activities also deserve added attention. The safety of the first generation VVERs, reassessments of ageing reactors, information exchanges on regulatory practices, enhanced safety of the next generation of nuclear reactors, and consensus on waste disposal are some of them. The three activities I have expressly singled out, those on fundamental principles, on operational safety services and on event reporting, were chosen not solely for their technical priority but also for their high visibility to the public. They would be significant ingredients in a more formalized programme of international participation in global nuclear safety.

An International Nuclear Safety Regime

In this regard, the nuclear community may well profit from the experience at the ICAO, with its more formalized approach, and the mechanisms it has used in fostering air transport safety in a beneficial and convincing manner. The basic tool which allows the ICAO to operate so efficiently in the safety field is its Convention, which permits the inclusion of binding technical requirements in Annexes which can be approved and adopted by its governing Council.

The IAEA has no simple Annex process for its Statute, but an international agreement formalized in a nuclear safety convention would serve a similar purpose. As with air transport, a nuclear safety convention need not diminish the national responsibility for safety nor in any manner establish a supranational regulatory authority. There are conventions already in force at the IAEA. In 1985, conventions on early accident notification and assistance were drafted and then adopted by the IAEA General Conference.

A convention on safety could formalize an **International Nuclear Safety Regime** with an internationally accepted set of fundamental principles along with a review system that ensures their global application. It may be difficult to achieve consensus at this time on a more prescribed international safety approach, but the idea is attracting the attention of more and more governments. The ICAO experience, which emphasizes the highest practical degree of uniformity, serves as a successful and useful example.

Budgetary Resources

In concluding I must very reluctantly turn to budgetary considerations. I would be remiss in not doing this. Suggestions alone from this conference for new and strengthened IAEA nuclear safety activities will not be sufficient. Resources are necessary for implementation. The Director General has referred to the need for stable financing and with your patience, as Director of the IAEA's Division of Nuclear Safety I wish to briefly return to this theme.

The IAEA has over the past years produced a programme of activities within the budgetary limits of zero growth which has been sustained by extrabudgetary resources and an unusually dedicated staff. During the past 12 months we have completed the International Chernobyl Project and initiated an extrabudgetary project on VVER reactors, both of these major undertakings during a period which also witnessed an unexpected and steady increase in the use of our safety services. This increase was not limited to operational services. It has included design and siting re-evaluations and peer reviews of probabilistic safety analyses, as well as radiation protection and research reactor missions.

These achievements have had an effect on the quality of some ongoing activities and have also caused delays and cancellations of others. The process of perpetually producing more within restricted resources has its limits. As Director of the Division of Nuclear Safety I would say that perhaps at this time this process is no longer sustainable. If the IAEA is to fulfil the safety role its Member States expect, there must be a realistic support of its safety efforts through the necessary expansion of resources. Currently, nuclear safety and radiation protection activities are assigned 6% of the IAEA's regular budget.

Building a stronger international presence in nuclear safety will not only contribute to safety but will also simultaneously maintain the nuclear option. If called upon by its Member States, the IAEA, along with its Division of Nuclear Safety, is unquestionably ready to do its part.

Keynote Address

THE SAFETY OF NUCLEAR POWER

HERBERT KOUTS

Chairman, International Nuclear Safety Advisory Group

The real reason for the conference in which we are about to participate is the world's need for growing amounts of electric power. Electric power is required at this stage of civilization for almost every economic and cultural activity of mankind. I use the term 'required' advisedly, because electricity as a form of energy is unique in relation to the ability to substitute one source of energy for another. For a large fraction of the uses to which electricity is put, there are no reasonable substitutes. No one would seriously entertain the possibility of returning to the era of gas lights, oil lamps and candles in those regions where electricity is available for lighting. This is now almost all of the world. There is no possible substitute as an energy source for the many labour saving devices that are used in the home, for radio, television, the telephone and the computer, for the parts of industry based on electrochemistry and electrolytic processes, such as extraction of aluminium, magnesium, sodium, zinc and nickel. As for driving rotating machinery in industry, I simply wish to quote the superb article on electrification of industry in my old copy of the Encyclopaedia Britannica, which referred to the replacement of steam and water power driving entire factory ensembles of machines, saying, "In no situation have the benefits accruing from industrial electrification been more important than in the factories, where the amelioration of the working conditions has been able to affect the lives of so great a portion of the population".

In short, electricity has become so ubiquitous and essential as to have almost joined the classical list of food, shelter and clothing as one of the necessities of modern life. It has attained this state in just over a hundred years of our modern history, for it was just in 1882 that Edison started up the first central station electricity generating plant, the Pearl Street Station in New York City, to power street lights in a small part of the city.

Just as the terms 'bronze age', 'iron age', and 'industrial age' have been used as indices to technology in characterizing periods in the advance of civilization, today we can say that we are in the 'age of electricity'.

Yet in many industrialized nations, the supply of electricity in essential amounts is entering a crisis state. Opposition has grown to all forms of central station electrical power generation: hydropower, generating plants where fossil fuels are burned, and especially the energy source that suppliers had recognized as the best hope for the future -- nuclear plants, whose development had arrived just in time.

Conservation has been urged as an alternative, and it has been practised extensively by industry to reduce rising energy costs, but is seen to have a one time benefit. Once achieved, conservation only renormalizes the curve of growing demand. For domestic situations it is found that conservation can be very expensive, and most householders do not have the means to pursue it either for its ideological value or its possible later financial benefits, which after all may never materialize.

Likewise, the so-called soft energy options, principally solar and wind, have been unable to compete economically with central station power plants. Their sources of energy are of low density. Therefore they require large arrays of generating capability, with high land costs and capital costs. They are only available part of the time, when the sun shines or the wind blows. This means that either they must be superposed on a complete electrical industry that can supply the entire electrical demand when solar power or wind power is unavailable, or they must be supplemented with costly energy storage systems. The soft energy options have been unable so far to overcome these disadvantages, and it may be that large scale use of solar power or wind power will never occur unless single-minded advocates succeed in eliminating the less costly alternatives.

Most electricity is now generated through burning fossil fuels: coal and to a lesser extent oil and natural gas. A number of environmental problems have been identified as results of burning fossil fuels. The major adverse effects are atmospheric pollution, acid rain and possible greenhouse warming of the Earth. To these must be added the large amounts of carcinogens and heavy metals, such as mercury, lead and uranium, emitted in smoke from the burning of coal, with serious health effects. Furthermore, the burning of fossil fuel depletes carbon reserves that have been formed over hundreds of millions of years. From a practical standpoint, these reserves can never be replaced.

A number of international conferences have been held to consider the implications of such adverse effects, and to take up the question of alternative strategies that can have lesser consequences. In the conclusions of the conferences, the nuclear option has sometimes been dismissed or skirted for reasons associated with the acceptability of nuclear energy.

All comments on the possibility of increased use of nuclear power in supplying electricity recognize that nuclear power plants do not generate the undesired products that are released from fossil fuelled plants. Nuclear plants do not emit CO_2 or other greenhouse gases, do not release chemical compounds that cause acid rain, and generate no smoke containing carcinogens or heavy metals. As is well known, nuclear plants and their associated nuclear fuel cycle can and do release some radioactive material, but this is readily managed, and in normal operation the amount of such material released is held to very low and harmless levels.

The problems that the conferences associated with nuclear plants are safety, nuclear waste disposal and the possible misuse in proliferation of nuclear weapons. Because of the importance of the central question of the supply of needed amounts of electricity in the future, the International Nuclear Safety Advisory Group, INSAG, which advises the Director General of the IAEA on nuclear safety questions, has taken up the question of the safety of nuclear power, past, present and future. This encompasses the safety of the entire nuclear fuel cycle, including the disposal of the high level nuclear waste generated in the operation of nuclear plants. The result is incorporated in the report INSAG-5, The Safety of Nuclear Power, which is now in the process of publication and should appear before the end of the year.

I wish to bring before you this afternoon the principal analysis and conclusions of this report. They relate to power plants of specific types, those that we expect will continue to be built at reduced rates for the present, but to a greater extent as time goes on. These are plants that use nuclear reactors cooled and moderated with light or heavy water. INSAG has analysed the current level of safety of these plants and has extrapolated that state to the future, when evolutionary trends in design will have taken further advantage of improved technology and of lessons from the past; such principles had also guided INSAG's previous publication, Basic Safety Principles for Nuclear Power Plants. The analysis draws heavily on the observation that the Basic Safety Principles have been widely adopted and are being followed by the nuclear industry throughout the world, either directly or indirectly through diffusion of culture.

The analysis of the safety of present day light and heavy water reactor nuclear plants is made in two ways. The first is examination of the historical record. The second is probabilistic safety assessment.

INSAG-3 had proposed a safety target for existing nuclear plants, which was a likelihood of occurrence of severe core damage that is below about once in 10 000 reactor-years. An associated target was that accident management and mitigation measures should reduce the probability of large off-site releases requiring short term off-site response to less than once in 100 000 reactor-years.

Approximately 5000 reactor-years have now been accumulated with commercial nuclear plants cooled and moderated with light or heavy water. By the end of this decade that number will have grown to nearly 10 000 reactor-years. Only one water reactor plant has experienced a large accident leading to severe damage to such a reactor core; this was the accident at Three Mile Island.

An argument can be made that the Three Mile Island nuclear plant was not operated in accordance with modern safety standards, and that would be true. But to ignore Three Mile Island in the statistical record for this reason would not be appropriate. Until the accident took place it had been generally assumed that the plant was being operated safely.

The record is then one severe core damage accident with no off-site effects in about 5000 reactor-years. At first sight that is not quite as good as INSAG's target for existing plants, which is that there should be no more than one severe accident to a reactor core in 10 000 reactor-years, but statistically it is not inconsistent with that target. Year by year, the record will approach the target more closely if, as expected, no further severe accidents occur.

INSAG's companion target is phrased in terms of the need for off-site protective measures. None were necessary at Three Mile Island, although for a time poor understanding as to what had taken place caused measures to be considered. So there have been no requirements for off-site protection from accidents over the 5000 reactor-years, against a target of no more than one in 100 000 reactor-years. Clearly, the historical record is far too short to be helpful, and many years must pass without a need for off-site protective action before the record can be said to support this INSAG target.

Probabilistic safety assessment (PSA) must be used with caution in assessing the level of safety achieved, but is can be used in this way when its limitations are recognized. The most dependable results are obtained when several plants with dissimilar features are analysed, because common conclusions are less subject to systematic error from common input data.

The methods and results of PSA have recently been given a searching review in the United States of America, in a report by the Nuclear Regulatory Commission numbered NUREG-1150. Results were presented from new PSAs on five US nuclear plants, developed through the use of methods that produced improved estimates of the effects of uncertainty in input data. The depth of analysis used and the international peer review that the report received place the results of NUREG-1150 in a class separate from and above other PSAs. The conclusions relevant to the INSAG targets are given in Table I.

The presentation of results in NUREG-1150 did not permit a direct estimate of the probability of requiring off-site action. Therefore those values in Table I are estimates of the probability that an accident will occur causing one or more subsequent cancer fatalities. This is a conservative substitute for the INSAG target.

All of the plants analysed in NUREG-1150 appear to better the INSAG target for the expected frequency of core damage for nuclear plants of the present generation, i.e. core damage less than once in 10 000 reactor-years. All but Sequoyah meet or better the second target, of need for off-site action less than once in 100 000 reactor-years. Sequoyah misses by a factor of two, which is well within the uncertainty in estimates.

The original analysis for Zion identified one type of accident as the major contributor to the risk, causing the total probability of core damage to be greater than once per 10 000 reactor-years. For that reason, modifications are being made to Zion to avert this exceptional sequence and to reduce the estimated probability of severe core damage to the value 0.6 per 10 000 reactor-years in the table. This illustrates how improvement in the safety of a plant can be a result of its PSA, becoming one of the most important benefits of the methodology.

Unfortunately, it is believed that several nuclear plants with water reactors have probabilities of core damage an order of magnitude higher than the INSAG target, because of inadequate safety systems or specific design weaknesses that have not yet been corrected or compensated. National regulatory programmes assisted in some cases by international programmes are actively pursuing their improvement. It may be that within the accuracy of PSAs even some of these plants would really meet the INSAG targets, but in the interest of conservatism, INSAG believes that when any plant does not seem to meet the safety target, it should be improved accordingly.

From examination of the historical record and the results of probabilistic assessments, INSAG has concluded that with certain exceptions, light and heavy water nuclear plants of the current generation have levels of safety in reasonable agreement with the INSAG targets.

While the absolute values of probabilities calculated with PSA are not as precise as one would like, the trends with time are more meaningful. A report has been published by the Nuclear Regulatory Commission in the United States,[1] comparing the current rate of accident 'precursors'[2] with that in previous years.. This has been used in estimating the probability of the severe accidents themselves. It was concluded that the average probability of core damage is now much lower than it was before the lessons learned from the Three Mile Island accident were implemented in operating plants. It was estimated that the probability of core damage for a single plant has been reduced from a value of the order of 1 per 1000 reactor-years before 1979, to a value now between 1 per 10 000 and 1 per 100 000 reactor-years.

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[1] MURLEY, T.E., "Nuclear power plant safety experience in the United States", Proc. LAS/ANS Topical Mtg Rio de Janeiro, 1991.

[2] An accident precursor is an equipment failure or a mistake that could have been the cause of a severe accident if it had not been compensated or corrected by defence in depth.

The implication is that improved culture and the benefits of technology have already improved the safety of water reactors in the United States above the level INSAG has proposed as a target for existing plants, towards the target proposed for future plants, which is a level ten times higher than the target for existing plants. Since in most of the world the same improvements in safety have been made, the conclusion can be extrapolated accordingly.

Therefore, INSAG has further concluded that similar plants to be built in the future, which should fully meet the principles enunciated in INSAG-3, will be safer still, and should meet the long term safety target that INSAG has proposed.

The significance of meeting this long term target must be fully understood in ordinary terms. In a world with 1000 nuclear plants of a future type, more than twice as many plants as now existing, 100 years on the average would elapse between accidents of the Three Mile Island type, which cause no harm off-site. A millennium on the average would pass between accidents requiring public protection.

INSAG has recognized, however, that the safety of the nuclear option must be evaluated in terms of its complete fuel cycle, not simply the electricity generating plants. The other parts of the cycle include the front end activities, mining and the chemical and physical processing of uranium into fuel elements, and the back end activities, spent fuel storage and disposal. In some countries, the last activity includes chemical reprocessing, which makes part of the contents of the spent fuel reusable and is capable of greatly reducing the volume of waste to be disposed of.

The safety of these activities was reviewed, and it was concluded that the adverse effects on human beings from the front end and the back end of the nuclear fuel cycle pose a minor part of the total radiological risk from nuclear power, which is itself very small compared with that from the normal exposure of people to cosmic rays, radon and direct radiation from the Earth.

This analysis is supplemented by an appendix to the report which reproduces data on the relative risks of alternative methods of generating electricity, extracted from Key Issues Paper 3 presented at the Helsinki Senior Expert Symposium on Electricity and the Environment.

The conclusions can only lead to the view that nuclear power is now impressively safe. Yet INSAG notes that the current slowdown in growth of the nuclear power industry offers an opportunity to further consolidate nuclear plant safety by means of design improvements for future reactors. This process could start by incorporating more naturally the safety features that have been added onto earlier designs. Plants built according to such restructured designs may be less expensive in the long run, may be less complex, and may be more readily accepted by the public.

Beyond this process, which would consolidate past gains, is a possibility of further substantial improvement of the level of safety of nuclear plants through future design features. INSAG proposes a number of features of designs of future plants, which would build on and even exceed in important respects the safety capability offered by the Basic Safety Principles of INSAG-3.

It is believed that the level of safety that could be achieved from these advances would be substantially higher even than that attached to the previously stated INSAG targets. The safety would exceed that of competing means of generating electricity by at least a factor of ten, and would reach a level unprecedented in this modern technological world. However, INSAG also believes that implementation should take into account the need to devote society's resources to the most fruitful means of reducing risk of all kinds, not only that from nuclear power.

The advances being made in design of nuclear power plants are discussed in INSAG-5. Evolutionary improvements are being supplemented by further design concepts aimed at simplification and introduction of passive safety features. More radical redesign concepts are also proposed in a number of countries. These will be discussed in the course of this conference.

I shall summarize all of this by repeating the conclusions with which INSAG closes its analysis, though some may be repetitions of what I have already said.

INSAG notes and accepts the widespread view that the demand for energy worldwide will grow, particularly as developing countries seek to elevate the lifestyles of their people. Electricity will continue to be a growing component of the energy mix, increasing more rapidly than the total energy production. The potential of renewable energy sources and conservation measures is insufficient to meet the likely demand, and exploitation of all acceptable means of energy production will be necessary, particularly of electricity.

It is noted, moreover, that there is growing acceptance that emissions from generating plants that produce electricity through burning fossil fuels cause extensive environmental harm. In contrast, nuclear energy causes no such emissions.

Yet there is a widely held fear of nuclear power generation and of related activities. Such concerns must be shown to be unfounded if the nuclear option is to be exploited fully to mankind's benefit.

INSAG has defined safety objectives for both existing and future nuclear plants, such that the risk attached to their operation should be acceptably low, and has defined safety principles, the implementation of which would secure the objectives.

In spite of public concerns, the need for expanded electricity production has led to continued construction of nuclear plants throughout the world, albeit at a rate lower than that of a few years ago. All relevant signs indicate that, at least for some time, new nuclear plants will continue to be evolutionary developments from the light and heavy water cooled and moderated plants that are the principal types in use today.

INSAG has reviewed the available information on safety of these types of existing plants, seeking to determine how closely existing plants of these kinds meet INSAG safety objectives. It is found from the historical record that nuclear plants of the light and heavy water types that are likely to continue being built are now in approximate conformance with the INSAG safety targets for plants in current use. Recent state of the art probabilistic safety analyses also support this conclusion, although there are apparently some outstanding exceptions of nuclear plants requiring improvement to attain this safety status.

The evolutionary descendants of current types of water reactor plants that have been designed in accordance with the Basic Safety Principles in INSAG-3 and should be operated in accordance with these Principles, should meet the even more stringent safety targets proposed by INSAG for future plants. This would mean that in a world with a thousand operating nuclear power plants of the advanced designs, a number more than twice that of plants now existing, an accident severely damaging some nuclear plant somewhere should not occur more often than once a century, and an accident anywhere threatening to harm people should not occur more often than once in a millennium.

On reviewing the other phases of the nuclear power generation cycle, INSAG finds no basis for concern regarding them, especially considering the care they now receive. In particular, this conclusion has been reached in connection with disposal of nuclear waste, a topic that arouses concern in many quarters.

INSAG also notes that if society so wishes and is willing to devote the necessary resources, even more improvement of safety of nuclear plants is possible. Designs of plants that will have evolved further from the present types may be suited to such gains, as may other more radical designs that have yet to be proven out in detail.

INSAG concludes that there is no technically valid reason to reject a role for nuclear power in meeting society's needs for an expanding supply of electricity, and further, that the fullest exploitation of the nuclear option to alleviate environmental concerns should be pursued.

TABLE I. RESULTS FROM NUREG-1150

	Core damage probability per 10 000 reactor-years	Probability of requiring off-site action per 100 000 reactor-years
Surry	0.2	0.3
Peach Bottom	0.02	0.3
Zion (modified)	0.6	1.0
Sequoyah	0.6	2.0
Grand Gulf	0.4	0.1

CHAPTER II

ISSUE OVERVIEWS, SUMMARY DISCUSSIONS OF SUBSTANTIVE TOPICS, CONCLUSIONS AND RECOMMENDATIONS

ISSUE I: FUNDAMENTAL PRINCIPLES FOR THE SAFE USE OF NUCLEAR POWER

1. OVERVIEW

(Summary of Background Paper for Issue I, Appendix 1)

The primary objective of nuclear safety is to protect individuals, society and the environment against radiological hazards that may arise from the use of nuclear power. Radiation protection and accident prevention and mitigation objectives support this primary objective, and are achieved by a defence in depth strategy.

The protection that has been achieved during the normal operation of nuclear power plants is such that the contribution to both individual and collective radiation doses is now negligible by comparison with those from natural sources and most other artificial sources. Further improvements are, however, possible; they will depend on the integration of strategies addressing the whole spectrum of design, operation, maintenance and administration.

The defence in depth concept is a fundamental characteristic of the design and operation of nuclear installations. Prevention of accidents is the first safety priority. Designers also assume that component, system and human failures are possible and incorporate engineered safety features to counteract such failures, and ensure that installations are tolerant of such errors. Accident management strategies and effective off-site emergency plans are also developed to deal with accidents which are extremely unlikely, but which have a potential for major radiological consequences.

Improvements in accident management could be obtained by improving off-site emergency measures, but to reduce the socioeconomic impact the best additional level of defence is realized by placing more emphasis on effective on-site accident management. Off-site emergency planning continues to have value, but opinions differ as to the extent and nature of planning required. However, the implementation of improved severe accident management and release mitigation capabilities in both existing and future reactor designs should reduce by an order of magnitude the probability of a large off-site release requiring a short term off-site response.

The assessment of the safety of nuclear plants is provided through the application of analytical tools such as Probabilistic Safety Assessment (PSA). This is a powerful methodology permitting assessment of the probability of a whole range of consequences of mishaps. The strength of PSA in safety assessment is in determining weak points in nuclear power plant design and operation, and in providing indicators as to changes which would provide safety improvements. However, there are limitations to PSA techniques which still require attention.

The through-life safety of nuclear power plants requires the application of a well developed safety culture, where the personal dedication and accountability of all individuals involved with nuclear installations provide the means to ensure safety. Such attitudes can only be cultivated if the safety policy of the organization and all corporate and individual responsibilities are defined and supported by an adequate mechanism to implement, promote, maintain and monitor the effectiveness of the policy. The necessary personal attitudes can only develop if the policy and the management structure enable the managers to demonstrate their commitment to safety culture achievement.

The responsibilities of governments, regulatory agencies, operators, and advisory bodies must also be clearly defined and all parties must accept their responsibilities. The responsibilities of regulators and other parties need to be separated to ensure that regulators retain independence as a safety authority and are protected from undue pressure. While the ultimate responsibility for the safety of a nuclear installation rests with the operator, quality assurance programmes need to be applied by all organizations.

The independent assessment, in-depth periodic safety reviews and monitoring of operational experience at national and international level form an essential part of the process of verification of safety. The process of maintaining adequate through-life safety is assisted through the application of lessons learned from operational experience feedback. Indeed, the application at local and national level of lessons learned from events which in themselves have no direct safety significance is essential to improve the effective level of safety. The structured collection and analysis of operating experience should be used as a mechanism for improving plants, together with performance indicators which monitor the quality of operation, maintenance, staff performance and overall safety performance. International exchange of such information is practised but is not without its problems, and the efficiency and effectiveness of the collection process need to be improved. Efforts need to be focused on the dissemination of the results of in-depth analysis of events rather than distribution of unevaluated data.

The verification of safety needs to be continued throughout the life of the nuclear installation, with the operating organization carrying out periodic reviews of safety. Such reviews should consider cumulative effects of modifications, changes of procedures, component ageing, operating experience and technical developments. Additionally, the regulatory bodies should ensure that systematic programmes exist to provide adequate coverage of the issues and should assess the quality of the results, while the quality of safety management, operations and maintenance should additionally be subject to outside peer review.

A comprehensive set of tools has been developed to make nuclear energy a safe technology, and it is now reasonable to focus effort on encouraging the wider use of the available tools, and on improving the procedures for applying the tools. For example, the procedures for implementing and monitoring the adequacy of safety culture need to be improved. Also, attention needs to be given to aiding the process of interpretation of PSA results. Additionally, further development of international objectives, criteria and standards should focus on their interpretation and application.

International collaboration also needs to be strengthened to expand the areas of common understanding and resolve remaining differences. While some channels exist for the exchange of information on completed safety analyses, it would be reasonable to broaden this exchange and establish a universal system for presentation of information about relevant findings of safety analyses.

At many plants periodic safety reviews are used as a basis for identifying major deviations from state of the art safety levels and for deciding on necessary backfits, and such reviews should be applied to all plants. The development of some guidance as to where claims for the safety of backfits are reasonable and where they are not, would also constitute a substantial advance. It is also important to recognize that technological solution does not automatically disqualify the existing technology, and the coexistence of different generations of plant should be accepted by the decision makers and explained to the public.

There remains a significant gap between the public perception of the risks and benefits of nuclear power and the evidence of low risks obtained from the corresponding technical assessments. There is also a lack of common understanding of basic concepts such as the definition of risk. It is important for the future of nuclear power that communications between regulators, operators, the scientific community and the public are improved.

It is concluded that progressive establishment of bilateral technical relations and information exchanges can help to ensure that adequate safety criteria are applied. However, the question remains as to what extent binding international standards and regulations can be applied across national boundaries.

2. SUMMARY DISCUSSION OF SUBSTANTIVE TOPICS

(Rapporteur's Report for Issue I)

The session discussed the four main topics introduced in a lively and constructive manner. No secondary topics were introduced.

Topic No. 1

Safety objectives and standards: What should they cover and is there a need for more binding international safety standards and regulations?

Findings:

It was pointed out that a clear distinction should be made between safety goals and objectives and binding formal standards and regulations. Indeed a three tiered structure can be discerned:

- long term safety goals or aims;
- medium term objectives as a basis for specific action plans to reach long term safety goals;
- formal standards and regulations being the means to achieve goals and objectives.

There was widespread agreement that existing, internationally agreed safety and radiation protection objectives, tools, methods and standards have reached such a state of maturity that if the quality of implementation is high, a very high level of safety will be achieved. Nevertheless some further development is warranted. Also, it is the achievement of this safety level at each plant that should be the final objective.

There was not a consensus that this could be achieved by the development of more binding international standards. However, there was agreement on the benefits of more exchange of regulatory experience, methods of verification of safety and use of peer reviews.

It was strongly stressed that no measures taken in the international arena should take away or be seen to take away any responsibility for maintaining and developing safety from manufacturers, operating organizations and national regulatory bodies.

There was, however, an overall agreement to move forward in a very cautious way towards an international safety regime, based on some general safety principles, methods of verification, exchange of experience and peer review. This regime should build on existing IAEA documents and activities as well as activities of other international organizations such as the OECD/NEA and WANO.

There was a widespread, strong feeling that binding, detailed international standards would be impossible to verify and enforce and could be counter-productive to safety by hindering flexibility and development.

Topic No. 2

Approaches to systematic safety reassessments throughout the operational lifetime of nuclear installations: Should periodic safety reviews be used to supplement or replace continuous assessment programmes? Should some combined assessment and review approach be used and if so, what form should it take?

Findings:

It was agreed that systematic safety reassessments have three objectives:

- to confirm that the original safety intentions are still met;
- to identify any possible future life limiting features;
- to review the safety level with respect to new criteria, based on operating experience and technical development, and to identify safety improvement measures which are necessary and any further measures which are justified.

There was consensus that the safety level of a nuclear installation should be reassessed in a systematic manner throughout the operating life of the installation, and also that the basis of such an approach should be the use of continuously ongoing safety assessment programmes. Analysis of operating experience and plant specific, living PSAs were emphasized as important tools for use in such reassessments.

Also, there was agreement on the benefits of periodic, plant specific reassessments with longer intervals, standing back and taking a more long term overview. Periodic reassessment may also help in transferring knowledge about the plant safety case to new generations of operators and plant management. The appropriate balance between continuous and periodic safety reassessment programmes has to be decided on a national basis.

There was also agreement that better exchange of findings and conclusions from analysis of operating experience and PSAs should be encouraged. Compilation of data on systems and component reliability should preferably be a matter for groups of owners/operators, whereas international organizations such as the IAEA and OECD/NEA have an important role to play in exchanging findings and conclusions from systematic analyses of operating experience, in particular human and organizational performance, and to promote such systematic analyses.

Topic No. 3

Emergency planning as a part of the total defence in depth concept: How may requirements for emergency planning be affected by implementation of improved severe accident management and release mitigation capabilities in both existing and future reactor designs?

Findings:

There was a strong consensus expressed on the need for emergency planning as a last line in the defence in depth strategy. Preparedness for supplying prompt information to the public and some type of confirmatory off-site radiation measurements are basic components. There may be some scope for relaxation of detailed and extensive planning in the future as plants become safer, especially taking into consideration the effects of improvements in severe accident management and release mitigation measures.

Nuclear emergency planning should be harmonized, as far as possible, with planning for other types of emergencies, e.g. at chemical plants. There was consensus on the need for more international exchange of information and discussion on basic criteria for emergency planning, e.g. the choice of reference accident scenarios for various reactor designs and sites.

Topic No. 4

What are the desirable components of information dissemination, information exchange and communication activities with political decision makers and the public? For example, how should issues such as "are our (or our neighbour's) nuclear installations acceptably safe?" be addressed?

Findings:

There was general agreement that the fundamental principles for the safe use of nuclear power are not the exclusive concern of the regulators, owners, operators and vendors of nuclear installations. The basic principles, as well as the safety level achieved through their implementation at each particular plant, must also be communicated to, and understood by, political decision makers, investors and the general public as a basis for their acceptance of a nuclear power programme and their consideration of energy policy options. Such communication and understanding are essential not only in the national context, but also with respect to reactors in neighbouring countries, because of possible transboundary effects of accidents.

There was also general agreement that communication on nuclear risk and safety matters should never be a one way process; rather the creation of multiple networks for communication with various groups was recommended. It was also pointed out that public acceptance has to be based mainly on trust in the professionals controlling a complex technology, rather than on an attempt to make the general public understand the technology. This trust has to be earned by utilities and regulators on the basis of demonstrated performance and attitudes in safety matters and demonstrated transparency and openness to peer reviews.

It was also recognized that if utilities wish to obtain public acceptance of nuclear power, their information has to be based rather on demonstration of benefits and operational safety performance than on simply an understanding of low risks.

Particular attention should be paid to explaining that the introduction of new reactors built to higher safety standards does not necessarily make older reactors unsafe.

In view of the findings reported above, there was no consensus that more binding international standards would improve public acceptance - it is the local performance that counts.

3. CONCLUSIONS AND RECOMMENDATIONS

(Co-Chairmen's Summary)

The conference's Conclusions on the Fundamental Principles for the Safe Use of Nuclear Power are the following:

1. There was an overall agreement to move forward in a deliberate but very cautious way towards an international safety regime, based on some general safety principles, methods of verification, exchange of experience and peer review. This regime should build on already established IAEA documents and activities as well as activities of other organizations such as the CEC, OECD/NEA and WANO. An international framework convention could be one option for a mechanism to eventually formalize this regime.

2. There were, however, some fundamental disagreements on the merits and demerits of binding international standards of a detailed prescriptive nature, particularly standards to be conformed with, by which accuracy or quality could be judged, rather than general principles.

3. Moreover, further development of international safety objectives, principles and standards should focus on their interpretation and application.

4. There was general agreement that safety should be enforced primarily at the national level, by conscientious application of existing safety principles, standards and good practices at each plant, and within each national regulatory body, making the best use of national legal frameworks and working practices.

The conference therefore recommended that:

The IAEA should set up a small group of experts from relevant organizations and Member States to make recommendations to the Board of Governors as soon as possible on ways in which the IAEA can make a further step towards the achievement of a high level of safety at all nuclear installations, building on the IAEA's existing documents and activities. The group should examine the merits and demerits of various options leading to a formal framework to promote an international safety regime, within which Member States could commit themselves to maintaining such a high level of safety.

ISSUE II: ENSURING AND ENHANCING SAFETY OF OPERATING PLANTS

1. OVERVIEW

(Summary of Background Paper for Issue II, Appendix 2)

While many existing plants currently operating in Member States are considered to be in the best operating plant group, some plants may have deficiencies. The desired goal is to raise the safety performance of all plants to the standard of the best. Fundamental to the development of this paper was the rationale that plants designed and constructed to current standards can be operated safely.

The necessary high levels of operational safety are achieved by implementation of a coherent set of criteria, standards and practices, coupled with continuous verification that the appropriate level of safety has been reached and is maintained. A number of practices and principles are involved in achieving and maintaining a high level of safety and these are discussed below. These practices and principles should be should be considered as a set. Prioritization among the set should be based on Member States or invidiual plant reviews regarding degree of implementation.

In order to ensure that the plant is operated in a safe and efficient manner, all plant personnel need to be given adequate training. One concern is that the status of training varies widely among operating organizations throughout the world and that the operators' basic understanding of plant characteristics needs to be improved.

The use of simulators, training and requalification of staff and constant reviews of existing operating practices will aid the training process. However, a fundamental training standard should be encouraged, worldwide, which would ensure ongoing training for all nuclear power plant staff and ensure an ongoing commitment to regular training. The use of international training workshops and provision of specialized training for regulators as part of the training programme are advised. The planned improvement of the OSART process and exchange visits from operating organizations should also be implemented.

An additional problem is that there is a reduction in enrolment in university courses for nuclear occupations, and a corresponding curtailment of suitable engineering programmes, reducing the supply of suitably educated personnel. Member States need to take action to rectify this shortfall, with support from international bodies, such as the IAEA.

The analysis and feedback of operating experience are mechanisms for ensuring and enhancing through-life plant safety. However, there are significant differences between the level of utilization of existing practices between Member States, and improvements and unification of the handling of operational feedback data are needed. Support should be given through the involvement of international organizations to promote the exchange of information on the best available processes for collecting, analysing and using operating experience. Particular emphasis needs to be placed on the evaluation of human factors and root cause analysis, and on improving the speed and efficiency of communication of evaluated information between Member States.

Probabilistic safety analysis (PSA) can be particularly effective in assessing and managing safety related operations and plant changes. However, PSA applications require considerable effort. Some interested users do not have the necessary technology; there is a lack of specific equipment reliability data, and misuse of the technology through lack of training.

The priorities should be to encourage the use of PSA in operating plants not yet using the technology; to provide international support to aid the achievement of excellence in the use of PSA in all nuclear power plants; and to reduce PSA limitations associated with issues such as human factors, management effects and common mode failures.

With regard to through-life verification of plant safety, the current status of verification varies considerably among operating organizations. For example, the use of self/independent and continuous verification plus safety performance indicators is not adequately understood and Member States need to encourage their nuclear organizations to make better use of such processes.

One of the principal root causes of failures is human error, which is often the initiator of incidents. The introduction of the concept of a safety culture is advised as an aid to minimizing such errors by ensuring that corporate management and individuals are made aware of their safety responsibilities. However, methods for collecting, analysing and using human performance data need to be improved. Additionally, international co-operative activities are recommended as a mechanism for achieving a wider understanding of the human factors issues.

Continued safe operation throughout the life of a nuclear power plant requires engineering support, particularly with regard to issues such as ageing of plant, the implications of fire and external events and the use of more sophisticated technology, and there is concern that inadequate support is provided at some plants. Member States are advised to assess the level of engineering support required to raise the standard of their plants to that of the best operating plants. International agencies are also encouraged to provide guidance on the requirements for engineering support and to facilitate the dissemination of the requirements through international exchange visits.

The best plants may be approaching practical limits for the reduction of exposure to radiation, releases, and solid waste, but substantial improvements can still be achieved at many plants. International peer pressure should be brought to bear to improve practices at poorer performing plants.

With the increasing age of the current generation of plants, the impact on safety of ageing processes needs to be considered. Considerable work has been done, and is continuing, to understand the significant ageing mechanisms in nuclear power plant which give rise to the degradation of safety significant components, systems and structures. Studies performed by the nuclear industry indicate that a significant potential exists for extending nuclear plant life. It is recommended that the IAEA should continue and enhance its activities to promote the integration of information on the evaluation and management of safety aspects of nuclear power plant ageing into a common knowledge base.

Currently the process of backfitting of design improvements is implemented through different processes among Member States. While backfitting is a necessary process to methodically implement the lessons of experience to reduce risk, uncontrolled imposition of backfits may reduce overall safety. The IAEA should promote the exchange of experience and methodology for implementing backfits from which guidance should be developed for use by Member States.

Many Member States and utilities have implemented measures to adequately communicate event information to the media and the public. Public trust is dependent on open communication. The gravity scale initiated by the IAEA and NEA is intended to assist in improving communications. However, there has been some misunderstanding by the media and the public about numbers of low graded events. International organizations need to support the initiatives aimed at educating the public and news media towards a better understanding of the adequacy of nuclear safety. Care should be taken to prevent misuse of such scales, designed for near term communication to the public, as long term scientific measures of plant safety performance.

With regard to core damage prevention, there are significant differences between the status reached in Member States. Generally, only countries with large nuclear programmes have been able to develop and implement accident management strategies. International effort should be directed towards providing adequate accident management strategies to all Member States. Additionally, the results of development and implementation of such strategies should be made available and independent review of individual plant internal and external emergency plans should be implemented.

In some instances the lessons learned from nuclear incidents have yet to be fully implemented. Although an international system is in place, the necessary infrastructure for notification and assistance does not exist in all Member States to assure its timely use. Co-ordination of actions between countries with plants at or near their borders has not been accomplished and Member States are advised to ensure that adequate planning and co-ordination activities are developed.

Strong regulatory bodies with the necessary independence from the production side of nuclear energy should be developed in all Member States to provide review and overview capabilities to ensure adherence to safety standards by utilities. It is evident that there are deficiencies and those governments which have not set up such regulatory capabilities should do so. The IAEA should provide assistance in this activity.

It is concluded that Member States should assess their level of operational safety performance using the above practices and principles. Where deficiencies are identified, corrective actions should be initiated. Where good practices are identified they should be made available for emulation. The overall objective should be to strive for and maintain excellence.

2. SUMMARY DISCUSSION OF SUBSTANTIVE TOPICS

(Rapporteur's Report for Issue II)

The Background Paper prepared by the expert working group and the comments received from Member States made clear that most nuclear power plants operating today meet current quality and safety standards, and that they can achieve and maintain a high quality of operational safety. The discussions addressed the case of the small fraction of plants that do not achieve that high level of safety and so constitute a main safety issue. How can they be identified and how can the safety performance of all of them be raised to the standards of the best?

Plants that do not meet current safety design and construction standards will be discussed in Session III. Some conclusions should be common to both sessions.

Topic No 1

What should be the approaches by utilities and regulatory organizations in order to promote excellence in safety performance of all nuclear power plants?

Findings:

It was generally agreed that all 15 areas identified in the Background Paper were important to this aim. They constitute a coherent set of criteria, standards and practices, in accordance with the contents of IAEA documents, such as the INSAG-3 and INSAG-4 reports.

On the utility side, they include:

- the need for acceptance of full responsibility for the safety of the plant with the appropriate commitment and involvement of the senior staff;
- the need for education, training and motivation of personnel, including a competent technical capacity;
- the use of experience analysis and feedback at the appropriate level of responsibility;
- plant maintenance, replacement parts and configuration control developed to an adequate level;
- independent in-house safety evaluations and adequacy of quality assurance programmes.

It was emphasized during the discussions that the continuous verification of the plant operational safety level, by incident analysis, use of performance indicators and of specific probabilistic safety evaluations based on operational experience, internal audits and peer reviews, would act as an early warning system for possible safety degradation involving an increased risk of accident.

The discussions underlined the importance of the role of a strong competent regulatory body, with enough power to make it independent from undue pressures. It is essential that there should be no confusion of responsibilities between the operating organization and the regulatory body, and that open and trustful relations should be established between the two sides.

The effectiveness of the regulatory system should be assessed with reference to the operational experience record and by use of international peer reviews.

Topic No. 2

What more can be done to strengthen national commitment to safe operation of nuclear power plants?

Findings:

The conference generally agreed that improvements were needed among the Member States that include:

- a regulatory regime with adequate expertise and independence and a clear understanding of its responsibilities and authority;
- provision of information to the public so that a transparent safe operation is shown, and so that when this is not the case corrective actions are taken;
- the regulatory authorities and utilities doing all they can to stimulate, develop and enhance a safety culture in each utility and nuclear plant;
- international exchanges of successful national regulatory practices and proven programmes directed towards the goal of improving the safety of operating plants to the level of the best.

Topic No. 3

What positive actions can be taken on the international level to enhance safety in nuclear power plants?

Findings:

The first priority is that all national organizations, operating or regulatory, should have free access to all relevant information originating from foreign countries. There should be complete openness in all countries. Programmes in the IAEA and OECD/NEA aimed at such exchange and dissemination of information should be supported.

On the other hand, it was stressed that international organizations should make sure that their actions cannot be interpreted as relieving the national organizations of any part of their own responsibilities*. Actions of international organizations must be reviewed, assessing the quality of the national performance, and assisting Member States in achieving the highest possible safety level. This applies to the present IAEA programmes as well as to future new programmes (see Topic No. 4).

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* One of the governmental responsibilities is to provide the national regulatory body with appropriate financial resources to sustain its activities at a proper level.

It was agreed that the IAEA should launch a programme of information to the public about the operational experience of nuclear power plants, based on the data collected in the IRS and INES programmes, keeping in mind the need for adequate speed of delivery and full transparency of such information.

During the discussions it was suggested that the IAEA could provide, as a service to Member States, the assistance of an international inquiry team in the case of an accident with large impact on public opinion, in order to support the credibility of the national authorities. This was generally considered as being neither feasible nor desirable.

Topic No. 4

What should be the roles of the various international organizations in addressing the safety of the world's nuclear power plants?

Findings:

WANO has recently been created and is starting to develop its activities. It is necessary that they move forward into specific activities such as the technical support of weak organizations, development of good practices for the overall operation and independent peer reviews of operating organizations. Although some of these activities could overlap in the future with ongoing programmes of the IAEA, for the time being this problem does not exist. The long term goal would be for WANO to dedicate its efforts to operators.

The IAEA could then dedicate its activities mainly to the government organizations. It is essential that the countries review their activities in light of the international consensus that exists in relation to the topics addressed in the Background Paper.

At the same time on going programmes for safety review at the international level should be pursued and all countries should participate in these programmes on a regular basis.

The IAEA Board of Governors should consider the appointment of a standing committee that would regularly review the results of national and international activities so that the necessary remedial actions would be undertaken.

3. CONCLUSIONS AND RECOMMENDATIONS

(Co-Chairmen's Summary)

The conference's Conclusions on the Issue of Ensuring and Enhancing Safety of Operating Plants are the following:

1. The design and construction of the vast majority of operating plants in the world today meet current quality and technology standards and the means to achieve and maintain a high operational safety level exist and are being practised in these plants.

2. The plants which do not meet the highest performance levels and pose the largest safety risk must be identified and improvements undertaken so that their safety performance is raised to the level of the best.

3. This task is primarily a national responsibility but it should be facilitated by assistance from the international community. The necessary information exchange of good operating practices is the first step in ensuring that corrective measures are implemented and verifications performed. The necessary principles and practices to be applied in these activities are in existence or are being developed as indicated in the Background Paper and conference discussions on the substantive topics. All countries should participate.

4. International mechanisms to assist Member States are in existence but further development is required and should be pursued so that all countries participate in these programmes on a regular basis.

The conference therefore recommended that:

(1) The IAEA through its Governing Bodies should develop a more formalized overview process which would review the results of the national and international activities and initiate remedial actions as appropriate to achieve the objective of a uniform high safety performance in all operating plants. Further strengthening and use of processes such as ASSET and OSART missions should be developed as part of that strategy.

(2) The IAEA should also improve its public information mechanisms to ensure a prompt distribution of accurat,e authoritative information on all nuclear power plant events on a worldwide basis.

ISSUE III: TREATMENT OF NUCLEAR POWER PLANTS BUILT TO EARLIER SAFETY STANDARDS

1. OVERVIEW

(Summary of Background Paper for Issue III, Appendix 3)

The safety standards current in many countries may be significantly different from those applied to its operating plants when they were designed and the extent of such differences may also increase with time. Older plant may not fully meet new concepts and standards, but because of conservative design and excellence of maintenance a demonstration of adequacy of safety is still possible. However it is evident that, for a few older plants, the acceptability of the safety level is questionable and a solution is required.

Factors which may reduce the safety margins of older plant include ageing, plant incidents and design changes, while conservatism in the original design and changes to the operating regime can provide enhanced margins. The mechanism for controlling and justifying the safety of through-life changes varies worldwide. Many countries address changes as specific issues as they arise. However, some countries have older plant which has operated for several years without consideration of changes in safety standards. There are also new plants whose safety standards do not adequately comply with current international safety objectives.

There is a growing need to demonstrate whether older operating plants are safe when judged by current safety standards. There is also concern that adequate arrangements may not exist in all countries to maintain safety in compliance with improving standards and action needs to be taken to introduce such arrangements. It is appropriate to propose a common international approach to the treatment of operating plants built to earlier standards.

Many countries have implemented systematic reviews of their older plants and in certain countries a legal requirement has been introduced for safety reassessment of nuclear installations every 10 years. While the national approaches differ in some respects, there is significant consensus regarding the need for a systematic review process, and areas of consensus include:

- all plants should have levels of overall safety which are publicly acceptable,
- operating plants should always comply with their original safety objectives where these remain valid,
- safety standards of older operating plants should be reasonably compliant with current safety objectives,
- there should be arrangements for assessing and monitoring of ageing effects.

In the absence of any commonly accepted and internationally agreed review process, the concern is that some plants may not be submitted to review until there is an accident. In contrast, where an inadequately conceived review process has been implemented, plants could be prematurely shut down. With increasing economic pressures on operators to extend the operating life of their plants, the need for an adequate safety review process is paramount. However, it is difficult to demonstrate that the processes adopted for demonstrating an adequate level of safety for plant in different countries are equally acceptable.

It is advisable that a unified approach be established to determine that an operating plant is adequately safe. Within that process factors to be considered include plant operating experience, physical plant state, safety and modification documentation and safety culture of the installation. With older plants, where there has been no systematic review process in operation, such data may not be readily available.

The acceptable level of safety also needs to be defined. This requires a consensus of opinion both nationally and internationally. The identification of what constitutes safety significant issues must form part of this judgemental process and the use of techniques such as PSA is an aid to the process.

There is also extensive experience available worldwide concerning methods for safety review and this knowledge needs to be imparted to all nuclear installation operators.

Owing to the limitations of assessment techniques applied when the plant was built, the original analysis may not have comprehensively addressed issues such as natural phenomena, external hazards or the impact of waste discharges. Guidance on their updated assessment is required and plant siting acceptability needs to be reviewed.

In addition, the adequacy of the safety culture within a nuclear plant organization needs to be determined and the extent of human factors such as staff motivation and training needs should be particularly assessed.

A structured safety review should certainly be carried out for each of the older plants in addition to the routine safety activities presently in place and a common international review framework should be developed, addressing both the structure of the initial review and that of subsequent reviews. However, the detailed conduct of the reviews should be determined by individual countries to suit national needs. Several approaches to implementing periodic reviews are possible, but whatever method is adopted the objective should be an overall assessment integrating all factors within one coherent picture.

Each Member State should develop a review plan to meet its own requirements but based upon the common international review framework, giving priority to those plants in service for 10 or more years or built to an outdated safety design concept. An example review framework is proposed which would operate in two stages. A comparison is first made with current safety objectives using up-to-date methods and actual plant data. If current safety objectives are not fully met then the actual plant status should be compared with the original safety objectives using current techniques.
The principal steps of the process are:

- make a comparison with current safety objectives,
- identify shortfalls,
- identify overall safety significance of all shortfalls,
- determine if continued operation is acceptable,
- take action to correct deficiencies or shut down the reactor.

In order to prevent severe economic or social hardship, it is essential that premature or unwarranted plant shutdowns should not be ordered. All relevant assistance to counteract such hardships should be provided by the more developed countries and by international organizations.

While the proposed review process should demonstrate the current safety status of a plant, there is also a need to address the effects of factors such as ageing, which could accrue between reviews. At each review, a study should be made to determine the remaining safe working life, taking account of factors such as ageing.

It is proposed that subsequent reviews should be undertaken at intervals of about every 10 years after the first review, or that a continuous formal programme be applied to ensure that any subsequent changes are adequately addressed as they arise. Such reviews, which should be simpler than the first, should take account of plant status, safety methods and analytical techniques current at the time of review.

In order to ensure that a consensus is obtained within the nuclear community on the structure of the review framework and that the implementation of national review plans is consistent, the IAEA is encouraged to initiate actions to address the development of processes for the treatment of plants built to earlier safety standards. Issues which need to be addressed include:

- development of guidance on how to review the safety of plant,
- achievement of consensus on the question of what constitutes an acceptable standard of safety,
- encouragement of Member States to undertake plant reviews,
- provision of assistance and guidance to Member States on reviews,
- encouragement of Member States to publish the results of such reviews,
- conducting of workshops to exchange findings and provide a forum for peer review.

2. SUMMARY DISCUSSION OF SUBSTANTIVE TOPICS

(Rapporteur's Report for Issue III)

Topic No. 1

How should reactors built to earlier safety standards be shown to be adequately safe?

Findings:

It was agreed that the safety of plants built to earlier standards needs to be justified against current safety thinking. The framework for safety reviews proposed in the Background Paper was well accepted.

The reviews should be plant specific and use current safety assessment methodology. The nine factors defined in the Background Paper, that is the safety concept of the original design, the plant's safety history, its operational experience and physical state, the management and training of the operating staff, the safety analysis, plant records and trends, and the qualification of its equipment, required for the safety assessment should be treated in a balanced way.

For poorly designed and operated plants, an immediate upgrading of operational safety based on proven safety practices has first priority and should be realized with the support of other operators representing good practices. All older plants will need to be reviewed, but first priority should be given to the most suspect plants. A plant specific PSA should be carried out to identify further improvements only after immediate and necessary improvements have been completed.

While the amount of work required for reviews was questioned, those who have already done integral safety reviews were strongly in favour of this approach, stating that the effort is worth while and pays off.

Effective regulatory control is considered as an indispensible prerequisite for an adequate review process and necessary consequential actions.

For some countries with limited capacities and expertise additional international support is necessary to strengthen both the operational safety practice and the regulatory system.

Existing documents such as NUSS Codes and the Basic Safety Principles need review, but should be applied by all. Appropriate means such as peer reviews should assure that the common international principles and requirements are applied in an adequate way.

The IAEA should give additional guidance on safety reviews and on the process required to judge acceptability. Special consideration should be given to generic issues typical for older designs, for example relating to physical separation, seismic design and containment function. Experience from Member States and from the ongoing special programme for the VVER 440/V230 should be evaluated systematically and used for the development of planned documents within the NUSS programme and for related activities in international organizations.

Topic No. 2

Should an international consensus be sought to define a minimum level of safety to be met by reactors built to earlier standards?

Findings:

There was a consensus that a minimum level of safety should be defined and established internationally which all plants must meet. The definition of a minimum level of safety should include consideration of the ideas presented in the Background Paper, NUSS standards and INSAG documents, as these sources already represent international experience.

Judgement of the level of safety achieved should include the nine factors identified in the Background Paper.

An international workshop was proposed on current practices and experiences for the judgement base and on the main parameters to be taken into account when deciding on the acceptability of further operation.

Topic No. 3

What should be the role of the various international organizations (IAEA, OECD/NEA, WANO) in the implementation of recommendations on these topics?

Findings:

The conference considered that there was a need for assistance to Member States from these international organizations not only in the review process but also in the verification of the resultant decisions on the operating regime of each specific plant. Verification that the specific plant safety level was at least equal to the proposed minimum level was an activity preferably undertaken by an international organization in order to gain public acceptability not only in the host country of the plant but also in its neighbouring countries. The verification process could be built around specific plant missions or assessment of suitable reports from the plant operator.

The conference considered that the roles of each of these international organizations, and also the CEC, WHO and the World Bank, in this issue (treatment of older plants) should be more clearly defined to allow a more efficient use of the limited resources and finance available for the proposed reviews and the implementation of the findings. Co-ordination of their relevant activities was necessary to gain maximum advantage from their work.

Workshops should also be convened to develop an assistance strategy which considers the role of training courses, safety missions, etc.

Direct assistance to operators to improve procedures, training, maintenance practices and implementation of corrective measures and to assist operators to develop an adequate safety case and hence to promote self-regulation by operators should be provided by WANO.

The IAEA should expand its present activities, particularly its OSART and ASSET missions for older plants.

The IAEA should also provide technical assistance to those Member States who require safety assessment of their older plants but who do not have adequate expertise, particularly in the regulatory aspects.

The conference supported the proposal from the USSR for an IAEA programme to review the safety level of RBMK nuclear power plants.

A proposal was made for the IAEA to provide permanent missions in those Member States requiring assistance.

Topic No. 4

What weight should be given to socioeconomic factors when making decisions on reactors built to earlier standards?

Findings:

Socioeconomic factors should not be used to justify operation of a plant below an acceptable level of safety. Socioeconomic factors should influence the level of effort and the degree of international assistance required to bring the plant up to an acceptable level of safety so that the plant need not be shut down, and so that significant adverse socioeconomic effects can be avoided.

In some cases, the level of effort required within a country and from international assistance may prove to be too high. In such cases, the plant should be shut down, and other means of supplying electrical power should be used, for example supplies from other countries. A judgement on the viability of achieving the minimum level of safety should be made at an early stage.

3. CONCLUSIONS AND RECOMMENDATIONS
(Co-Chairmen's Summary)

The conference's Conclusions on the Issue of Treatment of Nuclear Power Plants Built to Earlier Safety Standards are the following:

1. An acceptable level of safety should be defined and agreed internationally, that all plants should meet as a minimum.

2. The concept and procedure for safety review contained in the Background Paper were agreed as a suitable way to demonstrate the level of safety achieved.

3. International support and overview are needed to ensure adequate safety reviews. International assistance is required to bring unsatisfactory plants up to an acceptable level of safety and to verify this level.

The conference therefore recommended that:

1. The structured review strategy of the Background Paper can serve as a basis for strategies which could be implemented by all national authorities, with the IAEA's role being to establish detailed guidance for this strategy, to encourage related activities, to provide a forum for fostering the exchange of related experience, and to provide assistance as appropriate.

2. National operators and regulators should identify those plants that need to be reviewed and improved to ensure acceptable safety levels and take necessary actions including international assistance and overview.

3. The IAEA should initiate a process to develop the basis on which the level of safety of nuclear power plants can be judged and the minimum level be defined.

4. The IAEA should initiate the necessary actions to clarify the roles of the international organizations to ensure efficient application of national and international resources.

5. Operating organizations, where needed, should be supported directly by WANO to assist them to develop adequate operational practices. The IAEA should assist and support the regulatory bodies to ensure a strong regulatory regime.

ISSUE IV: THE NEXT GENERATION OF NUCLEAR POWER PLANTS

1. OVERVIEW

(Summary of Background Paper for Issue IV, Appendix 4)

The objectives of the next generation of plants include achievement of enhanced safety, increased reliability, greater public acceptability and improved economics. However, success in achieving safe and efficient operation of these plants requires that the constraints of the current generation be recognized, understood and overcome.

The earlier projections concerning the growth of nuclear power were overly optimistic, and real growth remained below earlier forecasts, partly owing to the oil crises of the early 1970s, while public resistance to nuclear power increased in many countries. The public, after the Chernobyl accident, is only slowly beginning again to look at nuclear power in a balanced manner. Several contributory causes have been identified, including the unavailability of smaller nuclear power plants which would better fit the needs of the developing countries, increases in capital cost and difficulties in financing construction of larger plants, plus the need for an expanding infrastructure to cover all the facets of nuclear activities. The legal system of licensing in some countries also offers ample opportunity for intervention by opponents to nuclear power, which has caused long delays in the implementation of some nuclear projects.

Those large reserves of electrical generating capacity released when growth rates decreased are now depleted and some base load capacity plants, both nuclear and fossil, are approaching the end of their design life and must either be replaced or have their lifetime extended. Environmental concern is now being expressed with regard to new and existing non-nuclear energy technologies and a strong incentive for increased use of nuclear energy is evolving.

If the next generation of nuclear power plants are to be a success then their economic performance must be shown to be competitive with alternative sources of energy, considering all life-cycle costs. The size of plant, simplified designs, shorter construction times and fuel cycle costs are among the factors which need to be considered.

One of the necessary prerequisites for the revival of the nuclear power programme is the regaining of public acceptance, and future reactor designs must be perceived as safe by the public. Of special importance to public acceptability are the techniques used to limit off-site consequences and decrease the sensitivity to human errors. Increased openness on the part of nuclear proponents, education of the public on nuclear issues and a greater international agreement concerning nuclear safety matters will all contribute to the success of nuclear power.

The next generation of plants should be at least as safe as the best plants operating at present, but should be expected to provide some significantly enhanced safety and economic characteristics. Improvements in safety will require a review of how the many barriers which comprise the defence in depth principle can best be enhanced. Though current civilian plants have in general a very satisfactory safety level, improvements are advisable at some plants and in a few cases the necessary upgrading may not be viable, leading to consideration of permanent shutdown of such plants. It is also important to note that the development of the next generation of nuclear power plants with enhanced safety characteristics does not disqualify the existing generation, which already meets acceptable safety standards.

There are a number of desired characteristics which should be incorporated into the next generation of nuclear plants, and these are discussed below.

Next generation plant designers are striving to enhance the safety characteristics of the defence in depth barriers and the level of protection provided for each barrier in order to provide enhanced overall safety. From available design information it is evident that designers have critically examined the barriers relating to prevention of deviations from normal operation, failure of the fuel cladding barrier, failure of the reactor coolant pressure boundary, and containment of the fission products within an adequate containment building, in order to enhance safety.

Improvements in prevention and mitigation of severe accidents are possible, and will be incorporated in the new designs, although some aspects of severe accident phenomena remain too uncertain to permit modelling with the desired accuracy. Efforts needs to be made to remove the effects of these uncertainties. Additionally, a more general review of designs may be justified on the basis of operating experience and the insights from PSAs.

With regard to the use of Probabilistic Safety Assessments, while targets have been proposed, the use of absolute numerical values of results from PSA has been overemphasized and has often served to confuse the public rather than educate. However, PSAs are very important in identifying vulnerabilities in the design and also provide valuable insights into the likelihood of accident scenarios.

Recent studies of off-site consequences indicate that rapid evacuation may not be a necessary prerequisite for the assurance of public safety and the basis for sheltering and evacuation needs to be reviewed.

Future plant designs should continue to embody the fault tolerant concepts of earlier plants, providing enhancements to ensure that the plant is easy to operate, so that the behaviour of the plant can be readily understood by operators, with a resulting reduction in the possibility of human error.

The use of passive safety features is a desirable method of achieving simplification and increasing the reliability of the performance of essential safety functions and should be used wherever appropriate. However, a careful review of potential failure modes of passive components and systems should also be performed to identify possible new failure mechanisms.

Additional issues to be considered are the benefits of simplification in design, the use of proven technology and operating experience, reduction of occupational doses and a review of waste generation and storage issues.

The use of standard designs has already proven to be very beneficial both in terms of safety and overall life cycle costs. Indeed, safety benefits accrue from greater concentration of resources, stability in the design and licensing process, the volume of feedback of common experience, standardized training and maintenance. Additional worthwhile benefits can be obtained through the harmonizing of licensing criteria and procedures used by the nuclear community to the greatest possible extent, based on worldwide scientific resolution of technical issues and accepted standards of safety adequacy.

Early developments in nuclear power have occurred on a more national basis, but more co-operative approaches to achieving improvements are now proceeding on an international basis. The way forward is still a matter of debate. In countries where there is a large background in nuclear power development, there is an emphasis on the evolutionary approach to design in the near term, although there is some development of the more innovative designs. Some countries are more favourably disposed towards smaller evolutionary plant or the innovative plant, while others see the innovative designs offering significant advantages. It is evident that continuing international co-operative approaches are needed to address the safety and socioeconomic issues surrounding the further development of evolutionary and innovative nuclear power plant designs in order to achieve the perceived benefits.

In conclusion, the achievement of the perceived benefits of evolutionary and innovative nuclear power plant designs will only be possible through international co-operation between Member State organizations in resolving the issues discussed here. Support to this end should be given by the IAEA to enable the work with Member States to continue towards the development of an international consensus on the safety targets that could be attained by the future generations of nuclear power plants, and to development of appropriate safety principles and safety characteristics.

2. SUMMARY DISCUSSION OF SUBSTANTIVE TOPICS
(Rapporteur's Report for Issue IV)

The session debated the four main issues presented in the Background Paper and the following findings to each topic can be identified:

Topic No. 1

Next generation nuclear power plant designs will have incorporated design improvements for accident prevention. Although different designs take different approaches to accident prevention, are their overall objective and approach acceptable?

Findings:

Examples of design approaches taken for accident prevention include improved component and system reliability, improved man-machine interface through design simplicity and human factors design improvements, increased design margins to safety limits, increased system redundancy and diversity including using passive systems, where appropriate, and improved accident management procedures. Also emphasized are design improvements that will enhance maintainability and protection against outside threats. These improvements in the framework of an increased quality assurance enhance both safety and plant availability, and are thus highly desired by nuclear plant owners and operators as well as the general public. These preventive measures contribute to a stronger basis for increased reliance on the nuclear option for future energy needs.

Topic No. 2

Next generation nuclear power plant designs incorporate features for the mitigation of potential severe accidents. Is there a need for harmonization or consensus on different aspects such as design approaches, accident scenarios and analytical methods?

Findings:

The next generation of nuclear power plant designs will improve accident mitigation systems. They will consider severe accident scenarios explicitly and systematically in design. The containment system will then play a key role for the next generation of reactors. This approach is considered acceptable. There is a need for and a benefit expected from an international consensus on design approaches (e.g. containment design parameters, accident scenario selection and methods of analysis), and on how to treat severe accidents in the regulatory process. The limitation of off-site consequences should enhance public acceptance.

Topic No. 3

What should be the role of emergency planning for future reactor designs? Do design improvements and recent severe accident research results provide an adequate technical basis for simplifying or eliminating emergency planning for future designs?

Findings:

Advanced reactor designs will explicitly incorporate design features that would permit the technical demonstration of adequate public protection with significantly reduced emergency planning requirements, e.g. relief from the requirement for rapid evacuation. Potential future owners of these designs have encouraged incorporation of such design features, and although no consensus has been established to totally eliminate emergency planning, many desire to eliminate the more onerous aspects of current procedures, particularly rapid action requirements. Such modifications to emergency planning should be considered.

Topic No. 4

What should be the role of the IAEA with respect to future reactor designs? Specifically, should the IAEA develop a set of desired safety characteristics for the next generation of nuclear power plants?

Findings:

There are many areas where increased international co-operation has been beneficial and could be expanded further. Many multinational efforts are already under way outside the IAEA to help define user needs, harmonize regulatory approaches, consolidate designer efforts, etc. The IAEA has started an effort to develop a set of desired characteristics covering all of the principal features for the next generation of nuclear power plants, irrespective of type.

3. CONCLUSIONS AND RECOMMENDATIONS
(Co-Chairmen's Summary)

The conference's Conclusions on the Issue of the Next Generation of Nuclear Power Plants are the following:

1. Accident prevention was identified to be the primary safety objective of a design.

2. Participants stressed that nuclear power plant safety can be achieved by using either passive or active systems or a combination of both. However, both should be analysed from the standpoint of reliability and economics.

3. Probabilistic Safety Assessment is a valuable analytical tool. However, it was concluded that the numerical estimates deriving from Probabilistic Safety Assessments numbers should not be utilized solely to make licensing decisions, but should be used to provide supplemental information and insights. Some participants disagreed and indicated that such numbers could be used to some extent for licensing decisions. It was stressed that too much confidence should not be placed in low probabilistic numbers because of the associated large uncertainties.

4. The majority supported the view that the containment of the next generation of nuclear power plants should be designed to include severe accident considerations, so that off-site emergency planning could be simplified. Some participants think the effects of severe accidents could be practically limited to within the boundary of the plant site. Some argued that traditional containments are judged to be unnecessary for some innovative designs.

5. During the discussion, it was pointed out that for both prevention and mitigation the contribution of positive actions by operators should not be overlooked.

6. The consensus was achieved that emergency plans for the Next Generation of Nuclear Power Plants should be simplified. Some participants wish to reach the condition that emergency plans could be limited to the plant site. Others expressed the opinion that general emergency planning must be retained as a part of the defence in depth principle in the framework of a national plan for all types of emergencies.

7. The consensus was reached that design targets and objectives should be harmonized to the greatest extent on a worldwide basis.

The conference recommended that:

The IAEA should set up a small group of experts to establish in the long term safety criteria for the design of future reactors using a step by step approach which should begin with the development of safety principles. INSAG documents could provide an important input to the process.

ISSUE V: FINAL DISPOSAL OF RADIOACTIVE WASTE

1. OVERVIEW

(Summary of Background Paper for Issue V, Appendix 5)

The quantity of radioactive waste requiring disposal is expected to increase as a result of nuclear energy's continuing development and nuclear reactor plant decommissioning. Such disposal will require isolation over very long periods of time and it is a matter of international consensus that countries using nuclear energy should make adequate provisions for disposal. The disposal of low level waste is currently undertaken on an industrial scale; however, programmes for disposal of long lived, highly radioactive waste have not reached the stage required for the licensing of repository construction. This delay is due in part to the gap which exists between the confidence specialists have in disposal technologies and the impressions of the general public that waste disposal presents unacceptable hazards and environmental risks. As a result the process of selection of a disposal site has become the focus of public opposition. The expert consensus is that feasible and safe options for disposal do exist, but this has not yet alleviated public fears.

The principal fuel cycle options are first, that spent fuel itself can be disposed of as waste, after a suitable period of storage for radioactive decay and second, the spent fuel can be chemically reprocessed to recover plutonium and uranium for recycling. The second reprocessing cycle produces greater quantities of low and intermediate level waste than the once-through cycle. A variation of the reprocessing option receiving increasing attention is the partitioning of high level liquid waste from reprocessing to remove long lived products for transmutation into shorter lived products by irradiation. The general requirement to dispose of the waste does not demand that it be done immediately and there may be a preference to store the waste for an interim period of several decades or more. However, this is only a temporary measure allowing flexibility in spent fuel management and is not a substitute for final disposal.

A number of waste disposal options have been considered to cope with the different types of waste produced. Near surface disposal facilities are suitable for disposal of low level waste and short lived intermediate level waste only, whereas geological disposal facilities cater for long lived intermediate level waste, high level waste, etc. Ocean disposal is another technical option covering disposal of packaged waste or deep seabed disposal. Neither option is in practical use today.

The objective of the waste disposal process is to isolate radioactive substances from the human environment sufficiently well that releases during the period when a significant hazard remains are within acceptable levels. The isolation capability depends on the implementation of a system of barriers. Three principal components of such a system are the waste package, engineered barriers and the geological barrier. Together these must permit the disposal system to play a dual role in first confining the radionuclides over a certain period of time and then limiting and retarding the transfer of the radionuclides to the biosphere.

A general consensus has been achieved at national and international levels on the principles and qualitative objectives for these barriers for underground disposal. Except for radiological protection objectives, quantitative objectives are generally site specific. There is also a continuing need for agreement on how to interpret the period of time for which it is necessary to demonstrate that the basic radiation protection criteria are met.

Low and intermediate level short lived waste repositories have been operating satisfactorily for several decades and improved disposal techniques are now in use. For long lived and high level waste, the concept of deep geological repositories is being developed. National and international programmes have investigated the feasibility of a geological confinement system, and current programmes range from laboratory studies to operation of experimental underground facilities and development of full scale repositories. The continuation of research using field and laboratory studies, plus analysis of naturally occurring migration phenomena, is seen as a means of improving the understanding of radionuclide migration related processes. International and national performance studies have concluded that releases from deep geological repositories would carry only minor quantities of radioactive products. However, several issues related to waste disposal need to be addressed. From a technical point of view, the methodologies for performance assessment are suitable for evaluation of disposal safety. Data specific to proposed disposal sites are necessary for such an evaluation in order to further improve performance assessment models. Additionally, the long time-scales associated with the disposal process introduce uncertainties into the safety analysis which need to be evaluated, and will also require site specific data from candidate sites.

From a regulatory perspective difficulties exist in producing detailed and quantitative performance objectives and safety standards. Developers and regulators need to discuss and resolve these issues at national and international forums. Adverse public reaction to the siting of a repository also needs to be overcome by improving communications and public awareness of the adequacy of such constructions.

A number of issues covering technical and regulatory concerns require further attention and are briefly noted here.

Unnecessary delays in implementing site selection programmes should be avoided, because site specific investigations of confinement properties of barriers and the radiological impact of a repository are an essential part of the safety assessment process.

Technologies for the design, construction, operation and sealing of repositories must be demonstrated.

The ability of safety assessment models to describe actual processes in real repository systems needs to be further validated through effort at both national and international levels.

Current international activity to consider the limits of applicability of safety assessment methods for very long periods should be continued.

Regulatory bodies must be given sufficient and independent resources to undertake safety reviews.

The developers need regulatory guidance as to the acceptability of the whole process of repository location, design, construction and justification. Because of the complexity of the task and the time-scales involved, a stepwise iterative review process is proposed.

In the interests of safety it is advisable that no special measures be provided for access to the waste repository once the facility has been sealed.

Safeguard requirements and their application to particular types of waste should be clearly defined as soon as possible, with due regard to the requirements for safe disposal.

The public should be made aware of the way safety is achieved and the thoroughness of the regulatory process regarding waste repositories.

In conclusion, the achievement of consensus on the final disposal of radioactive waste can only be reached through international co-operation, which should be permanently promoted, notably as far as the development of protection objectives and/or standards and criteria for disposal is concerned. The IAEA should work with Member States and international organizations to provide a forum for discussion and resolution of the issues surrounding waste disposal, both at a technical level and between national regulatory bodies. In particular assistance should be given to reaching consensus on the application of radiation protection criteria over long time-scales. Additionally, support should be given to ensuring the validation of safety assessment models, improving technology transfer and defining requirements for safeguards measures for nuclear materials disposed of in a geological repository.

2. SUMMARY DISCUSSION OF SUBSTANTIVE TOPICS

(Rapporteur's Report for Issue V)

The session discussed the three main topics presented. No new main topics were raised.

Topic No. 1

How should the developed strategy for the final disposal of radioactive waste be implemented?

Findings:

There was general agreement that ongoing R&D programmes for final disposal of radioactive waste should be pursued. It was, however, pointed out that in many countries there is no need to take speedy actions and that sufficient time is available to study outstanding issues. On the other hand, it was stressed that there is a need to demonstrate progress in disposal technology and safety, interalia in consideration of the wider public perception of the nuclear energy option.

Issues that could be studied, in order to achieve a common understanding both on a national and on an international basis, include the following:

- retrievability of waste after sealing the disposal facility;
- actinide partitioning and transmutation;
- the role of extended storage;
- the possibility of regional or international repositories.

There are, however, differences of opinion as to the emphasis that should be put on these issues, relating to the progress and decisions regarding national programmes on geological disposal.

There was general agreement on the importance of public understanding and acceptance of final disposal strategies and their implementation. This should be achieved by increasing communications, with the objectives of increasing confidence and credibility. Research into the issues mentioned above could be seen in this context as well. Finally, public participation in the review of and decision making on the various steps in national programmes would add to the public confidence.

Topic No. 2

What role should the regulatory body have in relation to the implementing organization with regard to the programme for disposal of HLW?

Findings:

Nations should have clearly defined legal frameworks, including a definition of the responsibility of the regulatory body and the implementing organization. The regulatory body should establish safety objectives that are understandable to the general public. On that basis standards and criteria should be developed, for example via an iterative process between the implementing organization and the regulatory body. Because of the long time process involved in developing repositories and their licensing, such an iterative process should start at an early stage. However, the regulatory body should maintain its independence throughout this process. It is the role of the regulatory body to determine if the repository is acceptable and if it meets the safety objectives. The regulatory body should have a firm technical basis, justifying its licensing decisions. It is the role of the implementing organization to select the site and demonstrate its suitability and that the proposed repository meets the safety objectives.

Topic No. 3

International co-operation, how can it help? What should be the role of the IAEA?

Findings:

To achieve responsible and safe management of radioactive waste, the possibility of an internationally legally binding arrangement was discussed. This could also be seen in the context of the proposed nuclear safety convention. The basis for such an arrangement could be the safety fundamentals of the IAEA's RADWASS programme.

The importance of the ongoing IAEA programmes in the area of radioactive waste management was recognized and supported. To complete this programme with regard to the disposal of spent fuel, safeguards approaches should be studied, with due regard to safety requirements.

3. CONCLUSIONS AND RECOMMENDATIONS

(Co-Chairmen's Summary)

The conference's Conclusions on the Issue of Final Disposal of Radioactive Waste are the following:

- The ongoing R&D programme for final disposal of radioactive wastes should be continued.
- Matters on which opinions differ should be studied further.
- Efforts to increase public understanding and participation should be reinforced.
- The roles and responsibilities of regulatory bodies and implementing organizations should be clarified.
- Work towards international arrangements should be undertaken with a view to accepting obligations and harmonizing safety objectives for final disposal.
- Safeguards approaches for spent fuel repositories should be worked out.

The conference therefore recommended that:

a) Work should be started towards an arrangement that lays down the obligations of participating States with regard to radioactive waste management and disposal and the safety objectives to be reached.

b) Safeguards approaches should be worked out for the final disposal of spent nuclear fuel.

CHAPTER III

MAJOR FINDINGS OF THE CONFERENCE

MAJOR FINDINGS OF THE CONFERENCE

The International Conference on the Safety of Nuclear Power: Strategy for the Future, after

reviewing

- the fundamental principles for the safe use of nuclear power,
- the safety of operating plants,
- the treatment of nuclear power plants built to earlier safety standards,
- the next generation of nuclear power plants, and
- the final disposal of radioactive waste;

and

considering the discussions held on several substantive topics related to these issues,

DECLARES that:

1. There was general agreement that safety should be primarily enforced at national levels, by conscientious application of existing safety principles, standards and good practices at each plant, and within each national regulatory body, making best use of national legal frameworks and working practices.

2. Operating organizations and National Authorities should identify operating nuclear power plants which do not meet the high safety performance levels of the vast majority of operating plants and undertake improvements with assistance from the international community.

3. The Governing Bodies of the IAEA are invited to develop a more vigorous overview process with the objective of achieving a high safety performance in all operating plants, inter alia by expanding and strengthening services such as ASSET and OSART services, and by promoting the achievement of sufficient national regulatory oversight.

4. The IAEA should initiate a process to develop a common basis on which the acceptable level of safety of all operating nuclear power plants built to earlier standards can be judged. In some cases, international cooperation and support will be necessary to ensure the completeness of safety reviews and the adequacy of implementation of measures to achieve that acceptable level of safety.

5. International organizations should enhance mechanisms to improve the quality and timely exchange of findings and conclusions of systematic analysis of operating experience, in particular relating to human and organizational performance. This could be achieved in part through regular use of the Incident Reporting System available at the IAEA.

6. The IAEA should improve its mechanisms for timely public dissemination of authoritative information on operational safety performance experience. This could be achieved in part through a regular use of the International Nuclear Event Scale of the IAEA.

7. The IAEA should set up a small group of experts to establish safety criteria for the design of future reactors using a step-by-step approach which would begin with the development of safety principles and evolve, in the long term, into a comprehensive set of criteria. INSAG documents could provide an important input to the process.

8. The IAEA should develop international safety objectives for use by participating Member States with regard to the implementation of waste management and disposal. The programmes should include consideration of the provision of advice on safeguards commensurate with the safety of the final disposal of spent nuclear fuel.

9. There is a need to consider an integrated international approach to all aspects of nuclear safety, including safety objectives for radioactive wastes, which would be adopted by all Governments, and in this connection, the potential value of a step-by-step approach to a framework convention is recognized; and, therefore the Conference requests the Governing Bodies of the IAEA that they organize the preparation of a proposal on the necessary elements of such a formalized international approach, examining the merits of various options and taking into account the activities and roles of relevant international and intergovernmental bodies and using the guidance and mechanisms already established in the IAEA.

10. Member States of the IAEA are reminded that appropriate budgetary resources must be made available if the objectives of these findings are to be achieved.

PRESIDENT'S CLOSING STATEMENT

Mr. Director General,
Ladies and Gentlemen!

The presentations by the Chairmen of the five sessions have shown to you that a considerable amount of successful work has been completed during the last four days.

This effort was worth while. Together we have made a significant step ahead to strengthen the foundations and procedures for our co-operation in the area of nuclear safety. We have defined a common stepwise approach to establish a formalized framework for future safety assurance in a global context.

Supported by the five session authorities, the Conference President and his advisory bureau and the Scientific Secretary have extracted the major findings achieved during the past four days, which should guide the overall further development of international safety co-operation. We consider these major findings as an important input for the coming meetings and conferences of the IAEA. The document we have elaborated together reads as follows:

[Note of the Editor: The President reads the Major Findings of the Conference]

The next step will be that the Director General Dr. Blix will present the findings of this conference to the Board of Governors and afterwards to the General Conference.

The General Conference will consider and discuss the concrete recommendations we have made.

I want to make some personal comments on the process we have initiated here.

The most essential common two starting points were again marked right at the beginning of this conference:

1. Adequate safety must be considered as the indispensable prerequisite for the future contribution of nuclear energy to world energy supply.

2. Adequate openness, transparency and public information must assure that an unbiased assessment of the safety performance and the perspective of nuclear power can be developed in the political process.

It is a common understanding that for this control we need a global framework to strengthen, but not to replace, national responsibilities of operators and regulators for the safety of their installations.

I proposed at the beginning an international convention on nuclear safety as the appropriate legal framework to assure adequate control of nuclear safety and protection against risks in a global context.

Similar proposals were made - in principle independently - by Director General Dr. Brinkhorst from the Commission of the European Communities and by Dr. Rosen from the IAEA. Also the Swedish proposal for a convention in the area of nuclear waste goes in the same direction.

This elucidates, that the time has now come for a convincing reply to this challenge and I am convinced that in the political arena at the end it would not be understood, if we cannot find a convincing solution to this issue.

The workload for this conference was too large to address all issues directly.

One issue, for example, is the preparation of answers of the IAEA to the questions posed by other UN organizations for the preparation of the UN conference on Environment and Development in 1992 in Brazil. I want to ask the IAEA to make optimal use of the inputs and the outcome of the present conference to prepare adequate contributions of the IAEA to UNCED 1992 in Brazil.

There are also other important developments that will be influenced by the findings of this conference and the follow-ups under the auspices of the IAEA in the recommended direction.

Director General Dr. Brinkhorst has outlined the European approach to strengthen nuclear safety and radiological protection not only within the western European countries but also in the countries of central and eastern Europe.

One also has to mention the work initiated by the Dutch Prime Minister Lubbers on a European energy charter. This charter should be the basis for restructuring the European energy supply towards a more environmentaly sound and energy efficient system. A specific protocol for nuclear safety is planned and the consequences drawn out of this conference of course will be a major input to the formulation of such a protocol.

These developments will take time to evolve. Pushing this ahead must not be an excuse for postponing the solution of current problems. Appropriate tools and processes have already been developed and must be used now to offer the international assistance and review where these are needed urgently. The example of Kozloduy shows that the international community is prepared to take the necessary actions.

The structures established to deliver this support need further strengthening. The Steering Committee for assistance at Kozloduy that has been organized by the European Community in Brussels, which includes the IAEA, OECD/NEA, World Bank, European Bank for Reconstruction and Development and the G-24, should be extended to a co-ordination instrument for the whole assistance programme for nuclear safety in the central and eastern European countries.

In his opening speech Director General Blix said that this is an action oriented conference. Indeed the results achieved prove that this conference has defined a lot of useful actions:

- Different concrete actions were defined to improve openness, transparency and public information on nuclear safety performance. The actions relate to practices of national authorities, operators and organizations of plant operators. Also concrete actions were defined to improve the use of the Incident Reporting System (IRS) and the International Nuclear Event Scale (INES) especially by the IAEA to assure timely public dissemination of relevant information.

- Specific workshops were proposed, oriented towards a common approach of implementation of the existing safety documents, that have already been agreed upon, like the basic safety principles from INSAG, the NUSS Codes and others. Based on the practices and experiences in member countries these workshops should help to develop the best practice in each country solving current safety issues.

- Based on an extensive discussion on the safety of reactors built to older requirements, concrete actions were recommended to develop a common approach to safety reviews and to the assessment of adequate safety levels, which must be achieved as a minimum for further operation. It was stated clearly, that socioeconomic factors should not be used to justify operation of a plant below an acceptable level of safety.

- A very concrete action plan must result out of the proposal of the Soviet Government for an IAEA programme on the safety of RBMK nuclear power plants. This proposal was supported by the conference. Further steps should be initiated soon.

- Concrete actions have been defined for the stepwise development of a next generation of nuclear power plants. A consensus has been achieved that these plants will have a strengthened containment due to the inclusion of the consideration of severe accidents in the design. The final objective is to limit damage to within the boundary of the site.

Ladies and gentlemen, this listing is not complete but I just want to reconfirm that during this conference we really have achieved considerable progress in important current issues.

More than that we also have achieved a major advancement for the further development of the worldwide nuclear safety co-operation.

I explicitly welcome that this conference has in principle reacted in a positive way to my proposal for the development of an international convention on nuclear safety.

I also welcome that the conference has discussed the problems of nuclear waste and underlined that the solution of this issue is also a decisive factor for the future use of nuclear power. Therefore it is important that we develop common objectives. It is therefore appropriate to include this issue in the step-by-step process towards a framework convention.

This really is the next logical step to implement an international safety culture on the basis of the safety principles and requirements already agreed upon, based on legally binding agreements.

An international convention for nuclear safety should only define the framework and should be restricted to fundamental principles. As other examples demonstrate, more detailed requirements can be included by protocols with reference to already existing and continuously updated international safety documents.

A look at existing conventions or conventions under preparation will help towards a better understanding and will - from my point of view - clearly reveal that international co-operation on nuclear safety and radiological protection has already achieved a level of detail higher than needed for such a convention.

These examples will also clarify that such a convention does not relieve national operators and regulators from their responsibility but will be an additional endorsement to take this responsibility very seriously.

It is exactly the right time to start with these concrete steps for further strengthening of an international safety framework. We must use the current momentum evolving from the dramatic political changes we have witnessed during the past two years.

There is a need to integrate nuclear safety issues into the global approach to environmental protection and technical safety. This is part of the agenda of the UNCED 1992 in Brazil.

The changes in the central and eastern European countries offer new possibilities for co-operation but at the same time result in a challenge to offer concrete assistance in improving nuclear safety.

During this conference a common spirit has developed to take this challenge and to go ahead with concrete actions. I want to thank all participants for their co-operation and personal involvement in making this conference a success.

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Appendices to the Attachment

APPENDICES TO THE PROCEEDINGS OF THE

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

APPENDIX 1

Background paper for
document GOV/2541

Item 6(a) of the provisional
agenda (GOV/2537)

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

Vienna, Austria

2-6 September 1991

BACKGROUND PAPER

FOR

ISSUE NO. I

FUNDAMENTAL PRINCIPLES FOR THE SAFE USE OF NUCLEAR POWER

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

ISSUE NO. I:
FUNDAMENTAL PRINCIPLES FOR THE SAFE USE OF NUCLEAR POWER

SIGNIFICANT TOPICS TO BE ADDRESSED AT THE CONFERENCE

Based on comments received to the Background Paper for Issue No. I, together with discussions in the Steering Committee, the following topics are recommended for inclusion in the discussion on Issue No. I. For each topic, there may be actions identified to be taken, by utilities, regulators, Member States, and international bodies including the IAEA.

For each topic recommended for discussion, some comments are provided both to facilitate an understanding of the issues and to assist the reader with preparations for the discussion sessions at the conference.

Topic No. 1

Safety objectives and standards: What should they cover and is there a need for more binding international safety standards and regulations?

First, a clear distinction should be made between safety objectives and binding formal standards and regulations. This is best illustrated by the following example. Nuclear utilities characterized by a well developed safety culture and a strong commitment to an ongoing safety programme can have zero incidence of accidents and safety significant events as a safety objective. Obviously, this cannot be made a binding regulatory requirement whereas, incident reporting can be made a binding regulatory requirement.

The background paper addresses a number of areas where safety objectives have to be pursued by application of appropriate tools and methods. These areas include:

- design evaluations according to state of the art methods and criteria;
- quality in operation and maintenance;
- safety culture;
- plant-specific, living PSAs using recorded operational reliability data for components and systems.

The background paper generally concludes that existing, internationally agreed safety objectives, tools, methods and standards have - notwithstanding that some further development is merited - reached such a state of maturity that if the quality of implementation is high and uniform, nuclear installations will reach a very high level of safety. It is the achievement of this safety level at each plant that should be the final objective. The issue to be discussed is which are the best ways to achieve this objective for all plants; perhaps by more binding international standards? If so, what should be the extent of such standards, and how should compliance with them be evaluated?

Topic No. 2

Approaches to systematic safety reassessments throughout the operational lifetime of nuclear installations: should periodic safety reviews be used to supplement or replace continuous assessment programmes? Should some combined assessment and review approach be used and if so, what form should it take?

As stated in the background paper, it is a key component of a high safety culture that the safety level of a nuclear installation is reassessed in a systematic manner throughout the operating life of the installation. There are various approaches to such systematic reassessments such as:

- Essentially continuous reassessments. These are typically performed on an issue by issue basis including both design improvements (backfitting) and operation and maintenance practices;
- Plant-specific reassessments with specific intervals, typically around 10 years. These may be described as standing back and taking a more long-term overview of the adequacy of plant design features and operational performance as compared to the original safety justification, current state of the art and future trends. As an example ageing effects could be a topic for review during such periodic reassessments.

There is currently a diversity of approaches in various countries. The pros and cons of different approaches should be discussed. More specific issues might include

- the interest in some sort of international effort in exchanging and evaluating experience from the various approaches used so far;
- the need for some international system for efficient exchange of information on findings and conclusions of generic interest from such reassessments (e.g. complement or extension to the IRS system).

(Note: The specific factors to be included in a systematic reassessment programme are discussed under Issue III).

Topic No. 3

Emergency planning as a part of the total defence in depth concept: How may requirements for emergency planning be affected by implementation of improved severe accident management and release mitigation capabilities in both existing and future reactor designs?

Off-site emergency planning involves many components such as:

- preparedness to inform people living near the installation in case of accidents both to ensure protective actions are taken (if necessary) and to alleviate unfounded fears, e.g. in case of conspicuous but safety insignificant events (e.g. associated with large releases of steam or smoke);

- preparedness for off-site radiation measurements;
- preparedness for evaluation in case of large releases.

If emergency planning is considered a part of a total defence in depth concept, then it would seem appropriate that the level of emergency planning is suitably balanced by considering the efficiency of other components in the defence in depth strategy. The issues involved in such an appropriate balance appear worthwhile to discuss, especially considering the effects of ongoing improvements in severe accident management and release mitigation measures such as may be provided by new plant designs, as well as the diversity of approaches to emergency planning in Member States. A particular issue is the level of preparedness for evacuation, e.g. requirements for fast evacuation, size of the evacuation planning zone.

Topic No. 4

What are the desirable components of information dissemination, information exchange and communication activities with political decision makers and the public? For example, how should issues such as "are our (or our neighbour's) nuclear installations acceptably safe?" be addressed?

The fundamental principles for the safe use of nuclear power are not an exclusive concern of regulators, owners, operators and vendors of nuclear installations. The basic principles, as well as the safety level achieved through their implementation at each particular plant, must also be communicated to, and understood by political decision makers, investors and the general public as a basis for their acceptance of a nuclear power programme. Such communication and understanding are essential not only in the national context, but also with respect to reactors in neighbouring countries, in consideration of possible transboundary components of the risk profile.

Important aspects in achieving such communication and understanding may include:

- A common understanding of what are the important components in the risk profile (or safety profile) and how they should be described. This includes inter alia a more harmonized approach to safety and radiation protection issues;
- The roles of the different parties involved. For example, in several countries the regulatory bodies are required to report their findings and conclusions on a regular basis to political decision makers and the general public.

Experience with different approaches to such communication issues as well as desirable paths for future development appear appropriate topics to discuss.

BACKGROUND PAPER NO. I

FUNDAMENTAL PRINCIPLES FOR THE SAFE USE OF NUCLEAR POWER

FOREWORD

GENERAL BACKGROUND

Today there are about 425 nuclear power plants operating throughout the world in both industrialized and developing countries, supplying 17% of the world's electricity needs. Four countries obtain more than half of their electricity from nuclear energy, while 13 countries obtain at least 20% of their electricity from this source.

During the accummulated 5600 reactor-years of operation the safety record of nuclear power has been marred by two accidents of particular concern, Three Mile Island in 1979 (with small public consequences) and Chernobyl in 1986 (with large public consequences). Mainly as a result, the risk and possible local effects associated with nuclear energy are perceived by some in government and in the public as being too great for nuclear energy to be accepted as a viable means of resolving the health and environmental effects caused by the other means of generating electricity, particularly the burning of fossil fuels.

The UN World Commission on Environment and Development (Our Common Future) indicated a number of specific items related to the use of nuclear energy that require international agreement including regulatory activities, standards (for operation, radiation protection, waste repositories, and decommissioning), operator training, site selection criteria, emergency response training, reporting, etc.

The Conference on the Changing Atmosphere: Implications for Global Security held in Toronto, Canada, in 1988, concluded that "If the problems of safety, waste and nuclear arms can be solved, nuclear power could have a role to play in lowering CO_2 emissions".

To help resolve these concerns the holding of an International Conference on nuclear safety was suggested and encouraged by European Community countries through the IAEA Board of Governors during the spring of 1990 and presented to the IAEA General Conference in September 1990. The General Conference in its Resolution 529 welcomed the holding of the conference, with certain financial stipulations.

CONFERENCE OBJECTIVE

The Conference is directed to decision makers on nuclear safety and energy policy at the technical policy level. Its objective is to review the nuclear power safety issues on which international consensus would be desirable, to address the concerns on nuclear safety expressed by the UN World Commission on Environment and Development, and to formulate recommendations for future actions by national and International authorities to advance nuclear safety to the highest level including proposals for the IAEA's future activities for consideration by its governing bodies.

The conclusions of this Conference, addressing safety issues only, will complement the conclusions of the Senior Expert Symposium on Electricity and the Environment held in Helsinki, Finland, May 1991 which address the comparative health and environmental effects of the various alternative means of producing electricity.

The conclusions of the Conference will also form part of the IAEA's contribution to the 1992 UN Conference on Environment and Development.

The Conference should promote more effective international co-operation between IAEA Member States on the safety of nuclear energy.

The particular issues selected for consideration by the Conference are:

(i) Fundamental principles for the safe use of nuclear power;
(ii) Ensuring and enhancing safety of operating plants;
(iii) Treatment of nuclear power plants built to earlier safety standards;
(iv) The next generation of nuclear power plants;
(v) The final disposal of radioactive waste.

For each of these issues the present status, present and foreseeable problems, recommendations for future actions required to deal with these problems at both the national and international levels, and recommendations for the role of the IAEA in these activities are outlined.

This Background Paper deals with the subject of "Fundamental Principles for the Safe Use of Nuclear Power".

TABLE OF CONTENTS

1. RATIONALE FOR THIS PAPER

Closely associated with man's use of nuclear energy for beneficial purposes is the awareness of potential harm arising from unwarranted exposure to radiation of individuals and populations, and releases of radioactive materials to the environment. In order to understand fully the association of ionizing radiation and its potential impacts, there have been widespread investigations of biological effects of radiation spanning the last half of the twentieth century, and these investigations are continuing.

With the deployment of nuclear power, the earlier concepts of assuring nuclear safety have developed into a comprehensive methodology that rests on a broad foundation of experience and expanded analyses. This development has been forced to keep pace with demands made on it because the nuclear plants themselves have also evolved in size, number and complexity, and because of an increased desire by people everywhere for improved safety technology.

Such continued improvements have been possible because of the growth in knowledge of the technical bases for ensuring nuclear safety. This has been the result of an intense programme of engineering research in safety, accompanied by the lessons learned from a broad range of operational experiences including accidents ranging from inconsequential to a few accidents involving various degrees of reactor core damage. Important examples are Three Mile Island (USA, 1979) and Chernobyl (USSR, 1986). There have also been a range of accidents in non-commercial reactors such as Windscale (UK, 1957) and SL1 (experimental facility, USA, 1961). One effect of these accidents has been to give impetus to programmes of research and development and to the review of operational and regulatory procedures.

This paper first sets out the general objectives of nuclear safety (Section 2) and the biological effects of radiation on which a rational system for protection against radiation hazards is built (Section 3). The paper then describes the fundamental basis of protection during normal operation (Section 4). Subsequently the essential means for prevention and mitigation of accidents applied to achieve the safety objectives are dealt with (Section 5). The effectiveness of all these principles and measures depends on the discipline of the people involved; the main features of a safety based attitude are presented (Section 6). A separate section is devoted to the verification of safety (Section 7) while the subsequent chapter (Section 8) addresses a number of issues of a more general nature inside and outside the nuclear community, in order to enlarge understanding of the issues and provide guidance for the improvement of the global level of safety. Finally, the principal conclusions of this background paper are presented (Section 9).

2. GENERAL OBJECTIVES OF NUCLEAR SAFETY

It is an objective of technology to achieve some benefit for society. However, no technology is free of risks, so absolute guarantees of safety are not valid. Some risks will have to be tolerated, even if they are unwelcome. Therefore decisions whether to use a technology include some weighing of benefits against risks. But for each technology, there is a set of risks ranging from occupational hazard to the risk of large accidents with substantial economic and societal consequences. This set of risks may be referred to as the risk spectrum or profile of the technology. Thus when comparing technologies we should talk of comparing risk spectrums or profiles.

For nuclear energy, this process includes a very broad range of aspects. For instance, general strategic considerations such as avoiding too great a dependence on a single specific source of primary energy are an important factor. Environmental consequences of available alternatives should also be considered. As those factors are to some degree uncertain and subject to complex interactions among each other, the weighing of benefits against risks is generally a high level and mostly political issue. The outcome may well vary from country to country.

Given the decision to use nuclear energy, it is the **PRIMARY OBJECTIVE OF NUCLEAR SAFETY** to protect individuals, society and the environment against radiological hazards. The radiological hazards are those which present adverse health effects to plant workers and the public, e.g. via radioactive contamination of land, air, water or food products.

These hazards exist in normal operations because there will always be some exposure of workers to radiation. Because of the inevitable production of radioactive wastes (including effluents) there will also be some exposure of members of the public. Radiation exposures also occur in the event of accidents. Most accidents are minor and do not expose members of the public. Some are more severe and a few have caused significant public exposure.

This primary safety objective is supported by two complementary ones, which are:

(i) **THE RADIATION PROTECTION OBJECTIVE:** To ensure in normal operation that radiation exposure within the plant, due to any release of radioactive material from the core, is kept as low as reasonably achievable and below prescribed limits, and to ensure mitigation of the extent of radiation exposures due to accidents.

(ii) **THE ACCIDENT PREVENTION AND MITIGATION OBJECTIVE:** To prevent, with high confidence, accidents in nuclear installations; to ensure, for all mishaps (events that may lead to an accident) which have been taken into account in the design of the installation, that the consequences, if any, would be only a minor accident; to ensure that the likelihood of a severe accident with serious radiological consequences will be extremely small; and to provide on-site and off-site emergency arrangements aimed at reducing the severity of accidents and at reducing the radiation dose that they may cause.

The combination of prevention and mitigation forms a defence in depth strategy, which provides a hierarchically ordered set of different, independent, levels of measures to implement effectively the aims of prevention and mitigation.

In recent years, several attempts have been made to produce a classification of "levels of risk", with the aim of concentrating attention on areas where resources could most usefully be applied. Risk has often been used descriptively, considering probability and severity of adverse outcomes in a qualitative manner and not in a strictly quantified way. However, for the purpose of systematic risk analysis a stricter definition of risk is necessary, typically the probability of a specific harmful effect occurring.

The classification of levels of risk has typically involved three levels:

(1) It is a common understanding that there exist levels of risk, for individuals or society, which exceed tolerable limits and which should not be accepted as the consequence of implementing a technology irrespective of the benefits of that technology. There is less agreement on how to define these levels in quantitative terms.

(2) Safety cannot be absolute and, as the knowledge of how to improve it is never complete, responsible action in any field of technology should include continuing to strive for improvements, provided that the effort required to achieve these improvements is not disproportionately high. Such improvements address a broad range of aspects such as design and operation improvements, safety culture, safety research and feedback of operational experience.

(3) However, some risks are so low that they should be regarded as trivial in order to avoid the unnecessary deployment of resources.

3. THE BIOLOGICAL EFFECTS OF RADIATION

From the beginning of life, every kind of organism has developed in an environment naturally containing radiation from cosmic rays, terrestrial radiation, ingestion of radioactive substances with food, and inhalation of radioactive gases contained in the air. (Refer to Appendix 1 for information on the natural radiation environment.) There are significant geographical variations of the level of natural radiation exposure. However, the influence of these variations on health is small and it is extremely difficult to detect the health effects.

Nevertheless, it is well established that high levels of radiation are harmful. Radiation induces ionization and ionization can damage cells. If cellular damage does occur, and if it is not adequately repaired, it may prevent the cell from surviving or reproducing, or it may result in a viable but modified cell.

A substantial loss of cells in an organ will result in a loss of tissue function. This will occur only at doses above a threshold. This type of effect is called "deterministic".

If an irradiated cell is modified rather than killed, it may lead to a cancer. This outcome is very unlikely because of the existence of highly effective defence mechanisms. The probability of a cancer resulting from radiation, however, increases with dose, probably with no threshold. This kind of effect is called "stochastic", meaning "of a random or statistical nature". If the damage occurs in a cell whose function is to transmit genetic information to later generations, any resulting effects are called "hereditary". Prenatal exposures can affect the unborn child.

More details on the biological effects of radiation and on the quantitative estimation of the associated risks are given in Appendix 2.

4. THE RADIATION PROTECTION CONCEPT AND ITS APPLICATION

4.1 PROTECTION CONCEPT

The objective of radiation protection is to avoid with high confidence any deterministic health effect and to limit strictly the incidence of possible stochastic effects. In order to meet this objective the means of implementation as noted in Section 2, i.e. defence in depth with prevention and mitigation, is applied.

Human activities that increase the overall exposure to radiation, e.g. by introducing new sources, are here called "practices". The generation of electricity from nuclear sources is one such practice. Human activities that decrease the overall exposure by influencing the existing pathways between the sources and man are called "intervention". Protective action following an accident is an example of intervention.

The system of radiological protection recommended by the International Commission on Radiological Protection (ICRP, an independent international scientific body) for practices is based on the following general principles.

(a) A practice involving exposures to radiation should produce sufficient benefit to offset the radiation detriment it causes (the justification of a practice).

(b) In relation to any particular source within a practice, the doses should be kept as low as reasonably achievable, economic and social factors being taken into account (the optimization of protection).

(c) The exposure of individuals should be subject to dose limits aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable in any normal circumstances (individual dose limits).

The 1990 ICRP recommendations also deal similarly with exposures that may occur as the result of mishaps and accidents (potential exposures).

The corresponding system of radiological protection for intervention is based on the following general principles.

(a) The expected reduction in dose should be sufficient to offset the harm and the costs, including social costs, of the intervention.

(b) The details of the intervention should be chosen so that the net benefit of the reduction of dose is as large as reasonably achievable.

(c) At some level of projected dose to an individual, some intervention will almost always be justified with the aim of preventing serious deterministic effects.

Dose limits do not apply in the case of intervention because they might conflict with Principle (a).

4.2 PROTECTION OF THE PUBLIC

Nuclear power plants cause some exposure of members of the public as a result of the discharge of effluents to the environment. The disposal of solid wastes and the transport of radioactive materials have the potential to add to those exposures, but, in practice, they make an insignificant contribution.

Discharges of liquid and gaseous effluents are limited when necessary by the use of delay tanks to reduce the radioactivity of short lived materials and by filtration and chemical treatment to convert other materials to forms of solid waste.

As a result of procedures such as those discussed above, the doses to individuals due to the discharge of effluents have always been low and have been decreasing. The contribution to both individual and collective doses* is now negligible by comparison with those from natural sources and from

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* The collective dose to a group of people is the product of the mean individual dose and the number of individuals.

most other artificial sources. Any further proposed reductions in discharge levels will need careful consideration because they are likely to cause increased exposures of workers and to introduce non-radiation-related risks.

The transport of radioactive materials is governed by detailed procedures and regulations based on recommendations from the IAEA. These recommendations are used globally and have proved very effective.

4.3 PROTECTION OF WORKERS

The principles of protection are applied to workers first by reducing radiation sources in or near workplaces. Shielding is used to reduce radiation fields. Access to areas with high radiation fields is restricted. Radioactive material is confined by multiple levels of containment aimed at preventing the spread of contamination to workplaces and thence to surrounding areas. Much of this is a matter of design, but operational controls are also effective.

These physical means of protection are supplemented by the use of operating instructions for both normal and accident situations and by thorough training.

There has been continuing improvement, in that radiation exposure has been reduced by as much as an order of magnitude, in the level of protection of workers in nuclear power plants. This has been partly the result of a sustained use of the techniques for optimizing the above protection procedures. In addition, the feedback of operating experience to designers has proved extremely useful.

Further improvements will depend on integrated strategies addressing the whole spectrum of design, operation, maintenance and administration.

4.4 EXEMPTION AND EXCLUSION FROM REGULATORY CONTROL

In order to avoid excessive regulatory procedures, most regulatory systems include provisions for granting exemptions in cases where it is clear that a practice is justified, but where regulatory provisions are unnecessary. Provision may also be made for the complete exclusion of some situations from the scope of any regulatory instruments. Both the IAEA and the Nuclear Energy Agency of the OECD have issued advice on this subject.

There are two grounds for exempting a source from regulatory control. One is that the source gives rise to small individual doses and small collective doses in both normal and accident conditions. The other is that no reasonable control procedures can achieve significant reductions in individual and collective doses. Neither of these criteria allows the exemption of operating nuclear installations. However, it is also possible to consider the exemption of some aspects of the environmental effects of an installation that is not itself exempt. In particular, it may be possible to exempt the disposal of some waste materials.

5. THE SAFETY OBJECTIVES AND THEIR APPLICATION FOR ACCIDENT PREVENTION AND MITIGATION

5.1 POLICY

There is a rational implementation of the nuclear safety objectives given in Section 2. This started conceptually for nuclear installations with the idea of effectively localizing radioactive material and keeping it constantly under control, thus providing the means for restricting radiation harm.

5.2 STRATEGY: THE DEFENCE IN DEPTH CONCEPT

Accident prevention is the first safety priority of both designers and operators. It is achieved through the use of reliable structures, components, systems and procedures in a plant operated by personnel who are well trained and committed to a strong safety culture.

However, in no human endeavour can one ever guarantee that the prevention of accidents will be totally successful. Designers of nuclear installations therefore assume that component, system and human failures are possible, and can lead to abnormal occurrences, ranging from minor disturbances to serious accident sequences. The necessary protection is achieved by the incorporation of many engineered safety features into the plant. These are provided to halt the progress of an accident in the specific range of occurrences considered during design and, when necessary, to mitigate its consequences.

This graded approach using a hierarchically ordered set of different independent levels of protection is called "defence in depth" and is at the heart of nuclear safety.

In greater detail, the concept of defence in depth means a succession of physical barriers to contain the radioactive materials and a hierarchical deployment of different echelons of equipment and procedures in order to protect these barriers during normal plant status, anticipated events, and accidents in the facility. At each echelon, priority is given to those measures which prevent the plant status from proceeding to the next echelon. Those measures are supplemented by mitigation with the aim of ensuring that even an accidental release would remain well below intolerable levels. Defence in depth is singled out amongst the fundamental principles since it underlies the safety technology of nuclear power. All safety activities, whether organizational, behavioural or equipment related, are subject to layers of overlapping provisions, so that, if a failure should occur, it would be compensated for or corrected without causing harm to individuals or the public at large. This idea of multiple levels of protection is the central feature of defence in depth.

Within the broad range of aspects addressed by defence in depth, particular emphasis is put on the human factor. The possibility of human error is considered in the organization as well as in the several stages of the life-cycle of the plant through design, construction, conduct of operations, and control of the technical process, plus maintenance and decommissioning. A very comprehensive set of provisions is made in order to ensure that installations are tolerant of such errors. Besides the organizational measures such as training and managerial structures, the interface between man and machine is very important in this regard. Thus, nuclear power plants use ample automation and advanced information technology wherever benefits can be gained, in order to reduce the likelihood and the influence of errors and to support the action of the operating personnel. Those efforts greatly reduce the negative impact of the human factor (e.g. stress induced errors) and stimulate the positive role of the human operator in anticipating and averting potential safety related problems.

Irrespective of those extensive safety precautions taken within the design of a nuclear facility, attention is also directed to accidents of very low likelihood which are more severe than those considered explicitly in the design. Some of these severe accidents could cause such deterioration in plant conditions that fuel damage would occur. These accidents would have a potential for major radiological consequences if radioactive materials released from the fuel were not adequately confined. As a result of the accident prevention strategy, they are of low probability of occurrence.

Since these accidents could nonetheless occur, other procedural measures, termed "accident management", are provided for affecting their course and mitigating their consequences. Accident management would include taking full opportunity to use existing plant capabilities, if necessary going beyond the originally intended function of some systems and using some temporary or ad hoc systems to achieve this goal. Examples of hardware changes would be the use of alternative sources of water or the construction of a special filtration system for venting the containment. These additional measures are established on the basis of operating experience, safety analysis, and the results of safety research.

Accidents with severe consequences are extremely unlikely because they are effectively prevented or mitigated by defence in depth. Nevertheless, effective off-site emergency plans are needed for dealing with these accidents, should they occur (see Section 5.6).

The defence in depth concept is evidently a fundamental characteristic not only in the design but also in the operation and maintenance of nuclear installations. Prevention is ensured by the quality of design, a set of operational limits and conditions and well structured periodic testing and maintenance programmes or modification interventions. Limitation of the consequences of errors should be provided by independent control and functional requalification and in-depth study of the findings.

5.3 FEEDBACK OF OPERATIONAL EXPERIENCE

During about 5600 reactor-years of operation of nuclear power plants, a large amount of operational experience has been accumulated and is still increasing. It is used to find weak points of the technology and to improve them. That experience includes the few serious accidents which have happened so far in nuclear plants. However, the bulk of operational experience concerns events that are far below any direct safety significance. Owing to improving technology their share of the total is continuously increasing.

This experience of events without direct safety significance provides essential information on how to improve technology further. In-depth analysis of incidents is therefore performed, and information exchanged internationally in order to find the effects and problems which are relevant to achieving such improvements.

This principle of exchange of information on operating experience, discussed in INSAG-3, is not without its problems. There are concerns that the efficiency and effectiveness of the information collection process should be improved to meet current industry needs. Also, there is a perception that more attention needs to be given to the dissemination of the results of in-depth analysis rather than the distribution of unevaluated data. These issues are discussed further in Background Paper II.

5.4 PROBABILISTIC SAFETY ASSESSMENT

With the development of probabilistic safety assessment (PSA), a powerful methodology is now available to extrapolate the operational experience to situations severe enough to be of safety significance. By evaluating the probability that mishaps occur and that the engineered safeguards fail during an accident, PSA permits the assessment of the probabilities of a whole range of consequences of mishaps, and thus provides a quantitative value of risk and of the factors contributing to it. Nevertheless, PSA is not without its uncertainties.

The uncertainty of core damage prediction with PSA covers roughly one order of magnitude. For the evaluation of external releases, capabilities are limited for modelling containment loads and for predicting containment failure modes associated with severe accidents. As a consequence the cumulative uncertainty of related results extends over several orders of magnitude. More uncertainty is added by the inclusion in full scope studies of environmental models and extrapolated dose-risk relationships for the evaluation of the significance of low dose health effects in very large populations.

The interpretation of the results of a PSA is sometimes extended to extremely low levels of probability. In some instances a technical interpretation may still be useful, in particular if events of very low probability include new phenomena with large changes of consequences (cliff edge effects) as in the case of containment rupture. In general, however, the results of probabilistic analyses lose their meaning below a certain level of probability because of the inevitable incompleteness of input data, e.g. for rare external events.

The strength of today's probabilistic safety assessment methodology is to determine weak points and appropriate improvements of the plant design by establishing risk profiles of individual plants. In particular, the analyses of core damage frequencies have proved to be very effective for strengthening the prevention of severe core damage. The limits of the scope of PSA studies, together with the uncertainties, have to be considered when applying PSA methods. However, on the whole, probabilistic safety assessment constitutes a valuable additional basis for safety assessment and for decisions on safety improvements. Uncertainties are best dealt with by using best estimates throughout the analysis and presenting the estimated uncertainty as a supplement to the main results. Further information on PSA is given in Appendix 3.

5.5 LIMITING THE CONSEQUENCES OF SEVERE ACCIDENTS

There is a high probability that the safety features of the plant will deal successfully with initiating events. A limited low probability remains that a severe accident may occur, i.e. a sequence may exist in which failure has been considered to be too unlikely to justify the introduction of additional safety features in the design of the installation. For operating LWR plants in general, the probabilities of a core damage accident are mostly in the range 10^{-5} to 10^{-4} per year of reactor operation. Owing to the confinement function, the probability that an individual living near the plant might be exposed is much lower than indicated by the core damage probability alone. Nevertheless, taking into account the fact that more than 400 nuclear power plants will be in operation through the end of this century, there is a real possibility of a severe core damage accident in one of these plants during this period.

An accident involving severe core damage may have serious social and economic consequences, including a loss of confidence in nuclear power. It is therefore worth while examining the technical potential for reducing the probability of such accidents by improved accident prevention. However, there are difficulties and constraints which make it unlikely that the core damage probability can be reduced much below 10^{-5} per reactor-year.

One way of improving the situation is to expand the defence in depth concept by improving the preparation and organization of off-site emergency measures. However, although off-site countermeasures can reduce the socioeconomic impact of a large nuclear accident, they cannot remove it completely. The best additional level of defence is realized by emergency measures inside the plant, i.e. by accident management, including the mitigation of severe core damage. This approach should strengthen the containment function. An intact containment can sufficiently contain the consequences of a core melt accident, as the experience of the Three Mile Island accident has shown.

This defence in depth concept, incorporating accident management, represents a balanced approach, taking into account the actual state of technology. It ensures that a severe core damage accident is unlikely to happen during the lifetime of existing plants and, should it happen, it would be unlikely to lead to major health effects in the population and to the socioeconomic disruption which would be caused by the implementation of major countermeasures. This approach would progressively transfer the emphasis from off-site intervention to more effective on-site accident management.

5.6 OFF-SITE INTERVENTION

Even if those efforts described above are expected to be effective in limiting the consequences of a potentially severe accident, it would be inconsistent with a defence in depth philosophy to dismiss off-site emergency planning. Off-site emergency plans and regular exercises of emergency response therefore continue to be a prudent safety precaution.

Those plans should have the functions of collecting and assessing information about the levels of exposure likely to occur and of initiating and conducting the protective actions that constitute intervention. The primary basis for intervention is the reduction of dose that will be achieved by the protective actions. A further important feature of the plans is the communication of clear information to the public not only in areas where action is needed, but also in areas where it is not.

One continuing problem is that of deciding on the scale of accident for which detailed plans should be provided. Opinions differ, but it seems likely that specific plans for an installation should be fairly limited but should be flexible enough to provide links to national or regional emergency plans already in place for dealing with non-nuclear emergencies.

The extent and nature of off-site emergency plans for both existing and future designs of plant are discussed more extensively in Background Papers II (Section 3) and IV (Section 5) respectively.

6. ORGANIZATION AND RESPONSIBILITIES

6.1 SAFETY CULTURE

The first, and in many ways the most important of the practical steps in achieving a satisfactory standard of safety is the establishment of a safety based attitude in everyone concerned, in all the operations from siting and design to decommissioning, the "safety culture". Although the term has been used mainly in the context of accident prevention and the mitigation of consequences, the concept is equally important in the control of radiation exposures.

Safety culture is that set of attitudes and qualities in individuals and organizations which ensures that, as an overriding priority, nuclear safety issues, in the widest sense, receive the attention warranted by their significance. Thus, safety culture refers to the personal dedication and accountability of all individuals engaged in any activity which has a bearing on the safety of nuclear installations, to an all-pervading safety thinking, which allows an inherently questioning attitude, the prevention of complacency, a commitment to excellence, and the fostering of both personal accountability and corporate self-regulation in safety matters.

These personal and corporate attitudes to safety can only be cultivated if:

- there is an explicit safety policy defining the safety objectives of the organization;

- the management structure clearly identifies the corporate and individual responsibility and accountability for safety at all levels in the organization;

- there is an adequate mechanism for implementing the safety policy, monitoring the effectiveness of the policy, and maintaining the policy in the face of technical and socioeconomic changes.

6.2 SAFETY ORGANIZATION AND DISTRIBUTION OF RESPONSIBILITIES

It is of prime importance to have an effective national safety organization and to state clearly the related responsibilities of the operators and the regulatory bodies, with regard to technical competence, independence and transparency.

The responsibilities for achieving safety are necessarily distributed between governments, their regulatory agencies, the operating managements of the installations giving rise to the risks, and the designers and suppliers who provide the installations. If intergovernmental organizations have regulatory functions, they must accept responsibility for the validity of their regulatory requirements. Advisory bodies must accept responsibility for the advice they give.

The ultimate responsibility for the safety of a nuclear installation rests with the operating organization. For its part the government establishes the legal framework for a nuclear industry and an independent regulatory organization, which is responsible for licensing and regulatory control of nuclear installations and for enforcing the relevant regulations. Governments, or their regulatory agencies, may choose to specify safety goals, but these should not be allowed to detract from the responsibility of designers and operators to do better if this can be achieved by reasonable means. The separation between the responsibilities of the regulatory organization and those of other parties is important, so that the regulators retain their independence as a safety authority and are protected from undue pressure.

In order to ensure that an adequate, timely safety response can be provided, substantial resources are required and should be kept available to cover unexpected expenses for maintaining the plant and for dealing with outages (planned and unplanned) and incidents.

6.3 QUALITY ASSURANCE

Quality assurance programmes should be applied by operating managements, designers and suppliers to enable effective implementation of management directives and to provide feedback on the adequacy of the performance of activities. This involves all those planned and systematic actions necessary to provide adequate confidence that the specified safety requirements are satisfied.

Application of quality assurance practices involves a detailed analysis of tasks to be performed, the identification of skills required, the selection and training of personnel, the use of appropriate equipment and procedures, document control and record systems and a recognition of individual responsibilities. Quality must be verified through a disciplined approach. This includes audits, checks and examinations to ensure that each task is satisfactorily performed. However, all concerned must recognize that the basic responsibility for achieving quality lies with the performer of the task, not the verifier.

There is already a widespread acceptance of these practical approaches to proper management throughout the nuclear industries of the world, but there are no grounds for complacency. Safety can be maintained only by continued vigilance.

7. VERIFICATION OF SAFETY

Verification of safety is required in order to enable the safety principles and concepts to be translated into safe and reliable operation. It is important to remember that verification, like assessment, does not automatically provide additional safety. It has to be followed by positive action. Verification covers a whole range of activities and procedures such as quality assurance at all stages, independent assessment of the safety of design, continued monitoring and inspection of installations, in-depth periodic safety reviews of operating installations, and the monitoring of operational experiences at the national and international level. The ultimate purpose of verification of safety is to demonstrate convincingly that the safety objectives are met, i.e. that the risks associated with the operation of nuclear facilities are sufficiently low.

7.1 SAFETY ASSESSMENT AND CRITERIA

The proof of compliance with the safety objectives requires in-depth safety assessments. Those assessments check the compliance with a comprehensive set of criteria including the technical codes and standards defining the status of applicable technology. They also include the analysis of accident scenarios representative of the whole range of events and processes which have potential radiological consequences.

Traditionally, safety analysis does not explicitly consider probabilities. Instead, the check of compliance with safety criteria includes pessimistic assumptions made in the analysis of accident scenarios in order to ensure that the conclusions drawn from the analysis are on the "safe side". The development and the evolution of the probabilistic methodology open up the way to a more quantitative and, in some regard, more realistic assessment of safety and risk.

Despite the intrinsic limitations (e.g. modelling of organizations, management, and human factors) and characteristic uncertainties, probabilistic safety criteria provide essential insights which permit safety improvements to be made.

Several countries have adopted Probabilistic Safety Criteria (PSC) relating to the risk of accidents in nuclear power plants. Probabilistic Safety Criteria, as applied so far, indicate mostly a desired level of safety (target value or goal), although they are sometimes expressed as a value for the tolerability of the risk (limit value or criterion) or values below which the risk is judged to be negligible. These criteria are generally expressed in terms of the probability of occurrence of an undesired outcome.

For example, there is a wide agreement that, for nuclear power plants operated in accordance with the technical safety objective, the likelihood of occurrence of severe core damage is below about 10^{-4} events per plant operating year. However, the implementation of all safety principles at future plants should lead to the achievement of an improved goal of not more than about 10^{-5} such events per plant operating year. Severe accident management and mitigation measures should reduce by a factor of at least ten the probability of large off-site releases requiring a short term off-site response.

It is an essential advantage of the probabilistic approach that the result of an assessment does not directly depend on the specific system of standards to which the respective installation has been designed and constructed. Provided that an adequate assessment of uncertainties can be made, the probabilistic methodology opens up the way for comparing similar plants built and operated to different standards such as old and new plants or plants in different countries. The benefits of probabilistic assessments are clearly increasing in a situation where international co-operation is continuously getting closer and where the achievement of a high and fairly comparable safety level of all installations, including the old ones, is an important objective.

7.2 SAFETY ASSESSMENT THROUGH OPERATING EXPERIENCE

Periodic testing, maintenance and observed mishaps provide a large amount of information about the effective behaviour and reliability of components, systems and staff. Structured collection of this information allows comparison with design assumptions, correction of weaknesses and possible improvements. Performance indicators are being developed and implemented to be able to monitor in a more systematic way the quality of operation and maintenance, and the overall safety performance of technical systems, staff and management.

7.3 RECURRENT SAFETY ASSESSMENTS

According to current practices a thorough safety analysis, presenting the safety justification of the installation, is required as a condition for obtaining a licence to construct and operate a nuclear installation. The verification of safety is however something that should continue throughout the operating life of a nuclear installation. This is one of the main characteristics of a satisfactory safety culture.

In addition to the continuous attention paid to safety issues at plant level, the operating organization should carry out periodic reviews of safety to confirm that the design intent and safety justification for the installation remain valid. Such reviews should consider the cumulative effects of modifications and changes of procedures, of the ageing of those components that have not been recently replaced or requalified, of operating experience and of technical developments. The regulatory bodies should ensure that such systematic programmes exist and provide an adequate coverage of the issue and should assess the quality of the results.

In addition to using established methods of safety analysis, the quality of safety management, operation and maintenance should be subject to outside peer reviews. Mechanisms for such peer reviews have been established by the IAEA (OSART, ASSET, IPERS) and by the nuclear industry itself (WANO). The combination of day to day, and year to year surveillance and periodic safety reassessments at the national level, together with peer reviews, should be such as to verify that the operation of the installation remains within its safety justification at all times.

8. FUTURE PROSPECTS

The previous sections of this document presented the fundamental bases of nuclear safety. This section addresses some issues of a more general nature which are believed to be essential for the global evaluation and the further development of nuclear safety. For each issue, basic achievements and needs are summarized. Widely agreed answers to the posed questions would be desirable and would be relevant to achieving a consensus about the future role of nuclear energy.

Some of the questions are technical. Others involve a high proportion of judgement which would have to reflect a variety of political, ethical, social and scientific aspects. There might be no established common opinion about them. Some of them do not seem to induce significant debate. Other, more controversial questions will be raised for discussion at the conference.

8.1 ADEQUACY OF THE CONCEPTS AND METHODS OF NUCLEAR SAFETY

An essential basis of nuclear safety is defence in depth. It is a concept which is also used in many other fields of technology. It is generally considered the most effective way to reliably contain dangerous materials and to separate them from the biosphere.

There has been a continuous effort to strengthen defence in depth and to support it by further concepts and methods. Important contributions include the principles for good design and operation such as Nuclear Safety Standards (NUSS) and safety assessment techniques including:

- probabilistic analyses,
- quality assurance,
- accident management techniques,
- safety culture,
- feedback of operating experience,
- periodic safety reassessments,
- peer review techniques such as OSARTs, ASSETs, and many others.

Thus, a comprehensive set of tools is available in order to make nuclear energy a safe technology.

The combined lessons of experience and safety analyses clearly indicate that a proper use of these tools can assure a very high safety level. Thus, adequate protection in normal operation is firmly established in well managed facilities. Radiation exposures to both the public and the workers are generally kept well below levels recommended by international bodies such as the International Commission on Radiological Protection (ICRP). The 1990 ICRP Recommendations call for additional resources to keep exposures to the required levels. Safety analyses clearly indicate that the risk of accidents in nuclear facilities can be kept very low and that future developments can be expected to reduce the risk still further.

Therefore, it seems reasonable to focus attention on the application of available concepts and methods at best available levels rather than to search for new tools. Obviously, there is the need for a wide application at best levels and there is also a potential for making the procedures more easily applicable.

For instance, safety culture relates to attributes which are difficult to assess by objective judgement. That renders the implementation and monitoring of that important concept somewhat difficult. The methods for implementation and checking compliance could be improved in the future.

Probabilistic safety assessments (PSAs) constitute another example where special attention to applicability seems indicated. On the one hand, PSA has already proved to be extremely useful for strengthening the safety of a given installation by highlighting the priority of improvements through the determination of the most important contributors to risk. On the other hand, the application of PSA is still restricted by difficulties in the interpretation of results which are due to uncertainties of predictions, quality of data, and methodological limitations. Those restrictions are small in the very technical area related to accident prevention. They are larger in other areas. Thus, it seems appropriate to search for further methodological improvements and for ways to take into account the remaining uncertainties within decision making.

However, it should be recalled that the essential issue is the careful application of existing concepts and methods at best available levels. If that is done properly it will certainly ensure a very high level of safety.

8.2 BASES OF THE VERIFICATION OF SAFETY

It has been explained in Section 7 that verification of safety covers a broad range of activities such as initial and recurrent safety assessments and evaluating operational experiences. It includes the use of detailed and specific criteria and standards defining a coherent set of requirements related to the specific design of an installation. Those requirements may vary from design to design and from country to country.

The establishment of more universal methods for verification could render this process more homogeneous. Detailed international criteria, standards and codes are sometimes proposed in this connection. However when proceeding this way, it seems difficult if not impossible to maintain the required coherence of requirements and at the same time to keep the way open for future evolution of different types of nuclear technology.

Therefore, further development of state of the art international safety objectives, criteria and standards (such as formulated in INSAG-3 and NUSS) should focus on interpretation and application. That seems less a matter of improved formulations and more one of additional recommendations about stringent application and interpretation and of independent peer reviews making comparisons with good current practices.

8.3 CONTINUATION OF RESEARCH PROGRAMMES

Although not treated in detail in this paper, safety research has proved to be an essential basis for the best current levels of nuclear safety and for its further potential improvement. Further, bilateral and international research activities have turned out to be very effective in reaching a common understanding in many areas, including the characterization of serious accidents. There are many good examples demonstrating the benefits of such co-operation. It seems worth while to strengthen international efforts in this area in order to reach common understanding and to resolve remaining differences.

Research is also being done on the health risks from nuclear radiation; it provides a fundamental basis of the protection needs and concepts. The risk estimates depend on a combination of fundamental studies in radiobiology and of observation of actual effects through epidemiology. Efforts are being made to emphasize the contribution of epidemiology. However, taking into account the remaining uncertainties of low risk prediction and the concern about low level radiation, it might be better to take advantage of recent progress in molecular biology and biophysics to improve the links between these disciplines and epidemiology.

8.4 EVALUATION AND SHARING OF THE INCREASING KNOWLEDGE

The knowledge about safety issues is continuously increasing through the feedback of operating experience, efforts in safety analyses, research and development. Many procedures have been developed and are used effectively to disseminate the relevant information at national and international levels. The work of the World Association of Nuclear Operators (WANO) is important in this context.

The aspects related to research were addressed in the last section. Concerning the sharing of operating experience and lessons learned through incidents, the OECD/NEA set up, just after the Three Mile Island accident, the Incident Reporting System (IRS). Subsequently it was expanded by the IAEA for use by the worldwide community. The experience in this area demonstrates the benefits both of in-depth analyses of selected events by multinational teams and of international expert missions. Such activities should be encouraged in the future.

Apart from operational experience there is a large amount of knowledge acquired by the completion of numerous safety analyses. There already exist some effective national and regional channels to exchange that information. However it would be reasonable to broaden this exchange and to establish a universal system for information about relevant findings of safety analyses similar to what is done within IRS for operational experience. Such a system could broadly disseminate the available knowledge about scenarios and plant conditions relevant for safety.

8.5 COEXISTENCE OF FACILITIES OF DIFFERENT GENERATIONS

The technical life of nuclear facilities can be as long as 40 years or even longer. In that period, experience and technical developments will lead to improved design, construction and operation practices. Early plants will coexist with new ones. That raises the question how to deal consistently with plants with a wide range of characteristics. This problem is not specific to nuclear activities. Continuous improvement and proper backfitting processes are rather more developed in the nuclear field than in many others. Thus, periodic safety reviews of nuclear plants are carried out in most countries as a basis for determining major deviations from state of the art safety levels and to decide on necessary backfits.

However, a formal application of new standards to old plants at the time of a backfit is rarely feasible. A reasonable approach to adequate safety is rather to proceed on a case by case basis. Therefore, the development of some guidance, as to where claims with regard to the safety of backfits are reasonable and where they are not, would constitute a substantial advance.

Moreover, it is important to recall that the technological evolution towards enhanced facilities does not automatically disqualify the existing technology. The coexistence of different generations should be accepted by the decision makers and explained to the public in the same way as with all industrial activities. The acceptance of this principle is crucial for assuring the progress of any technology and for the effective implementation of the lessons from research and operating experience.

8.6 CURRENT TRENDS IN NUCLEAR SAFETY AND FUTURE DEVELOPMENT OF NUCLEAR POWER

It has been stated before that present good practices lead to a safety level which can be summarized as achieving a core damage probability below 10^{-4} per reactor-year. That is the conclusion of numerous probabilistic safety assessments and is consistent with the experience with light water reactors in western Europe, North America and Japan.

Current developments aim at further reducing this probability. However, it will be technically and economically difficult to achieve and to demonstrate convincingly core damage frequencies much below 10^{-5} per reactor-year. The reason is that PSA cannot accurately extrapolate experience so far. As a consequence, statements about core damage frequencies much below that level as well as the proposals for future "inherently safe" installations based on paper studies should be reviewed carefully. Indeed the term "inherently safe" as applied to the overall plant behvaiour is now widely discouraged.

Nevertheless, the efforts in accident management are expected to lead to a reliable limitation of off-site consequences, if a severe accident should occur. Thus a larger number of nuclear plants can be operated at a lower level of overall risks. The economic consequences of a contained accident continue to be serious but should not influence the scale of future nuclear power programmes. However, these consequences do provide an incentive for the design of advanced reactor systems with lower probability of severe core damage.

8.7 COMMUNICATION WITHIN THE SCIENTIFIC COMMUNITY

Nuclear energy has specific and non-specific safety issues and particular concepts have been developed to address them. The aim to achieve excellence makes those concepts and their realization somewhat different from the way safety issues are dealt with in other technologies. That raises the problem of understanding nuclear safety aspects for people not continuously involved. A characteristic example is the difficulty in understanding passive and active safety concepts and their relevance for safety.

There is also a lack of common understanding of basic notions, in particular if definitions involve value judgements in the choice of parameters. Examples are the definitions of risk and its various aspects such as individual health risk, collective risk and risk of land and food usage restriction. Those definitions involve questions of science, engineering, and sociology and include aspects of the perception of risk. They need an interdisciplinary approach.

On the whole it seems important to make the concepts of nuclear safety more transparent and to intensify the communication between different scientific disciplines about the relevant issues of general interest. Comparisons with risk management in other industries are often informative.

8.8 COMMUNICATION WITH DECISION MAKERS AND THE PUBLIC

There is clearly a significant gap between the public perception of the risks and benefits of nuclear power and the corresponding technical assessments. The importance of balancing risks and benefits is widely recognized in the nuclear community as it is in most modern industrial contexts. However, there is more difficulty in reaching agreement on such issues with the public and with the concerned groups who often speak for them. There are also problems in reaching a balance between the aspirations of individuals and those of society and in judging the tolerability of risks.

Greater transparency, and the use of clearer terminology and of comparisons with more familiar situations will help to improve the mutual understanding of the various views, but will not automatically bring agreement. Nor should it be expected that attitudes towards the tolerability of risk would be the same in different countries and at different times. Nevertheless, it is important to continue all the available options for improving communications, and for enhancing the credibility of the actions and decisions of the nuclear industry and its regulators, so that the public can be helped to a better understanding of the issues. There are still many areas where differences of opinion stem more from inadequate information than from different perceptions.

Much of the necessary work will fall to national institutions, but more can be done by international bodies, particularly in the supply of objective information. The recent introduction of an international nuclear event severity scale of nuclear incidents and accidents seems promising. The long term aim must be the encouragement of trust by transparency and continuing dialogue. It has to be emphasized that the choice is between different risks. There is never a choice of zero risk.

8.9 APPRECIATION OF THE SAFETY OF FOREIGN PLANTS

The question: "Are the plants across the border safe enough?" is a symmetrical question when neighbouring countries have both their own nuclear installations. However, simplistic approaches to that question are not helpful. Instead, progressive establishment of bilateral technical relations and information exchanges can provide mutual understanding and build up confidence between the parties, including the nuclear community and the regulatory bodies. There are very encouraging examples. A wider use of such approaches would be beneficial and should be fostered by international organizations.

Even if the knowledge about nuclear installations in a neighbouring country is sufficient, the question remains whether uniform criteria for judgements about safety can be established. The different background and different national approaches of the assessors add to the problem.

9. SUMMARY

Over the last few decades, the policies and practices of radiation protection and of accident prevention and mitigation in nuclear installations have made substantial progress. Experience and analyses indicate that the necessary tools to assure safety are available. It is seen that the protection of the public and the workers in normal operation is generally at a satisfactory level and that the risk of accidents can be kept very low and may still be reduced further.

Among the tools to be mentioned in this regard are fundamental concepts such as:

- defence in depth;
- quality assurance;
- accident management;
- safety culture;
- the basic principles for national organizations and for good design and operation;
- the methods to verify safety by analyses, including probabilistic safety assessments and peer reviews;
- the approaches to international co-operation and the evaluation of operational experience; and
- continuous research and development.

Future efforts should basically focus on careful implementation and application of the available tools. Some improvements of the tools are still required in order to facilitate this task. However, the main orientations of such developments are already known.

Further efforts are also required to improve understanding between the concerned groups such as the nuclear community, the scientists of other relevant disciplines, the public, and the political decision makers. A transparent communication about relevant issues including the effects of low radiation doses seems essential in this regard. Progressive establishment of bilateral and international technical relations and information exchanges could help to improve the understanding across national borders and the objectivity of related judgements.

The current level of safety has been achieved only by the application of substantial resources. This level will not be maintained unless that application is maintained. Society must recognize that the use of these resources contributes to the cost of nuclear energy and that excessive demands for even higher standards of safety for this energy source may well reduce its availability and thus lead to an increased use of fossil fuels, with the associated environmental detriment. In the long term, however, improvements in supporting technology, safety research and feedback of operational experience are expected to improve both the safety and the economy of nuclear power plants.

The nuclear industry is already making a major contribution to the provision of safe and clean electrical energy. The challenge of the coming years, where the international organizations are deeply involved, is in deciding what is safe enough and in getting social agreement to that judgement. Society will have to make the choices, but it must therefore be given the necessary information.

A number of issues have been raised in the background paper, but the principle issues can be brought together in four significant topic areas. These principle issues are recommended for consideration by the conference.

1. Safety objectives and standards: What should they cover and is there a need for more binding international safety standards and regulations?

2. Approaches to systematic safety reassessments throughout the operational lifetime of nuclear installations: should periodic safety reviews be used to supplement or replace continuous assessment programmes? Should some combined assessment and review approach be used and if so, what form should it take?

3. Emergency planning as a part of the total defence in depth concept: How may requirements for emergency planning be affected by implementation of improved severe accident management and release mitigation capabilities in both existing and future reactor designs?

4. What are the desirable components of information dissemination, information exchange and communication activities with political decision makers and the public? For example, how should issues such as "are our (or our neighbour's) nuclear installations acceptably safe?" be addressed?

APPENDIX 1

THE NATURAL RADIATION ENVIRONMENT

Mankind has always been exposed to a wide range of radiation from natural sources. The exposures are due to cosmic rays, gamma rays from the earth, naturally existing radioactive materials in the body resulting mainly from ingestion of food and water (mainly lead-210 and potassium-40) and from inhalation (mainly radon-222).

The average annual dose from natural sources is between 2 and 3 millisieverts (mSv) with a range commonly between 1 and 5 mSv. For the average case, cosmic rays, terrestrial gamma rays and ingested materials make roughly equal contributions (0.3 to 0.4 mSv). Inhaled radon makes a somewhat larger contribution.

The average value comprises a distribution with a number of very much higher doses in different locations. Cosmic ray doses in inhabited areas at high altitude are up to about 5 times the average. Annual doses from terrestrial gamma rays in a few places are as high as 35 mSv. The highest doses are those due to radon. Annual doses approaching 1 Sv have been reported in extreme cases.

These doses from natural sources provide no justification for additional exposures from artificial sources such as nuclear power. They do, however, provide a useful basis for comparison.

APPENDIX 2

THE BIOLOGICAL EFFECTS OF RADIATION

A2.1 THE BIOLOGICAL PROCESS

The process of ionization necessarily changes atoms and molecules, at least transiently, and may thus sometimes damage cells. If cellular damage does occur, and is not adequately repaired, it may prevent the cell from surviving or reproducing, or, more rarely, it may result in a viable but modified cell.

If the number of cells killed is large enough, there will be observable harm reflecting a loss of tissue function. Above some level of exposure (the threshold) the injury will be obvious and the severity of the harm will increase with dose. This type of effect is called "deterministic".

If the irradiated cell is modified rather than killed it may sometimes result, after a prolonged delay, called the latency period, in the manifestation of a malignant condition, a cancer. The probability of an induced cancer is a function of dose, but the severity of the cancer is independent of the dose. This kind of effect is called "stochastic", meaning "of a random or statistical nature". If the damage occurs in a cell whose function is to transmit genetic information to later generations, any resulting effects, which may be of many different kinds and degrees of severity, are expressed in the progeny of the exposed person. This type of stochastic effect is called "hereditary".

The detriment associated with a radiation exposure is thus complex. It includes the probability of an attributable death, which may not occur for some decades, the certainty of injury or death if the dose is high enough, and the possible transmission of detrimental effects to subsequent generations. It has been common to reduce these detrimental effects to a simple statement of the probability of an attributable death or a serious hereditary defect. This simplification ignores the time distribution of the consequences and the less serious, but still significant, effects such as non-fatal cancer.

If radioactive materials are released into the environment, they may be transmitted through the environment to man. They will also expose non-human species to radiation. The standards of environmental control needed to protect individual human beings to the degree currently thought desirable will ensure that other species as a whole are not put at risk. Occasionally individual members of non-human species might be harmed but not to the extent of endangering whole species. Accidental releases to the environment may well require transient limitations on the use that man can make of that environment even if there is no damage to species living within that environment.

A2.2 QUANTITATIVE ESTIMATES OF RADIATION RISK

The most relevant sources of information on the biological effects of radiation are those obtained directly from studies of the effects on man. In addition, however, a great deal of information about the mechanisms of damage and the relationships between dose and the probability of deleterious effects in man can be inferred from biological research studies on microorganisms, on isolated cells grown in vitro, and on animals.

Deterministic effects

Data on deterministic effects in man come from the side effects of radiotherapy, from effects on the early radiologists, from the effects of the atomic bombs at Hiroshima and Nagasaki in Japan, and from the consequences of severe accidents, some in the nuclear industry and some involving industrial and medical radiographic sources.

For most organs of the body, the threshold for serious deterministic effects is 1 Sv or more, even if the dose is delivered in a short time (minutes). Some organs, notably the gonads and the lens of the eye, are somewhat more sensitive. The standard of radiation protection now achieved ensures that deterministic effects do not occur in normal operations. They do sometimes occur as the result of accidents.

Stochastic effects

At present, the three principal sources of information on stochastic effects are the epidemiological studies on the survivors of the nuclear weapon attacks on Hiroshima and Nagasaki, on patients exposed to radiation for medical treatment or diagnosis, and on some groups of workers exposed to radiation or radioactive substances at work. When interpreted together with biological research studies, they provide the basis of radiation protection policy.

The epidemiological data need considerable interpretation and the studies can never provide conclusive information at low doses, meaning doses roughly equal to or less than the inescapable doses due to natural sources. This is because cancer and hereditary disorders occur commonly and naturally in human populations. The increments in the risks of fatal cancers and other disorders due to low doses are so small that they cannot be discerned above variations that are either truly stochastic or are attributable to various demographic factors (see Section A2.3). Statistically significant excess numbers of malignancies in man in homogeneous populations such as in the Japanese studies can be found only at dose increments exceeding about 0.2 Sv. Inescapable doses due to natural sources typically amount to more than 0.1 Sv in a lifetime.

The observable information at high dose increments above natural background, interpreted together with biological research results, can be extrapolated with some confidence to give estimates of the risks at smaller doses. There is a widespread agreement among radiation protection specialists, that for the purpose of radiation protection and its regulation, a linear non-threshold response relationship for stochastic effects is appropriate, based on current knowledge. The slope of the relationship is subject to uncertainties, but there is a widespread agreement that the current value of 5% chance of fatal cancer per sievert for a general population exposed to low doses is unlikely to underestimate the risk.

Hereditary effects have not been positively demonstrated in man so risk estimates have to be made from data in animals. The lack of significant findings in man is not inconsistent with these estimates. The very wide range of the severity of hereditary disorders makes it difficult to define a risk estimate, but for disorders classified as "severe" the value is about 1% per sievert for exposure of the general population.

Prenatal exposure can cause effects in the child. Exposures in the first few weeks of pregnancy are unlikely to cause such effects. Exposures in the later stages of pregnancy can cause developmental defects in the child if the dose to the conceptus is more than about 0.1 Sv.

There is probably a risk of attributable childhood cancer following exposure in utero, although the human data are not conclusive. The risk is likely to be somewhat higher than that following exposure of the adult.

Data from Japan indicate that there may be an effect on the intelligence quotient (IQ) of children irradiated during mid-pregnancy. It is likely that significant changes will not occur at doses below about 0.1 Sv in the period from 8 to 15 weeks post-fertilization.

A2.3 STATISTICAL LIMITATIONS OF EPIDEMIOLOGY

There are two kinds of limitations in the interpretation of the results of epidemiological studies, one statistical and the other demographical.

Statistical limitations

The lifetime probability of death being caused by cancers of any origin including those due to radiation from natural sources is about 20%. If two similar groups of people are being compared to detect a high cancer mortality in one of them, it is necessary to obtain a difference in cancer mortality that is statistically significant in relation to the standard deviation of the difference. An excess equal to twice the standard deviation would have a 95% probability of being genuine. The difference is given by $(N - C)$ and its statistical standard deviation by $\sqrt{(N + C)}$, where N is the expected number of cancer deaths in the observed group and C is the expected number in the control group. With 500 people in each group and an expected incidence of (20 + 5)% in the study group (corresponding, at the current estimated level of risk, to an additional exposure of 1 Sv) N would be 125 and C 100. The expected difference would be 25 with a standard deviation of √225, or 15. This difference would then be observable with a confidence of about 90%. To detect the effects of 0.1 Sv, the size of each group would have to be increased to about 50 000, giving a difference of 250 with a standard deviation of √20250, or 142. To observe the effect of 10 mSv in excess of the natural background would require groups numbering 5 million each.

Demographical limitations

The second limitation is imposed by the need to match the study and control groups for any factors that influence the natural incidence of cancer. These factors include age distribution, for which corrections can be made, and social conditions, genetic composition, environmental influences, and exposure to infections, for all of which the corrections are imprecise or unknown. For geographically separated groups, it is unlikely that these confounding factors can be eliminated to the extent that differences of a few per cent can be confidently excluded, i.e. if the control group has an incidence of fatal cancer of 20%, the figure for the study group may well be anywhere in the range from 18% to 22%. At current estimates of risk, this precludes the detection of the effects of doses of less than about 0.5 Sv, however large the groups may be unless, as in the Japanese studies, the study and control groups are drawn from a single homogeneous population. Conversely, a zero difference in cancer incidence can rarely be used to provide information about doses lower than 0.5 Sv.

A2.4 UNCERTAINTIES

There are several significant uncertainties. Most of the observations of radiation effects relate to high dose rates, which enhance the biological effects at high doses because more than one ionizing event can then occur in a cell in the relevant period. The International Commission on Radiological Protection judges that this enhancement can be represented by a factor of 2 in the range of doses for which direct observations exist. It therefore applies this factor by reducing the observed probability of stochastic effects when estimating the low dose and low dose rate effects. It then uses a linear relationship between dose and the probability of stochastic effects.

There is some uncertainty in the choice of the correction factor for low doses and dose rates, but the uncertainty is not likely to exceed a factor of 2. A further uncertainty is introduced by the fact that not all the members of the study populations are yet dead, so the ultimate number of deaths attributable to radiation has to be predicted. The current method of projection may be too cautious, but not by more than a factor of 2.

Finally, there is the uncertainty of transferring observations in one ethnic population to others. For cancer in individual organs this uncertainty is considerable, perhaps a factor of 10, but for the total of all cancers it is much less. It is unlikely that any national population with a reasonably high standard of life differs from the typical by more than about 30% in the overall sensitivity to radiation.

APPENDIX 3

PROBABILISTIC SAFETY ASSESSMENT; ITS STRENGTHS, WEAKNESSES AND OBJECTIVES

A3.1 STRUCTURE OF A PROBABILISTIC SAFETY ASSESSMENT

A Probabilistic Safety Assessment (PSA) is an analysis that:

- identifies and delineates the combination of events that, if they occur, will lead to a severe accident,
- assesses the frequencies of occurrence for each combination, and
- assesses the consequences of those events.

The PSA integrates into a uniform methodology the relevant information about plant design, operating practices, operating history, component reliability, human actions, the physical progression of core melt accidents, and potential environmental and health effects, usually in as realistic a manner as possible. The analysis involves the development of a set of possible accident sequences and an estimation of their outcomes. To this end, various models are used, and a great amount of data are analysed. Depending on the scope and the objectives of the study, the models may treat plant systems, the response of the containment, radionuclide transport, and off-site consequences.

The structure of a PSA can be split into three different parts. The first part, which is structured around the plant modelling, consists of an assessment of plant design and operation, emphasizing sequences that can lead to core melt. External events, such as floods or earthquakes, may or may not be included. The result is a list of the most probable core melt sequences, their frequencies, and insights into their causes. Such a scope provides an assessment of plant safety and of the adequacy of plant design and operating procedures, from the perspective of preventing core melt. This part is called a level 1 PSA.

In addition to the analyses performed in a level 1 PSA, a level 2 PSA also analyses the physical and chemical phenomena of the accident, the response of the containment to the associated loadings, the transport of radionuclides from the core into the containment, and the release of radionuclides from the core into the environment. This type of study does not provide an assessment of public risk, because off-site consequences are not included. It does, however, provide insights into this risk by generating the frequencies and magnitudes of the release categories.

A level 3 PSA, or a full scope PSA, analyses in addition to a level 2 PSA also the transport of radionuclides in the environment and assesses the public health consequences of accidents.

A3.2 THE STRENGTHS AND WEAKNESSES OF PSA

The strengths of the PSA methodology arise from both the integration of different analytical techniques and from the integration of the various aspects of design and operation of a nuclear power plant. Integration of system analysis, probability techniques and statistics, human reliability modelling, models to describe the physical phenomenology of accident scenarios, and consequence modelling into one coherent framework, enables a much wider array of accident scenarios to be managed in one analysis, than can be handled by alternative approaches. If they are well done, they give an approach to the safety (or risk profile) of a nuclear power plant that is more comprehensive and balanced than other approaches of reactor safety assessments.

A PSA is different from a traditional deterministic safety analysis in that it has a better chance of being complete in identifying accident sequences that can occur from a broad range of initiating events, and it involves the systematic determination of accident frequencies and consequences.

Although PSA provides very useful qualitative and quantitative information the accuracy and the robustness of that information are in fact limited by our overall state of knowledge. PSA is only a model for collecting and treating the body of knowledge that is amassed. This knowledge is expressed in accumulations of data and in models of system behaviour, and of physical and chemical processes. Any set of PSA results therefore will reflect the incompleteness and inherent variability of the database as well as the limitations and simplifications of the modelling procedure that result from our state of knowledge. A PSA is still a model. It has to use in many cases simplistic approximations, in order to keep the analysis manageable. Apart from the imperfections due to the approximations, there are gaps in the knowledge regarding the existence, the nature, the phenomenology and the magnitude of the accident scenarios. Omissions among the initiating events, root causes of failures - particularly common cause failures - in phenomenology or consequences can cause errors of unknown magnitude.

Despite these weaknesses, the principal challenge in using PSAs to support decisions concerning reactor safety is to take advantage of the power of PSAs to give a comprehensive, realistic and balanced picture of reactor safety without becoming vulnerable to wrong decisions because of the many substantial uncertainties involved. Uncertainties must be considered carefully before any decision is reached. The fact that PSAs provide a mechanism for displaying areas of uncertainty (more so than do conventional deterministic analyses) is actually a strength of PSA rather than evidence of a weakness in PSA methods. The weakness that must be guarded against is the tendency to take the PSA best estimates of risk, core melt frequency, or conclusions associated with these estimates as absolute. One of the principal advantages of PSA is the potential for providing additional qualitative and quantitative perspectives on the overall importance of uncertainties. Proper consideration of these uncertainties can enhance engineering judgement.

A3.3 OBJECTIVES OF A PSA

A PSA is an efficient tool for supporting and controlling the decision making process regarding risk management of nuclear power plants. This can be decision making by both the utilities and the regulatory bodies on, respectively, nuclear power plant operation and regulatory matters. A PSA can be used for taking another view of safety, in order to identify vulnerabilities in design and operational practice. This other view is supplementary to traditional licensing practice involving deterministic analysis and the defence in depth strategy. It includes viewing safety from the perspective of accident sequences that include system performance and operator response, and the continuation in time to the stage at which core damage occurs and containment integrity is challenged. The insights gained from this other view and the actions taken to address those insights are the most valuable products. Not only the insights are of importance, but also the final results are considered to be of importance in assessing the significance of safety issues, to support and promote allocation of resources to the resolution of these issues.

A PSA helps to identify the safety relevant issues which need to be resolved. Therefore a PSA can have various objectives and uses, such as:

a) Assessment of the safety of nuclear power plants for optimizing plant safety (identification of the most effective areas for improvement).

b) Assessment of the safety of the nuclear power plants by showing compliance with safety criteria or standards.

c) Support of nuclear power plant operation.

d) Support of nuclear power plant regulation.

A3.4 TOPICS NEEDING FURTHER ATTENTION

The limited number of thoroughly performed, full size PSAs cannot simply be used to pass judgement on the remaining nuclear power plants. In addition the effect of safety culture and its variability from one plant's operating organization to another's and the consequences of differences in management style and personal attitudes are not systematically taken into account in PSAs, yet they must have an effect on true risk. Other factors also contribute to error margins and complicate the application of these methods to meeting safety goals.

The development of the use of PSA has made clear the need for the improvement of knowledge in several areas:

- physical and chemical processes during severe accidents,
- general understanding of human reliability including the influence of safety culture and management style,
- behaviour of components beyond their design conditions and over long periods of time,
- effects of the variability of design and of the use of non-specific databases,
- common cause failure rates,
- knowledge of rare internal initiators, such as large breaks in pressure systems,
- knowledge of rare external events such as large earthquakes, floods or storms having probabilities lower than 10^{-5} per year.

APPENDIX 4

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APPENDIX 2

Background paper for
GOV/2541

Item 6(a) of the provisional
agenda (GOV/2537)

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

Vienna, Austria

2-6 September, 1991

BACKGROUND PAPER

FOR

ISSUE NO. II

ENSURING AND ENHANCING SAFETY OF OPERATING PLANTS

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

ISSUE NO. II

ENSURING AND ENHANCING SAFETY OF OPERATING PLANTS

SIGNIFICANT TOPICS TO BE ADDRESSED AT THE CONFERENCE

Based on comments received to the Background Paper for Issue No. II, together with discussions in the Steering Committee, the following topics are recommended for inclusion in the discussion on Issue No. II. For each topic, there may be actions identified to be taken, by utilities, regulators, Member States, and international bodies, including the IAEA.

For each topic recommended for discussion, some comments are provided both to facilitate an understanding of the issues and to assist the reader with preparations for the discussion sessions at the conference.

Introductory Comment: A consensus exists that there are appropriate criteria, standards and practices to achieve a high operational level in presently operating nuclear power plants, and that there are methods to "measure" the safety level and take corrective actions when needed. Achieving and maintaining a high operational safety level is therefore feasible and the task is one of implementation with a goal of raising the safety performance of all plants to the level of the best.

Topic No. 1

What should be the approaches by utilities and regulatory organizations in order to promote excellence in safety performance of all nuclear power plants?

On the utility side, areas identified as important to this aim include:

- The acceptance of full responsibility for the safety of the plant with the appropriate commitment and involvement of the senior staff;
- The education, training and motivation of personnel including a competent technical capacity;
- Experience analysis and feedback utilized at the appropriate level of responsibility;
- Plant maintainence, replacement parts and configuration control developed to an adequate level;

- Independent in-house safety evaluations and adequacy of quality programmes.

For the regulators important areas include:

- Senior staff involvement and commitment;
- Education, training and motivation of personnel;
- Knowledge of and, if possible, experience in plant design and/or operation.

Additionally specific items for discussion under this topic could be:

- The need for a clear set of mandatory standards;
- Capacity to analyse and discuss new technical matters as they may arise;
- Openness on areas needing attention and causing worries.

Topic No. 2

What more can be done to strengthen national commitment to safe operation of nuclear power plants?

The discussion should address:

- The development of a national technical capacity with national responsibility. This has to be achieved at the level of governments, companies, and scientific and professional organizations;
- The establishment of a regulatory regime with adequate independence and capability to assure independent safety oversight and that safety problems become known at the appropriate levels of authority;
- Information to the public so that a transparent safe performance is shown, and so that when this is not the case corrective actions are taken.

Topic No. 3

What positive actions can be taken on the international level to enhance safety in nuclear power plants?

The aim of international activities has to be to achieve an "International Technological Support Exchange and Transfer". National commitment to international openness and exchange has to be of high priority. For the plant operators emphasis should be placed on improvements in the dissemination of good practices for excellence. Programmes like the IAEA's ASSET, OSART, and IRS activities have been extremely useful. Can these be strengthened in any way? Is the general strategy proposed in the background paper sufficient? If an international "soft" watchdog developed it could be extremely useful in making consistent the safe performance of plants.

On the side of governmental organization, international support to newly created or weak organizations is necessary. Activities that could be promoted would be the exchange of personnel, the exchange of experience and practices, and peer reviews.

Topic No. 4

What should be the roles of the various international organizations in addressing the safety of the world's nuclear power plants?

The organizations referred to here include the IAEA, WANO, OECD/NEA, and for European Community countries the role of the CEC.

WANO has recently been created and is starting to develop its activities. Areas of improvement should be technical support of weak operating organizations, development of good practices for the overall operations and independent peer reviews of operating organizations.

The intergovernmental organizations have up to now divided their roles. The OECD/NEA has been a forum for an important exchange and development of technical capacity through working groups and international projects. The IAEA also has a high international status and has directed its activities to developing internationally agreed standards and channelling technical capacity and support to its Member States. This role could be maintained keeping in mind that a development of an international safety regime could be established through the IAEA.

The CEC has a direct supranational authority and the developments that are taking place will further clarify its role.

The discussions should further clarify the roles of these organizations to ensure excellence in safety performance worldwide.

BACKGROUND PAPER NO. II

ENSURING AND ENHANCING SAFETY OF OPERATING PLANTS

FOREWORD

GENERAL BACKGROUND

Today there are about 425 nuclear power plants operating throughout the world in both industrialized and developing countries, supplying 17% of the world's electricity needs. Four countries obtain more than half of their electricity from nuclear energy, while 13 countries obtain at least 20% of their electricity from this source.

During the accummulated 5600 reactor-years of operation the safety record of nuclear power has been marred by two accidents of particular concern, Three Mile Island in 1979 (with small public consequences) and Chernobyl in 1986 (with large public consequences). Mainly as a result, the risk and possible local effects associated with nuclear energy are perceived by some in government and in the public as being too great for nuclear energy to be accepted as a viable means of resolving the health and environmental effects caused by the other means of generating electricity, particularly the burning of fossil fuels.

The UN World Commission on Environment and Development (Our Common Future) indicated a number of specific items related to the use of nuclear energy that require international agreement including regulatory activities, standards (for operation, radiation protection, waste repositories, and decommissioning), operator training, site selection criteria, emergency response training, reporting, etc.

The Conference on the Changing Atmosphere: Implications for Global Security held in Toronto, Canada, in 1988, concluded that "If the problems of safety, waste and nuclear arms can be solved, nuclear power could have a role to play in lowering CO_2 emissions".

To help resolve these concerns the holding of an International Conference on nuclear safety was suggested and encouraged by European Community countries through the IAEA Board of Governors during the spring of 1990 and presented to the IAEA General Conference in September 1990. The General Conference in its Resolution 529 welcomed the holding of the conference, with certain financial stipulations.

CONFERENCE OBJECTIVE

The Conference is directed to decision makers on nuclear safety and energy policy at the technical policy level. Its objective is to review the nuclear power safety issues on which international consensus would be desirable, to address the concerns on nuclear safety expressed by the UN World Commission on Environment and Development, and to formulate recommendations for future actions by national and International authorities to advance nuclear safety to the highest level including proposals for the IAEA's future activities for consideration by its governing bodies.

The conclusions of this Conference, addressing safety issues only, will complement the conclusions of the Senior Expert Symposium on Electricity and the Environment held in Helsinki, Finland, May 1991 which address the comparative health and environmental effects of the various alternative means of producing electricity.

The conclusions of the Conference will also form part of the IAEA's contribution to the 1992 UN Conference on Environment and Development.

The Conference should promote more effective international co-operation between IAEA Member States on the safety of nuclear energy.

The particular issues selected for consideration by the Conference are:

(i) Fundamental principles for the safe use of nuclear power;
(ii) Ensuring and enhancing the safety of operating plants;
(iii) Treatment of nuclear power plants built to earlier safety standards;
(iv) The next generation of nuclear power plants;
(v) The final disposal of radioactive waste.

For each of these issues the present status, present and foreseeable problems, recommendations for future actions required to deal with these problems at both the national and international levels, and recommendations for the role of the IAEA in these activities are outlined.

This Background Paper deals with the subject of "Ensuring and Enhancing Safety of Operating Plants".

TABLE OF CONTENTS

1. RATIONALE FOR THIS PAPER

Safety assurance necessitates compliance to design standards, adherence to construction quality standards and conformance to operational requirements. Each factor is necessary but not sufficient in itself. Even with excellence in operational safety practices, a plant with inherent design deficiencies or with important defects in its realization cannot be considered as adequately safe. In turn, a well designed and constructed plant with poor operational practices is equally deficient. However, properly designed and constructed plants can be operated safely and indeed, experience shows that the operation of many of them has been very safe. Even faced with serious operating faults or abnormal events, their ultimate safety has not been impaired.

Within the scope of this issue, it is assumed that the design and construction of the operating plants meet satisfactory current quality and technology standards. Additionally, it is assumed that these standards have been maintained throughout the life of the plant*. The best performing plants worldwide are regarded as operating in a manner that assures safety. Further, these plants continue to pursue additional ways to enhance and maximize safety. The desired goal as addressed in this paper is to raise the safety performance of all plants to the standard of the best.

Many existing plants currently operating in Member States of the IAEA are by various criteria considered to be in the best operating plant group. However, some plants thought to be in this group may have deficiencies. Section 2 of this paper, devoted to the general status of the issue, deals with general ways of assuring safe operation and with methods to measure the degree of achievement. Section 3 deals with fifteen selected important issues associated with safe operation of nuclear power plants. Four of these are associated with administrative or daily operation, four with operator related issues, three with improvement of existing plants through plant operating

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* The question of the treatment of plants that do not meet current standards is the subject of Background Paper III. Background Papers II and III complement each other and should be read in conjunction with each other.

experience and four with plant events. Each issue includes three paragraphs: background on related principles and good practices, related main problems and corresponding recommendations. Priorities are not given since they are plant dependent.

Section 4 deals with recommendations for strategic actions by national and international authorities including the IAEA in order to achieve the desired goal.

2. GENERAL STATUS

Achieving and maintaining a high level of operational safety in a nuclear power plant is feasible as shown by experience. Plants built to modern design standards specifically incorporate defence in depth features to accommodate equipment malfunctions, equipment breakdowns and human errors. Systems are included whose sole purpose is to counteract such occurrences including further failures in these systems themselves. These include shutdown systems, emergency cooling systems, and containment systems.

In turn the regulatory safety limits are set at such levels that even when actions are initiated in response to events the additional margins, before there is real concern about the onset of plant damage and harmful public effects, are large. The resultant radiation doses to the public due to normal releases from well managed nuclear power plants including releases from operational occurrences are a small percentage (e.g. 1% in Germany) of the radiation doses from natural sources of radiation, and a fraction of the variation in the natural radiation from location to location in a particular country. While it is not possible to guarantee in an absolute sense that a future severe accident cannot occur, the possibility of such an event can be made very low and provisions can be made to mitigate the consequences of any accidents should they occur. For instance the considerable efforts made in operating plants in the USA since the Three Mile Island accident in 1979 have resulted in a significant decrease (more than two orders of magnitude) in the average estimated frequency of significant reactor core damage.

Achieving a high level of operational safety can be obtained by carrying out two main tasks:

- implementation of a coherent set of criteria, standards and practices related to the operation of the plant including the consideration of accidents in the training of personnel, the preparation of accident management procedures, and the provision of the necessary organizations, services and equipment, to respond to accidents should they occur;

- continuous verification that the appropriate level of operational safety has been reached and is maintained, taking corrective actions as needed.

The first task also involves the application of good management practices (having safety as the first priority), the establishment of a sound quality assurance programme, and the use of review bodies within the operating organizations to assess safety concerns independent of production matters. General guidance on all these matters is given by IAEA publications 75-INSAG-3 (Basic Safety Principles for Nuclear Power Plants, 1988) and 75-INSAG-4 (Safety Culture, 1991). More specific guidance is provided in the IAEA Code on the Safety of Nuclear Power Plants: Operation, 50-C-O (Rev. 1), 1988, in Safety Guides and related Technical Reports, Technical Documents etc. The Commission of the European Communities also published some general guidance: COM(81)519, Safety Principles for Light Water NPPs, and COM(88)788, Assurance of Safety in NPPs, Objectives and Methods. However, the most significant source of information in this regard are the plants which have successfully implemented this guidance or equivalent practices.

There is no single method by which the operational safety level of a plant and its evolution can be directly evaluated. But the combination of the following methods allows a good approach:

- the application of systematic feedback of operating experience including analysis of incidents and their root causes done at the plant level, corporate level, and national level to prevent reoccurrence. It is also important to learn the lessons from events occurring in NPPs around the world in order to prevent their reoccurrence in any nuclear based organization. Organizations such as owners' groups, WANO, the IAEA and the OECD/NEA also review the findings and disseminate generic lessons (see Section 3.2);

- the use of quantitative safety performance indicators and other methods to systematically analyse performance and the verification of adherence to basic safety objectives (see Section 3.4);

- the use of plant specific Probabilistic Safety Assessments (PSAs) based on operational data (components and human reliability) to detect and correct operational weaknesses (see Section 3.3);

- the use of peer reviews of operational safety activities to obtain the benefit of experience from other plants (see Section 3.1).

Nuclear power plants complying with current internationally accepted design and construction quality standards, when operated in accordance with the principles and practices described above are considered as safe, i.e. accidents that could impair public health or the environment are highly unlikely during the lifetime of the plants. An expansion of the principles and practices discussed above is developed in Section 3. This expansion represents ways to enhance and maximize safety among the operating plants.

The plants that have achieved a high level of operational safety are the most significant models for the implementation of approaches indicated in this paper to enhance operational safety.

3. ISSUES

3.1. OPERATIONS AND MAINTENANCE

Background

The best performing nuclear power plants operate according to prescribed manuals authorized by the operating organizations. In turn these organizations have consulted with or received the approval of the regulatory bodies. Safety significant operational activities in these plants are independently verified by other operators. In addition, computer based systems are frequently used to assist the operator for information retrieval, display, and diagnostic purposes.

Maintenance of the plant is performed on a regular basis in accordance with prescribed documents. Post-maintenance requalification tests are routinely performed as a part of quality assurance. Recently, some maintenance tasks have been performed at some plants using computer controlled robotics and remote operation devices to decrease radiation exposure of workers and to provide more accurate data. The accumulation of trending data and the analysis of operational and maintenance data have resulted in improved equipment reliability through the implementation of more predictive maintenance.

Monitoring and inspection of plant equipment are performed on a regular basis in order to ensure proper plant conditions. It is therefore important that they comprehensively cover all aspects of plant operation. The status of the plant is tracked by observing the condition of important equipment. This matter is further discussed in Section 3.4.

Accomplishments during the last five years in operation and maintenance are:

1. Development of advanced operator aids systems using computers to make plant operation easier and more reliable;
2. Accomplishing plant operation with lower radiation levels and lower radiation exposure to workers as a result of the use of low

cobalt materials, robotics and remote handling techniques, maintaining extremely good water chemistry and reducing fuel defects.

The IAEA's OSART process has been an appropriate means to assist Member States in using the best practices available. OSART reviews identify areas where improvements in operational safety can be made as well as those good practices that should be continued and sometimes reinforced. But OSART reviews are not intended to evaluate in detailed and absolute terms whether plants are safe nor to rank plants in comparison with each other. The IAEA is currently implementing measures to improve OSART review efficiency, following INSAG recommendations formulated in an evaluation report that was issued in 1990. WANO is currently completing reciprocal exchange visits between western sites and eastern sites associated with their Moscow centre (e.g. Finland, Hungary, Cuba, Poland, Czechoslovakia, Bulgaria and the USSR). The long term effect should be better plant reliability and longer steady state operation with fewer transients.

Equipment performance, given good design, is dependent upon the maintenance programme at the facility. An organized programme with highly skilled and trained craftsmen is essential to long term safe and efficient operation.

Problems

To assure that the operators have adequate abilities to handle routine situations and to prevent and handle abnormal events, including very infrequent but credible events, the operators' basic understanding of plant characteristics must be improved. Operators also must have frequent simulator training. These topics are discussed further in Section 3.6.

Maintenance policy and implementation play an important role in ensuring the continued safe operation of plant. Training and requalification of maintenance staff are important in ensuring they have an updated understanding of the plant and equipment functions.

Operating technology is continuously being improved. This requires constant review of existing guidance and practices to insure implementation of the best operating information for safe and effective operation.

Recommendations

The planned improvement of the OSART process, with special emphasis on maintenance, is encouraged to enhance plant operation in Member States.

Exchange visits by personnel from operating organizations among Member States to stimulate comparison, emulation and communication are also encouraged.

3.2. ANALYSIS AND FEEDBACK OF OPERATING EXPERIENCE

Background

The principle is stated in INSAG-3 that "Organizations concerned ensure that operating experience and the results of research relevant to safety are exchanged, reviewed and analysed, and that lessons are learned and acted on". Currently processes exist nationally and internationally to collect data from operating experience, analyse them and feed back lessons. While the processes exist there are significant differences between the level of utilization of existing practices between Member States.

The collection and reporting of information and the extraction and implementation of lessons learned are the responsibility of each operating organization, which must have its own feedback and analysis system. The effectiveness of this process is multiplied by independent reviews by regulatory authorities, industry organizations and international organizations such as the IAEA, OECD/NEA and WANO. Most Member States with operating nuclear power plants have access to both the IAEA and the NEA Incident Reporting System (IRS) and to the WANO Event Notification and Event Analysis Report through electronic telecommunications.

The use of computerized databases is needed for correlation of recent and past events to assist in identification of relatively obscure but important events or conditions.

Emphasis is now shifting from equipment failure to human factor considerations. Increased attention is being given to root cause analysis and evaluation of risk associated with complex events. There is also increased emphasis on collection of component failure data to help assess equipment reliability and availability.

Problems

Although practices are available, problems remain with utilization of the best available processes by all Member States.

The information collection process has not kept pace with improvements in overall safety performance and shifts in emphasis based on increased knowledge.

While large quantities of unevaluated information are collected and transmitted within Member States, emphasis should be placed on distribution of in-depth evaluations by utilities, regulatory bodies and industry organizations in the countries where the events happened and internationally. International bodies such as the IAEA and OECD/NEA Principal Working Group 1 should then bring national experts together to discuss commonalities and trends.

In some cases transmittal of lessons learned across the entities involved in the process is untimely.

Recommendations

The IAEA in co-ordination with the NEA and WANO should promote the exchange of information on the best available processes for collecting, screening, analysing, and using operating experience. There is also a need for IAEA initiatives to improve the type of information collected in order to take full advantage of recent improvements in analysis methodologies related to equipment reliability and availability, root cause determinations, probabilistic safety analysis and human factors. Increased emphasis needs to be given to the production of more evaluated information (not just factual) and to improving the speed and efficiency of communication of evaluated information between Member States, especially lessons learned and the decisions on the need for plant modifications.

All these activities should be mainly oriented to provide assistance to the operating organizations in their task of analysis and feedback of operating experience.

3.3. RESULTS FROM PROBABILISTIC SAFETY ANALYSIS

Background

Probabilistic Safety Analysis (PSA) has become a significant tool in complementing the deterministic design analysis of nuclear power plants, serving as a methodical approach to evaluating the plant safety design and the operational safety, and identifying vulnerabilities. It is particularly valuable in the evaluation of alternatives or changes to baseline system configurations. Among the three levels of PSA discussed in Appendix 3 to Background Paper No. I, level 1 is the most useful in support of enhancing the safety of operating plants.

In the last five years significant improvements in the methodology have taken place, the level of detail of the PSAs has increased significantly and more operational data have become available. Although there are certain limitations in the accuracy of PSA assessments, e.g. human reliability analysis and the analysis of common mode effects, in general the limitation embodied in the uses for operational safety (generally a level 1 assessment) are not so significant and knowledge of these limitations allows for a prudent use of results.

Presently there is wide consensus about the benefits that can and are being achieved by the use of PSA methods and results in operating plants.

On the international scene the IAEA is fostering co-operation and technology transfer among countries by means of co-ordinated research programmes, assistance missions, peer review teams, and development of non-commercial computer codes e.g. PSAPACK. The OECD/NEA/CSNI fosters a continuous exchange of information among its member countries essentially by means of Principal Working Group 5.

The CEC with the assistance of its working group on "Safety of Thermal Reactors" in which national safety authorities, electricity producers, manufacturers and research organizations are represented, has already had an in-depth exchange of views on the national practices in the field of the PSA methodologies, use and results, and is currently reviewing the national regulatory approaches to PSA.

In the operational area PSAs can be used for:

- Assignment of reliability targets to safety systems for in-service monitoring purposes;
- Improvements of procedures and technical specifications;
- Improvements in operator performance through emergency procedures improvements and related training;
- Improved equipment availability through optimized test and maintenance intervals;
- Improved communications with regulators;
- Improved internal decision processes;
- Improved knowledge of plant strengths and weaknesses;
- Improved selection of backfittings;
- Assessment of event significance.

The use of PSA can be particularly effective to assess and manage safety related operations and plant changes that routinely affect plant configuration. The process of updating the PSA according to the changes and the use of the PSA to evaluate and direct change is what has been called a "living PSA".

PSA should be used for operational safety although such use has the following constraints:

- The PSA has to be detailed and therefore is expensive;
- A living PSA requires rather sophisticated computing capabilities;
- The operating organizations and regulators have to believe in the benefits and capabilities of PSA;
- PSA can be discredited by the overzealous use of the numbers in absolute terms to prove the safety of the plant, or to prove the value of a particular backfit.

Problems

The most significant problems are the amount of work necessary to undertake a PSA, the lack of technology by some interested users, deficiencies in availability of plant specific equipment reliability data and the misuse of the technology due to lack of training.

Recommendations

The first priority nationally and internationally should be to further encourage the use of PSA methods, in particular the value of a level 1 PSA, in operating plants that have not begun to apply this tool.

The second priority nationally and internationally should be to raise the level of all PSA users to the level of those that are already making an excellent use of PSA.

To achieve these extensions of use of PSA techniques, the ongoing activities within the international organizations, such as the IAEA and OECD, should be maintained, but a follow-up system should be implemented for verification and assistance. Whenever possible, positive reinforcement and emulation should be encouraged.

The third priority should be to improve the status of the art of PSA by reducing the well known limitations, e.g. human reliability, management effects, common mode failures, specific data, physical/chemical phenomena associated with the accident progression and source term etc. (for level 2 and 3 applications), and to search for still unknown limitations.

3.4. THE CONTINUOUS VERIFICATION OF ADHERENCE TO BASIC SAFETY OBJECTIVES

Background

The current status of this verification varies considerably among operating organizations. Some examples of this verification process by the best performing plants, operating organizations, and involved regulatory organizations are as follows:

A. Self-verification

1. Daily management involvement with all aspects of plant operation including frequent visits to all parts of the plant by senior plant and utility managers;
2. Implementation of an organized surveillance test and inspection programme;
3. An aggressive programme for documentation and prioritization of deficiencies;
4. Prompt corrective action measures for deficiencies;
5. Use of plant quality assurance;
6. Continuous reinforcement of a safety culture;
7. Maintaining the plant configuration according to the design basis;
8. Line management involvement in the training process;
9. Effective use of operating experience information;
10. Expert assessment of safety significant activities and equipment.

B. Independent verification

1. Evaluation by independent bodies within the operating organizations (e.g. safety committees);
2. Periodic visits and assessments by national regulatory organizations;

3. Independent evaluations by industry organizations (nationally) using experts and peers;
4. Assistance visits (nationally and internationally);
5. Safety reassessments as needed.

Experience has shown that an effective verification programme requires commitment by operating organizations to correct deficiences found plus follow-up by the evaluating organization.

C. Use of performance indicators

1. A variety of performance indicators are currently being used by many operating organizations and regulatory organizations;
2. Most indicator trends show improving performance in many areas during the last decade;
3. An international set of 10 performance indicators and definitions has been adopted by all operating organizations through WANO membership. Data collection began in 1990 with the objective to present the first worldwide performance indicator report in 1991 and subsequently at periodic intervals;
4. Caution in use and interpretation of performance indicators is required to preclude overemphasis and inappropriate use which could result in management of the indicators themselves;
5. Performance indicators stressing safety continue to be developed, with the limitation that safety and safety culture are difficult to measure.

Problems

Currently there is inadequate knowledge and use of the techniques, and also of the guidance obtained from application of the techniques and of subsequent utilization of this guidance by the best performing plants and regulatory organizations.

Recommendations

Member States should examine their programmes with respect to continuous verification. Exchange visits internationally between sites such as those being conducted by WANO and some individual Member States should be encouraged.

Member States should encourage their operating, regulatory and independent organizations to utilize the verification and follow-up techniques of the best performing plants to enhance safety.

3.5. HUMAN FACTORS ASPECTS OF PLANT SAFETY

There is an increasing awareness of the dichotomy between the human adaptability to meet extreme demands and the limitations of human capabilities.

Background

Human error is often the initiator of incidents and, in combination with equipment failures and faults in design or procedures for instance, can contribute to accident occurrence. Yet the human mind is very effective in detecting and eliminating potential problems, and this has an important positive impact on safety.

The role of the operator, in nuclear power plants complying with current standards, is the management of information gathering, planning and decision making, occasionally including more active control when routine operation is disrupted. The operator is not relied upon to take prompt protective actions. The primary protective system provides this action through highly reliable automatic control and safety systems to protect the reactor from damage.

The operator must be able to recognize when abnormal conditions arise, what their significance is, and how to respond correctly to restore safe conditions (see Section 3.13). The operator has to be provided with the appropriate plant information, training and procedures to perform efficiently.

Safety culture, the importance of which was highlighted by the Chernobyl accident, is an essential concept for human error prevention. It is an individual and collective attitude which reflects with overriding priority, attention to safety questions with respect to their significance. More precisely:

- Each individual must, for safety related tasks, be and feel responsible; know the possible consequences of incorrect performance of a duty; perform work rigorously; identify, report and analyse inadequacies (self-criticism); comply fully with safety culture principles (commitment).

- Every manager up to the highest management level must define responsibilities; train staff*; create self-discipline; monitor and prevent self-complacency; evaluate criticisms and comments carefully; make management's involvement in safety matters visible.

Problems

The human factor remains a critical component of operational safety, in particular because of the difficulty of evaluating precisely human reliability. Because of progress being made on reducing other contributors to abnormal events, the human factor will be in the future an even more important contributor if human factors solutions are not implemented.

Today, insufficient practices exist to extract root causes of incidents with human implications and dispatch their lessons to other plants on a worldwide basis. However, important progress is being made with the accumulation of operating experience and improvements in methodologies related to the evaluation of human reliability.

Among the various causes of human errors sometimes encountered are tasks done by people well qualified in their speciality but not routinely involved in operating the plant, e.g. during special maintenance. If not correctly supervised, they may cause or contribute to safety significant situations.

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* Given the importance of training for operational safety it is covered separately in Section 3.6.

Recommendations

The main recommendations in light of the problems formulated are:

a) On a technical basis:

- Assign people to tasks that make an optimum use of their capabilities. Operators have an important role to play in complex abnormal situations, when time allows the application of judgement for decision making, as in the development of an accident. Such decision making may be necessary to cope with the possible diversity of paths an accident could take;

- Provide for human redundancy as far as possible (see Section 3.13);

- The potential for all management levels within an organization to contribute to degradation of safety must be recognized and addressed;

- Make the normal and accidental plant behaviour "transparent" for the operator, i.e. quickly and unambiguously understandable, by appropriate instrumentation, optimization of information display and the design of man-machine interface and computer aids to help in diagnosis and decision making;

- Develop methodology for collection, interpretation and use of human reliability data (based on human performance enhancement programmes in place in some Member States);

- Screen employees for fitness for duty and maintaining this fitness (caution required in implementation);

- International exchanges, co-operation, common work etc. are of paramount importance on the human factor issue because of the rapid growth of knowledge in this area.

b) On a general basis:

- There is a need for implementation of existing knowledge and practices;
- There is a need for improved ways of collecting, extracting and disseminating human factors experience;
- There is a continuing need for international exchanges, co-operation and joint work on the issue.

3.6. TRAINING OF PERSONNEL

Background and Problems

The current status of training varies widely among operating organizations throughout the world. Some organizations provide only minimal training for control room operators while others provide performance based training that is independently accredited for all operating disciplines with accreditation periodically renewed.

Training facilities also vary. For example, some organizations provide formal lectures with textbooks and on the job training, while others also employ plant specific simulators. The use of simulators provides the operators with a better understanding of the dynamic operation of the plant, improving the ability to identify and correct off-normal conditions and prevent incidents and accidents which could result in core damage. These simulators are also used to test and improve emergency and operating procedures. Other training facilities include laboratories and mock-ups of actual equipment similar to that contained in the plant for use as hands-on training aids.

Recommendations

A fundamental training standard should be encouraged worldwide that would:

a. Include all disciplines required to operate the plant (both plant personnel and external personnel), e.g.
    Managers and supervisors,
    Control room operators,
    Equipment operators,
    Maintenance personnel - mechanical, electrical, instrumentation and control,

Health physics personnel,
Engineers,
Chemists,
Reactor physicists;

b. Provide initial performance based training and qualification for the above disciplines to ensure that personnel have the basic knowledge and skills required for the performance of their jobs;

c. Provide continuing training on a regular basis for all disciplines
   - To maintain qualification,
   - To promulgate lessons learned from within the plant, and industry operating experience to prevent recurrence,
   - To promulgate good practices and provide a forum to exchange ideas for improved performance,
   - To reinforce the safety culture;

d. Promote workshops by the IAEA and interested parties, peer exchange visits, and assistance visits to encourage comparison and emulation;

e. Promote the use of qualified full scope and accident simulators*;

f. Promote a commensurate level of specialized training for regulatory personnel.

3.7. AVAILABILITY OF SUITABLY EDUCATED PERSONNEL

Background

During the years of developing or expanding nuclear power programmes in Member States, there was a strong career interest in nuclear power. The universities responded and programmes were developed to provide Nuclear Engineering and Radiation Physics education. In addition, the construction, testing and startup programmes served as an excellent training opportunity for the emerging nuclear educated personnel.

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* Engineering analysers and plant simulators that appropriately model the full range of events of interest including severe accidents.

Problems

Currently, owing to the curtailment of new plant construction (reduced growth) and adverse public opinion related to the Three Mile Island and Chernobyl accidents, there is a reduction in enrolment in university programmes supporting nuclear occupations. In response to declining enrolment some universities have cancelled or curtailed programmes. This is a potentially acute problem in countries facing an unusually high level of attrition of a generation of personnel through retirement.

Recommendations

Member States must each take measures to assure a continuing supply of adequately educated entry level personnel. Where insufficient numbers of nuclear educated personnel are available, organizations must make provisions to directly supplement the education of personnel in the needed areas.

The IAEA should take initiatives to assist Member States in making the best possible use of university and other training institutions to assure an adequate knowledge and skill base for replacement personnel.

The IAEA also has a significant role in assisting in education of the public regarding the risks and benefits of nuclear power generation to provide the most accurate perspective and outlook of future development.

3.8. SCIENTIFIC AND ENGINEERING SUPPORT DURING THE LIFE OF THE PLANT

Background

The design, construction and commissioning of a nuclear power plant require a significant amount of scientific and engineering support*.

Once the plant is in operation scientific support and research and development become a lower priority and there is a temptation to reduce engineering support and to orient the whole utility to the "operation" of the plant.

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* Including activities and applications of R&D.

However the continuing safe operation of a nuclear power plant requires engineering support, which can be called on as required to assist with plant maintenance, modifications, repairs and special tests, and to provide analytical support as necessary for the safety of the plant. This resource may be provided within the operating organization itself, or it may be available from the plant suppliers or specialist groups. It is the responsibility of the operating organization to ensure that the resources required are available to maintain and improve as needed the design basis of the plant.

In the last 5 years there has been a continuous increase in the amount of engineering effort devoted to the support of operations, in the use of sophisticated tools like complex thermohydraulic computer codes or detailed PSA models and in the amount of in-house engineering support to retain control of the results and to recognize the implications of the engineering analysis.

The IAEA recently created the Engineering Safety Review Service to help Member States to deal with safety concerns that may arise in operating nuclear power plants. For instance, in the 1990s, many Member States will have to deal resolutely with issues such as the ageing of nuclear power plants and the plant implications of fire and external events.

Additionally, given that the technology is getting more and more sophisticated, the utilities will probably require more in-house technical support. To obtain economies of scale there probably will be a tendency at national and international levels to share some of the engineering capabilities, e.g. activities of owners' groups and INPO analysis of operational experience.

Problems

There is a wide consensus that any nuclear power plant in operation must have timely access to experienced engineering support and that certain in-house expertise is necessary in order to appropriately understand engineering work performed by others.

To keep abreast with new technological developments requires dedicated and significant engineering resources. A significant problem to obtain appropriate support may arise for plants in Member States with reduced availability of suitably educated personnel (Section 3.7) in specific areas.

Recommendations

The first priority nationally and internationally should be to assess the existing engineering support level and raise this level to that of excellent plants. The IAEA may elaborate guidance and incorporate in the OSART process the verification that adequate engineering support is available including arrangements, as necessary, with external organizations. Whenever possible, positive reinforcement and emulation should be encouraged.

The second priority nationally and internationally should be to improve the level of engineering support by the incorporation and exchanging of new methods and ideas. Exchange visits to learn about operating organizations that have this excellent level of engineering support are needed and should be encouraged to provide the basis for emulation.

3.9. RADIOLOGICAL EXPERIENCE IN OPERATION

Background

In general, the control of releases of liquid and gaseous radioactivity and occupational radiation exposure has improved steadily at operating nuclear power plants. These releases and exposures are now much lower than the regulatory limits. The production of solid radioactive waste by plant operations has decreased significantly through the incorporation of lessons learned from experience.

The following activities at the best performing plants have contributed to these achievements when aggressively pursued:

1. The reduction of radioactive effluents by the recycling of radioactive liquids, filtering and ion exchange, the hold-up of gaseous wastes in decay tanks, monitoring of effluent release paths, and environmental monitoring programmes;

2. The reduction of occupational exposure by enhanced personal dosimetry, health physics monitoring, cleanup of contaminated areas, training of workers in measures to minimize exposure, maintenance of accurate and detailed records of exposure, and whole body assessment programmes;

3. Incorporating technological improvements in fuel cladding performance, water chemistry controls, materials to reduce activation components such as cobalt, and increased use of robotics and remote handling devices and of mockups and detailed training.

Problems

The best plants may be approaching practical limits for the reduction of exposures, releases, and solid waste, but substantial improvements can be achieved at many plants.

The reduction of individual personnel exposure limits to the new ICRP limits of 20 mSv/a may require an increase in the number of some highly specialized workers such as non-destructive test personnel, welders and pipe fitters performing major modification work during outages. However this reduction of the limits is not expected to cause problems for the majority of nuclear plant activities.

Recommendations

Technological and experience exchanges should be continued through IAEA conferences, WANO and other reciprocal exchange visits and seminars to provide the incentive, through increased knowledge and peer pressure, to improve practices at poorer performing plants.

3.10. AGEING AND LIFE EXTENSION

Background

Ageing affects all nuclear power plant materials to some degree, and if unmitigated, it leads to the degradation of functionality and integrity of plant components, systems and structures. From the safety perspective, ageing in nuclear power plants must be managed effectively to ensure that required safety margins of all components, systems and structures important to safety are maintained throughout plant service life, including any extended life. The overall programme of maintenance is of paramount importance in controlling effects of ageing. From the plant life extension perspective, ageing is a specific concern for plant components, systems and structures that are difficult to replace or cannot be fully tested or inspected during the life of a nuclear power plant.

The design life of plants has been set for a specific period, such as 40 years, following past industrial experience and assumptions as to the expected use of the equipment and components. Studies performed by the nuclear industry indicate that a significant potential exists for extending plant life, especially when materials and quality assurance improvements of recent years and the actual use of the equipment are taken into account. If plant lifetimes are to be extended, methods to test or replace equipment to assure continued safe operation must be developed. Knowledge of the effects of ageing on equipment and components is also important for maintaining equipment qualification for safety purposes (i.e. equipment functionality under postulated accident and post-accident conditions).

In some special areas of technology, the study of ageing to estimate equipment life has been completed. However, it is necessary to continue the study of ageing scientifically and to a greater extent than performed by industries in the past.

Some Member States have already started studies on plant ageing for life extension and continued equipment qualification. The studies explore the technical and legal feasibility on a plant by plant basis. The information and results obtained from these studies have been discussed in several international meetings and are being shared among the Member States.

Problems

The effective management of nuclear power plant ageing requires first an understanding of the significant ageing mechanisms, giving rise to the degradation of safety significant components, systems and structures. This includes knowledge of the availability of effective and practical methods for monitoring and mitigating age related degradation. Coupled with this is the need to establish the extent of technology available to support the above processes, plus the mechanisms for effective utilization of the available methods.

The study of ageing and estimation of the lifetime of equipment and components are very difficult technical matters, because they are mainly governed by a combination of different factors. These factors include the specific design and the materials from which the equipment and components were produced, and the environment and other conditions to which they were subjected during use. Sometimes a slight change in the environment causes a significant change in the life of equipment. Therefore, the study must include careful examination of data related to these influential factors; such data have not been recorded in the past. Further, existing methods and technology for the management of ageing must be thoroughly evaluated and implemented where appropriate. In addition new technology must be developed to ensure that required safety margins and overall plant safety are not jeopardized by age related degradation during the entire plant life, including any extended life.

Recommendations

The IAEA should continue and enhance its activities to promote the integration of information on the evaluation and management of safety aspects of nuclear power plant ageing, generated by Member State organizations, into a common knowledge base. The focus should be on collecting and disseminating evaluated information to the Member States.

3.11. BACKFITTING*

Background

As lessons are learned the determination to make a significant change to a nuclear plant constitutes a backfit decision. These backfit decisions may be plant specific or generic among a family of plant designs. Some can be rather significant as is the case for severe accident prevention and mitigation.

In addition, relatively minor changes taken as a group or summed in cost and impact may also constitute a backfit. Backfits are currently implemented through different processes among Member States. In some instances decisions are made issue by issue and in other instances through periodic reassessments. The decision process in some Member States has become highly formalized using cost-benefit and probabilistic safety analysis methodologies to assist in the determinations.

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* This topic is also dealt with in Background Paper No. III.

Problems

In some instances processes do not exist to make ordered decisions to implement safety improvements. In other instances new requirements may be imposed either officially or through informal means without full consideration of relative safety benefit and cost.

Uncontrolled imposition of backfits may reduce overall safety by distracting resources from high safety beneficial tasks while at the same time making plants more complex.

Failure to implement important safety improvements leads to continued risk.

Recommendations

IAEA should promote the exchange of experience and methodology for implementing backfits among the Member States. Based on that exchange, guidance should be developed for use by Member States.

3.12. REPORTING OF EVENTS TO THE PUBLIC

Background

Most countries have arrangements to systematically and rapidly inform the public of the evolution of safety issues, of radioactivity levels and of occurrence of incidents and significant events through already existing or new specific channels. A prompt notification is made to appropriate authorities of events of direct safety significance to initiate notification of the affected public regarding protective actions if needed. It is also important that plant workers be kept fully informed of plant events as an element of maintaining an appropriate safety culture. Public confidence is inspired by an openness or transparency of activities and events at nuclear plants and findings by the regulators. Gravity scales are now used to quantify the significance of events for the media and the general public. The IAEA recently produced an international scale for trial use by Member States.

The gravity scale initiative was generally welcomed by the media and most of the pressure groups but some countries are at the present time encountering some difficulties due to the large number of reported events. There is obviously a misunderstanding about the low graded events in the gravity scale (which reflects the normal life of any large industrial activity) but their large number is taken as a safety deficiency.

Problems

Without exaggerating the importance of the difficulty with the gravity scale mentioned above, which may be temporary, the nuclear community might be faced with a new challenge of public opinion: to make nuclear plant operation even more "resistant" to equipment malfunctions and human error in order to decrease in particular the rate of occurrence of minor events.

There continues to be a problem of public understanding of safety performance and particularly safety significance of occurrences at nuclear power plants.

Care should be taken to prevent misuse of gravity scales developed for communication of significant events to the public and the media as measures of nuclear plant safety performance.

Recommendations

International organizations like the IAEA should play an important role in supporting and rationalizing initiatives aiming at transparency towards the public and more generally at educating the news media and the public about nuclear safety. These types of actions would supplement strategies for public education which should be largely used on a national basis by industry, professional associations, government agencies and educational organizations.

3.13. ACCIDENT MANAGEMENT

Background

Accident management refers to the restoration of safe reactor plant conditions in incidents where safety equipment does not perform adequately to prevent or mitigate an accident. Within the framework of application of the defence in depth concept, accident management addresses two aspects:

- A contribution to prevention through actions modifying or reversing the course of an accident sequence before damage to the reactor core;

- A contribution to mitigation of the radiological consequences if prevention fails (the core is damaged and external releases are possible or have begun to occur).

During the first years following the Three Mile Island accident, measures were developed for the prevention of core damage. Following this the strategy for beyond core damage situations is progressively being developed. Today, there are still significant differences between the status reached in prevention of core damage in IAEA Member States. Implementation of mitigation measures after core damage is in a relatively early stage.

The overall strategy includes:

- Dedicated procedures adapted to the highly perturbed situation and referring to the physical state of the plant ("multisymptom" oriented instead of the normal "event oriented" procedures which are addressed to single initiators);

- the use of systems in ways outside their original intent to minimize core damage or radiological releases;

- Specific means of action (additional equipment, systems, instrumentation and controls);

- Specific organizational, training and staff drills (with the scientific and technical support of external study groups, and of regulatory authorities); computer aided means for diagnosis and radiological release projections are extensively used.

Problems

(a) Generally, only countries with large nuclear programmes have been able to undertake accident research and development work and subsequently develop and begin implementation of accident management strategies. Very few countries with small programmes could undertake the accident research and development but all must have access to the work in order to implement accident management strategies.

(b) The reader should note that accident management actions may have adverse impacts if improperly implemented, especially with respect to timing. An example is the concept of containment venting. The decision to vent non-condensible gases from the containment should be based on the knowledge that such actions will ensure that the containment integrity is not damaged, so ensuring that containment will still be available to provide mitigation at a later stage of an incident if required, giving an overall reduction in radiological consequences.

Recommendations

(a) On a general basis:

- Through international exchanges and co-ordination by the IAEA, accident management strategies, directed to prevention of core damage and mitigation of radiological consequences, should be made available to Member States for adaptation to their particular situation;

- Member States should make available the results of their safety research and accident management measures as they are developed and implemented, for the benefit of all.

(b) On a technical basis:
Special care should be given to the following points in setting up accident management:

- Each accident management decision must be carefully evaluated in view of all possible consequences for safety;

- Accident management training of all involved teams must be carried out on a regular basis;

- Accident management should be a major part of the plant internal emergency plan and should be independently reviewed and agreed upon by the regulatory authorities. Attention should be paid to the interactions of this plan with external emergency planning.

Consistency and good co-ordination with the responsible local authorities are necessary.

3.14. EMERGENCY PLANNING, RESPONSE AND INTERNATIONAL ARRANGEMENTS

Background

Emergency planning and preparedness comprise activities necessary to ensure that, in the event of an accident, all actions necessary for the protection of the public and the plant staff could be carried out, and that decision making in the use of these services would be disciplined (ref. 75-INSAG-3, Basic Safety Principles for Nuclear Power Plants, Section 4.7).

Emergency plans are prepared for measures to be taken on and off the site to protect the public from any serious releases of radioactive materials from the plant. The plans are tested appropriately by exercising their communications and logistics. The emergency plans define organizational arrangements and the division of responsibilities for emergency action, and they are flexible enough to be adapted to particular circumstances as they arise.

The emergency plans define the actions that would be taken in the event of an accident to re-establish control of the plant, to protect staff and the public, and to provide the necessary information speedily to the regulatory organization and other authorities. Emergency planning zones defined around the plant provide a basic geographic framework for decision making on implementing protective measures as part of a graded response. These measures include, as required, early notification, sheltering and evacuation, radioprotective prophylaxis and supply of protective equipment, radiation monitoring, control of ingress and egress, decontamination, medical care, provision of food and water, control of agricultural products, and dissemination of information.

Emergency planning, procedures and training of personnel have been significantly upgraded and improved on the basis of lessons learned from the Three Mile Island and Chernobyl accident responses. These improvements have occurred at all levels including plant personnel, local authorities and national authorities. Currently, provisions for prompt notification of off-site authorities are generally in place, special response and communication facilities have been provided, procedures and training have been provided and exercises are periodically conducted to assure integration of the various organizations and personnel. Internationally, the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency have been approved by IAEA Member States and partially ratified.

Problems

In some instances the lessons learned from Three Mile Island and Chernobyl have not been fully implemented. In particular, evaluated exercises involving all of the response organizations should be conducted periodically. There is a potential problem that the motivation for maintaining emergency preparedness may decline as plant safety performance continues to improve and this may be compounded by the results of recent analysis that indicates a reduction in the source term used in accident analysis.

Although an international system is in place for notification and assistance, the necessary infrastructure does not exist in all Member States to assure its timely use. In addition, co-ordination of emergency notification and response actions has not been accomplished between all countries with plants at or very near their borders.

Recommendations

Member States should assure that plant operating organizations have the means for early prediction of the extent and significance of any release of radioactive materials if an accident were to occur, for rapid and continuous assessment of the radiological situation, and for determining the need for protective measures.

The IAEA should stress the importance of the defence in depth philosophy, which argues for maintaining a strong emergency response capability by the Member States in addition to improving operating plant performance.

Member States should develop agreements with bordering nations to provide appropriate notification and protective actions for citizens near nuclear power plants. Response personnel should participate in periodic exercises with the neighboring nation to demonstrate integration of the response.

3.15. GOVERNMENTAL ACTIVITIES

Background

Governmental institutions, in particular regulatory authorities, have a key role in ensuring and enhancing the safety of nuclear power plants.

The International Nuclear Safety Advisory Group (INSAG) has prepared a report on Safety Culture (75-INSAG-4, 1991) in which the group makes the following statements concerning approaches and attitudes:

The practical approach that governments adopt towards safety in general and nuclear safety in particular has a major effect on all organizations influencing nuclear safety. The following aspects demonstrate government commitment:

- Legislation and government policies for the use of nuclear power set broad safety objectives, establish the necessary institutions, and ensure adequate support for its safety development;

- Governments assign the responsibilities of such institutions clearly, arrange that conflict of interest in important safety matters is minimized, and ensure in particular that safety matters are addressed on their merits, without interference or undue pressure from bodies whose responsibility for nuclear safety is less direct;

- Governments provide strong support for regulatory agencies, including adequate powers, sufficient funds for all activities and guarantees that the regulatory task can be pursued without undue interference;

- Governments promote and contribute to the international exchange of safety related information.

Regulators have considerable discretionary authority in matters of nuclear safety. This is conferred by legislation and the more detailed instruments under which the regulators operate, and is manifested in several general ways.

- The management style of a regulatory agency ensures that common concern for safety leads to relations with operating organizations that are open and co-operative and yet have the formality and separateness appropriate for bodies with recognizably different accountabilities;

- Controversial topics are dealt with in an open fashion. An open approach is adopted to setting safety objectives so that those whom they regulate and those whom they protect have an opportunity to comment on the intent;

- Standards are adopted that call for appropriate levels of safety while recognizing the inevitable residual risk. By this means a consistent and realistic approach to safety is achieved;

- Regulators recognize that the primary responsibility for safety rests with the operating organization and not the regulator. To this purpose, they ensure that regulatory requirements are clear but not so prescriptive as to set undue constraints;

- In dealing with new problems, while a generally conservative approach may be taken, innovation is not stifled by insistence on adherence only to approaches that have been used in the past. Improvements in safety result from a well judged combination of innovation and reliance on proven techniques;

- Regulators are adequately trained technically and regarding the regulatory process to assure appropriate focus on important safety issues and to assure appropriate actions are taken in response to identified safety problems.

Those who regulate economic aspects of nuclear power take into account the fact that decisions based on purely economic factors could be prejudicial to reactor safety.

Particular requirements relating to the establishment of a regulatory body are given in the IAEA Code on the Safety of Nuclear Power Plants: Governmental Organization (Safety Series No. 50-C-G (Rev. 1), 1988). This code represents the international consensus on regulatory body activities.

Problems

Strong regulatory bodies with the necessary independence from the production side of nuclear energy do not exist in all Member States. In turn some Member State regulatory bodies do not have the necessary authority or technical capability to ensure that the nuclear power plant operating organizations carry out their safety responsibility.

Recommendations

The governments which have not set up full regulatory capabilities should do so.

The IAEA should assist governments in this activity, provide assistance in developing the capabilities of the regulatory bodies, promote the exchange of training programme information and of good regulatory practices among all Member State regulatory bodies, and provide peer review services of regulatory body activities when requested.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS

4.1. WHAT NEEDS TO BE DONE

General strategy

The overall world risk associated with operational safety practices in nuclear power plants is dominated by deficiencies in safety performance at a fraction of the operating plants. Therefore, Member States should assess their level of performance in operational safety. Where deficiencies are identified corrective actions should be taken in order to reach the level of good performers. Where good practices are identified they should be made available for emulation. The overall objective should be to strive for and maintain excellence.

Section 3 of this paper has clearly shown for each issue that in most cases, appropriate good practices or standards do exist and are available to ensure safety but that most of the problems come from insufficient or incorrect implementation because of lack of know-how or of resources compounded by production demands. There were also a few issues, like ageing and accident management strategies, where incompletely solved technical problems have been identified. Work is currently ongoing on these subjects and should be pursued.

Therefore, the proposed general strategy is to help recognize and resolve weaknesses in implementing appropriate good practices or standards in all aspects of plant operation.

The actions necessary to implement such a general strategy are:

- Identify the plants that need improvements in their operational safety level;
- Assure that decision makers have the appropriate information regarding the importance of operational safety and its feasibility (that they have a safety culture);
- Identify the existing sets of criteria, standards and practices that assure safe operation;
- Continue the formalization of good practices and standards into readily retrievable and referenceable documents;

- Provide access to such a set of documents and facilitate its correct implementation;
- Identify the existing methods to assess performance;
- Provide access to such methods and facilitate their correct implementation;
- Identify the existing methods to improve performance;
- Provide access to such methods and facilitate their correct implementation.

4.2. HOW TO DO IT

There are two main categories of tasks to be implemented in order to achieve the actions identified in Section 4.1:

- Getting the needed information and know-how and disseminating it;
- Organizing the work; disseminating the lessons learned; verifying appropriate implementation.

Sources of information and know-how currently exist and include the following:

- Utilities and associations of utilities, e.g. WANO, INPO;
- IAEA;
- National regulatory bodies;
- Other government organizations;
- Intergovernmental bodies such as OECD/NEA;
- Professional associations such as ANS, ENS;
- CEC documentation.

The strategy described above should be the topic of a future IAEA workshop within the Implementation of Operational Improvement Programmes activity. The strategy should be developed in such a way that good performers transmit the keys to their achievements, help in their implementation, and participate in the evaluation of the results. Since a good assessment of performance is a crucial element to improve performance the strategy should place a high priority on relatively recent tools such as performance indicators. Moreover, since safety culture has proved to be an essential element for operational safety a high priority should be given to the further development of the concepts and tools described in 75-INSAG-4.

4.3. SPECIFIC ROLE OF THE IAEA

The role proposed for the IAEA consists of the following:

i) Obtaining agreement of Member States on the general objectives of the strategy for the enhancement of operational safety practices as outlined in this paper;

ii) The promotion of this general strategy encouraging all Member States to participate, emphasizing the positive benefits to all participants;

iii) Conducting workshops to exchange findings and experience and provide an opportunity for peer comments;

iv) The follow-up of the implemented exchange activities to ensure the programme's accomplishment;

v) Encouraging Member States to make available the findings, lessons, and experience of the exchange activities;

vi) Providing assistance to Member States upon request to implement the good practices identified in the exchanges;

vii) Compiling and disseminating the overall results of the strategy for international use.

5. SUMMARY

The processes involved in ensuring and enhancing the safety of operating plants have been considered. In order to achieve and maintain a high level of operational safety, and also verify that the required level is maintained, a number of safety issues must be adequately addressed.

The many plants which excel in their response to the identified issues provide a beneficial example to other plant operators of what can and needs to be done to maintain the required level of operational safety. The topics which need to be addressed are related to:

- operation and maintenance;
- analysis and feedback of operating experience;
- use of PSA results;
- aspects of continuous verification of adherence to basic safety objectives, e.g.
    - self-verification and independent verification
    - use of performance indicators;
- human factors;
- training and availability of suitably educated personnel;
- through-life scientific and engineering support;
- radiological operating experience;
- ageing, backfitting and life extension;
- event reporting;
- accident management;
- emergency planning, response and international arrangements;
- governmental activities.

For each topic, the background and related problems have been presented. Advice for improvement is provided in the form of recommendations, both to address specific issues and also at a more global level in terms of a general strategy for action directed to involved parties at national and international levels.

To facilitate a focused discussion of the issues at the conference, the following potentially significant topics are presented for consideration:

1. What should be the approaches by utilities and regulatory organizations in order to promote excellence in safety performance of all nuclear power plants?

2. What more can be done to strengthen national commitment to safe operation of nuclear power plants?

3. What positive actions can be taken on the international level to enhance safety in nuclear power plants?

4. What should be the roles of the various international organizations in addressing the safety of the world's nuclear power plants?

APPENDIX I

EXPERT GROUP PARTICIPANTS

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APPENDIX 3

Background paper for
document GOV/2541

Item 6(a) of the provisional
agenda (GOV/2537)

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER:
STRATEGY FOR THE FUTURE

Vienna, Austria
2-6 September 1991

BACKGROUND PAPER

FOR

ISSUE NO. III

TREATMENT OF NUCLEAR POWER PLANTS BUILT TO EARLIER SAFETY STANDARDS

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

ISSUE NO. III

TREATMENT OF NUCLEAR POWER PLANTS BUILT TO EARLIER SAFETY STANDARDS

SIGNIFICANT TOPICS TO BE ADDRESSED AT THE CONFERENCE

Based on comments received to the Background Paper for Issue No. III, together with discussions in the Steering Committee, the following topics are recommended for inclusion in the discussion on Issue No. III. For each topic, there may be actions identified to be taken, by utilities, regulators, Member States, and international bodies, including the IAEA.

For each topic recommended for discussion, some comments are provided both to facilitate an understanding of the issues and to assist the reader with preparations for the discussion sessions at the conference.

Topic No. 1

How should reactors built to earlier safety standards be shown to be adequately safe?

Although reactors built to earlier safety standards may have adequately conservative assumptions built into their design and analysis, they may not meet safety standards that have been developed since they were first licensed. Further, the general understanding of how reactors fail, and the analytical tools used to predict how reactors perform under off-normal or accident conditions, have improved significantly over the years.

Background Paper No. III and comments on it raise the question - "Should old plants be compared with current safety standards or should they continue to be licensed based on their original standards?" Most countries review old plants when specific safety issues of importance are identified that may require a degree of backfit modification which would result in the plant meeting, in whole or in part, new requirements developed as a result of the safety issue. In many cases however, it has been considered either not feasible, or economically not viable, to modify old plant to meet the new requirements.

Further, this type of review - reacting to specific safety issues as they arise - may not identify all the areas where modifications may be warranted if all current standards are to be met, particularly if the whole safety analysis were redone in a comprehensive and systematic way taking into account all that had been learned over a previous time period, say 10 years. Opinions differ on whether such a systematic review, carried out at intervals, would be beneficial when added to the existing, continuous review of specific safety issues. If it were done, should current safety standards be used to judge the result, and if they were, how should any shortfalls between the results of safety reviews and current safety standards be dealt with?

Topic No. 2

Should an international consensus be sought to define a minimum level of safety to be met by reactors built to earlier standards?

If a shortfall exists between the safety standards of an older reactor - or even of a new reactor built to earlier standards - and current safety standards, how should such a shortfall be dealt with? Safety standards are not absolute, in that they imply that the level of risk posed by a plant operated to those standards is acceptable. This does not necessarily mean a plant operated to lower standards, or less precise standards, is unacceptable. The level of risk may be higher, but still tolerable, taking into account the investment in the plant, and the effects of shutting it down.

The question for discussion, then, is should an international consensus be sought (given that risks do not respect national boundaries) that would define what standards represent the threshold of international acceptability?

Topic No. 3

What should be the role of the various international organizations (IAEA, OECD/NEA, WANO) in the implementation of recommendations on these topics?

In any international standard setting exercise, the question arises - how should one country satisfy itself that its neighbour is, in fact, meeting at least the minimum acceptable standard? Should the IAEA, for example, in addition to its traditional role of promoting international standards, also be charged with reviewing their implementation? The general consensus in the comments received on Paper III was "no". If the IAEA does not do it, how should it be achieved? What could the role, for example, of WANO be? Would WANO represent a degree of self-regulation on an international scale? Neither the paper nor the comments offer guidance on the matter.

Topic No. 4

What weight should be given to socioeconomic factors when making decisions on reactors built to earlier standards?

Reactor Plants that have already been built clearly represent a substantial investment that has already been made. The effect of shutting down a reactor may have a very significant impact on the economic and hence social health of a community or a country. How should such factors be weighed against a lack of adherence to current safety standards, and current values of acceptable risk?

BACKGROUND PAPER NO. III

TREATMENT OF NUCLEAR POWER PLANTS BUILT TO EARLIER SAFETY STANDARDS

FOREWORD

Today there are about 425 nuclear power plants operating throughout the world in both industrialized and developing countries, supplying 17% of the world's electricity needs. Four countries obtain more than half of their electricity from nuclear energy, while 13 countries obtain at least 20% of their electricity from this source.

During the accummulated 5600 reactor-years of operation the safety record of nuclear power has been marred by two accidents of particular concern, Three Mile Island in 1979 (with small public consequences) and Chernobyl in 1986 (with large public consequences). Mainly as a result, the risk and possible local effects associated with nuclear energy are perceived by some in government and in the public as being too great for nuclear energy to be accepted as a viable means of resolving the health and environmental effects caused by the other means of generating electricity, particularly the burning of fossil fuels.

The UN World Commission on Environment and Development (Our Common Future) indicated a number of specific items related to the use of nuclear energy that require international agreement including regulatory activities, standards (for operation, radiation protection, waste repositories, and decommissioning), operator training, site selection criteria, emergency response training, reporting, etc.

The Conference on the Changing Atmosphere: Implications for Global Security held in Toronto, Canada, in 1988, concluded that "If the problems of safety, waste and nuclear arms can be solved, nuclear power could have a role to play in lowering CO_2 emissions".

To help resolve these concerns the holding of an International Conference on nuclear safety was suggested and encouraged by European Community countries through the IAEA Board of Governors during the spring of 1990 and presented to the IAEA General Conference in September 1990. The General Conference in its Resolution 529 welcomed the holding of the conference, with certain financial stipulations.

CONFERENCE OBJECTIVE

The Conference is directed to decision makers on nuclear safety and energy policy at the technical policy level. Its objective is to review the nuclear power safety issues on which international consensus would be desirable, to address the concerns on nuclear safety expressed by the UN World Commission on Environment and Development, and to formulate recommendations for future actions by national and International authorities to advance nuclear safety to the highest level including proposals for the IAEA's future activities for consideration by its governing bodies.

The conclusions of this Conference, addressing safety issues only, will complement the conclusions of the Senior Expert Symposium on Electricity and the Environment held in Helsinki, Finland, May 1991 which address the comparative health and environmental effects of the various alternative means of producing electricity.

The conclusions of the Conference will also form part of the IAEA's contribution to the 1992 UN Conference on Environment and Development.

The Conference should promote more effective international co-operation between IAEA Member States on the safety of nuclear energy.

The particular issues selected for consideration by the Conference are:

(i) Fundamental principles for the safe use of nuclear power;
(ii) Ensuring and enhancing the safety of operating plants;
(iii) Treatment of nuclear power plants built to earlier safety standards;
(iv) The next generation of nuclear power plants;
(v) The final disposal of radioactive waste.

For each of these issues the present status, present and foreseeable problems, recommendations for future actions required to deal with these problems at both the national and international levels, and recommendations for the role of the IAEA in these activities are outlined.

This Background Paper deals with the subject of the "Treatment of Nuclear Power Plants Built to Earlier Safety Standards".

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1. RATIONALE FOR THIS PAPER

Safety standards of nuclear power plants have evolved and been steadily developed since the first plants were designed in the 1950s. The changes have occurred not only as a result of operating experience, research and technological development but also as a consequence of the assessment of accidents and the increasing concern of the public with nuclear safety. Thus the safety standards current in any country may be significantly different from those applied to its operating plants when they were designed. The extent of the difference may also increase with time. The difference and its extent are of course not an indication that the operating plant is unsafe. The safety record of all operating plants is generally good. Most operators have made plant improvements, giving higher levels of safety than those of the original design, in compliance with the universal objective of attaining the highest practicable level of safety. Nevertheless, the accident at Chernobyl in particular caused countries with operating plants to consider the extent to which they were compliant with their current safety standards, and to assess what further improvements are worth while. Such safety standards are necessarily determined by individual countries for their plants, though guided by standards issued by organizations such as the IAEA.

It is now appropriate to propose a common international approach to the treatment of operating plants built to earlier safety standards. The reason for this proposal is the growing need for all countries to demonstrate whether their operating plants, particularly the older plants, are also safe when judged by current safety standards, and whether arrangements exist, or need to be introduced, to maintain safety in the light of improving standards and the ageing of plants. The issues are not straightforward. For example, is it only necessary to rejustify plant to the standards current at the time of construction or should new standards be imposed as they are derived? Where backfitting has taken place should the whole plant be rejustified to the prevailing safety standards or just the updated sections of the plant? Furthermore are all plant operators worldwide equally able to provide acceptable plant reviews/justifications whatever the standard? This background paper addresses the relevant factors against which safety may be evaluated and suggests methods for an assessment procedure to attain a consistent level of safety. The ultimate goal is a common international approach applicable to all operating plants, which should assist in demonstrating that they at least achieve an acceptable level of safety. This paper does not take account of national legal requirements nor the possible consequences for national licensing arrangements. It is for individual countries to assess the impact on their regulatory requirements.

2. PRESENT STATUS OF THE ISSUE

2.1 GENERAL BACKGROUND

The age of operating plants is typically 5 to 20 years with the oldest being over 30 years old (see Figure 1). Their original safety standards were generally decided several years ago and may therefore differ substantially from current safety standards. However their generally conservative designs, and such actions as backfitting or upgrading programmes have caused older plants in general to maintain a high and acceptable level of safety when judged against current safety standards. It is also evident that there are a few older plants for which the acceptability of the safety level is questionable and for which a solution is required.

Safety standards are generally set in order to achieve the highest practicable level of safety in the design of new plants and take account of expected plant deterioration in service by requiring compensatory safety margins which are expected to be reduced during operation unless counteracted by an upgrading programme. The challenge to the operator is to stay within the resultant operational limits, taking account of any measured or anticipated reductions of safety margins. Such reductions may not only be due to expected effects of plant operation, such as ageing effects, but may be also due to such unexpected effects as plant incidents or plant changes to meet new economic demands. Operators can also enhance safety margins by changes to the operating regime and thus partly counterbalance any deterioration. In addition, several of the older plants were generally conservatively designed and consequently can have increased safety margins when reanalysed using modern methods. For example, many older plants have a larger thermal inertia than current designs.

The further challenge is how to address the consequences of new safety concepts, new safety standards and changes in standards and thus re-evaluate the safety of operating plants. It is recognized that old plants may not fully meet new concepts and standards, but their operating experience, operating regime, original safety margins, and existing improvements may allow demonstration that they are adequately safe, and could remain so for their remaining life expectancy.

Most operating plants have been improved in safety by various safety enhancements since operation commenced. These improvements vary worldwide and have been made for various reasons including comparison with current safety standards. Hence the need to address current safety standards varies considerably between countries. There are many countries whose operational regime addresses changes in current safety standards as specific issues as they arise at each of its plants in an organized manner with formalized safety decisions. There are however some other countries with old plants that have operated for several years without consideration of changes in current safety standards and it is largely with these countries in mind that the issue is addressed.

It is also considered that there are new plants whose safety standards are not adequately compliant with current international safety objectives. The proposals given in this paper for old plant should also be applied to such new plant.

2.2 ACCOMPLISHMENTS TO DATE

National

The first countries to address the issue systematically were, not surprisingly, those with the oldest plants. The United Kingdom began comprehensive safety reviews of its plants in 1976. These reviews identify worthwhile improvements which are implemented to ensure continued compliance with the original safety standards and adequate compliance with the current safety standards. The Nuclear Regulatory Commission in the USA started consideration of current safety standards with the Systematic Evaluation Program in 1976; this was subsequently augmented by other programmes and by the recently proposed Regulation for License Renewal when each plant reaches its licensed life of 40 years. All of these have caused some backfitting improvements to operating plants. Other countries have generally younger plants than the UK and the USA, owing partly to closure of their earliest plants for economic reasons, and are pursuing their own initiatives for their operating plants. The USSR has a major programme of improvements for its RBMK and WWER plants. Japanese authorities are developing a programme similar to that of the NRC. Several Canadian plants have had major backfits to comply with evolving standards. Germany began some years ago a systematic safety assessment of its plants against current German standards. In addition, economic reasons led to a reappraisal of the WWER 440 Model 230 plants of the former German Democratic Republic. Many other countries have also introduced requirements to reassess the safety of their plants on a periodic basis to address the issue. Belgium was the first country to impose a legal requirement that the safety of its plants be reassessed every 10 years throughout their operating lifetime. Similar legal requirements have been introduced in some other countries.

International

The IAEA has had a number of initiatives which are relevant to the issue, particularly following Chernobyl. The more recent are its Advisory Group on Ageing, which is developing a methodology for international use, and its Advisory Group on Older Reactors, which is now undertaking safety audits of all Model 230 WWERs in order to advise the user countries on shortfalls when judged against current safety objectives. In 1988, INSAG issued a report entitled Basic Safety Principles for Nuclear Power Plants, Safety Series No. 75-INSAG-3, which gives basic objectives and safety principles for existing and future reactor types of all countries. Its concepts are in general not new, rather, the best current philosophy is put forward. It proposes a technical safety objective for the probability of severe core damage for existing plants of "below about 10^{-4} events per plant operating year", and a lower level of 10^{-5} for future plants. The IAEA Nuclear Safety Standards (NUSS), originally completed in 1985, and constituting a framework of requirements for all aspects of nuclear power plant safety, are being regularly updated to reflect advances in safety worldwide, and serve as a reference for all Member States and the safety basis for the IAEA activities in providing assistance to developing countries.

In 1988 the utilities of all countries with nuclear plants formed an international group, the World Association of Nuclear Operators (WANO). It has centres in Paris, Moscow, Tokyo and Atlanta and promotes co-operation and sharing of information among utilities. A recent initiative, relevant to this paper, is its study of WWER Model 230 reactor plants to assist the operators in making improvements.

In 1990 the Commission of the European Communities published a report (EUR 13056 EN) presenting the approaches in different countries with regard to comprehensive periodic safety re-evaluations. The report examined the approaches against three main criteria:

- confirm that the plant is as safe as originally intended;
- determine if there are any structures, systems or components that could limit the life of the plant in the foreseeable future;
- compare the plant against modern safety standards and identify where improvements would be beneficial at justifiable cost.

The conclusion was that, while approaches may differ in some respects, for practical purposes comparable levels of safety are achieved in the periodic safety re-evaluation of nuclear power plants in the European Community.

There have been no international or major national conferences on this issue, though there have been several conferences on the related topic of ageing. This paper is one of the first to address the issue of the safety assessment of old plants built to earlier safety standards.

2.3 AREAS OF CONSENSUS

Experience on this issue has already shown some areas of general agreement. A common international consensus is that all plants should have levels of overall safety which are publicly acceptable.

A second consensus is that operating plants should always comply with their original safety objectives where these remain valid. In consequence, plants are often subject to regular reviews to check compliance with the original safety objectives. However, the periodicity, depth and scope of these reviews vary considerably between countries and sometimes between plants in one country. Each country seems to have its own approach and system for judging the safety of its operating plants.

A third consensus is that the safety standards of older operating plants should be reasonably compliant with current safety objectives. If any shortfall is identified, consideration should be given to suitable improvements, taking account of present views on safety requirements, the remaining life expectancy of the plant, and costs. There is however a need for a consensus on the extent of shortfall which causes the plant to be considered unsafe.

A fourth consensus is that there should be arrangements for assessing and monitoring ageing effects.

2.4 FORESEEABLE TRENDS

Countries already involved in addressing the issue have significantly different procedures, partly as a result of their regulatory arrangements, but each may be adequate to show an acceptable level of safety of their operating plants. However it is difficult to demonstrate this conclusion. Since there are some older plants which appear to have less than adequate levels of safety, there is a need to address this issue internationally, overcome present problems and provide a framework for avoiding such problems in the future.

The important factors that should be addressed are identified in Section 3, and ways in which the objective of assuring acceptable levels of safety at all operating plants are addressed in Section 4.

In the absence of an international initiative, there is the possibility that the issue will not be addressed for some plants until there is an accident. The reasons may be lack of recognition of the need, lack of relevant expertise, or complacency resulting from a poor safety culture or lack of financial resources to make necessary safety improvements including maintenance aspects. This includes those aspects of maintenance which have an impact on safety. Plants whose safety is only reviewed against original but not current safety objectives may now be unsafe or eventually become unsafe owing to inadequate safety provisions, with an increased probability of a major accident occurring. It is also possible for plants to be prematurely shut down owing to an inadequately conceived approach for reviewing their safety.

In addition, the present general reluctance to order new plants is putting economic pressure on operators in all countries to continue operating old plants, even beyond their original life expectancy. There is consequently an increasing need to ensure that such plants continue to be safe.

3. PROBLEMS IDENTIFIED

A number of problems have been identified and are presented below.

(a) How to determine that an operating plant is adequately safe

In order to judge whether an operating plant has an acceptable level of safety it is necessary to consider all relevant factors. Some of the more important factors are:

(i) the safety concept of the original design including safety margins and inherent safety merits;

(ii) the safety record of the plant - abnormal events and radiation doses;

(iii) operational experience (both positive and negative) of the plant and other relevant plants;

(iv) actual physical and operational state of the plant including operating and maintenance documentation and procedures which are controlled by quality assurance arrangements to an adequate level;

(v) quality of station personnel, management structure and staffing levels;

(vi) existing safety analyses including probabilistic safety assessment (PSA);

(vii) the availability of suitable records giving the details of design, manufacture, plant modification, and the maintenance and operational history;

(viii) trend analysis of plant records, particularly radiation doses and equipment performance;

(ix) environmental qualification of safety equipment and its protection against hazards such as fire and flood.

It is immediately clear that there may be problems in assessing the above factors, owing largely to a lack of suitable records at some plants. In addition, original design data may not have been released by the design organization or may have been destroyed. Knowledge of the physical state of the plant may be insufficient owing to lack of adequate monitoring of plant conditions, surveillance, or supporting research. Finally, the management of plant ageing effects becomes more important as a plant gets older in order to ensure that adequate safety margins are maintained; this requires a supporting programme of research into ageing mechanisms and their effects on safety. In particular, environmental qualifications may become suspect as plant life is extended, creating the problem of how to requalify aged equipment.

Nevertheless, in national reviews that have been carried out, many older plants do fare well in assessments against the above factors. Not only can they have good safety margins owing to a conservative design, they have often been regularly upgraded to maintain their high safety level.

(b) What is an acceptable level of safety

As indicated in Section 2.4, there is a need for a consensus on what is an acceptable level of safety for an operating plant. It is an issue which needs to be addressed internationally. It can be argued that there is sufficient experience and consultation between utilities and regulators and vendors in the more developed countries so that their experts are sufficiently able to ensure an acceptable level of safety even though they may each use differing approaches.

Thus the issue is of particular importance to countries which have operating plants but do not have a solid and extensive nuclear base. If such a country has no established national standards it has nothing against which to measure the quality and adequacy of existing plant.

The approach of using PSA to measure the safety level of a plant is to be encouraged, but there is insufficient certainty in the quantified conclusions and difficulty in defining a quantified level of adequate safety. In consequence its use should be complementary to other methods. Standardization and consensus on application of PSA methods should assist in eliminating part of the uncertainty. PSA is perhaps more useful in indicating whether any particular fault sequences dominate the total risk and hence where improvements may be worth while.

A reliable procedure may be to assess the safety significance of each of the factors in 3(a) above. PSA becomes part of one (factor vi) of nine factors. Judgement on each may be based on the extent of compliance with INSAG-3 and the NUSS Codes and Guides, but the judgement should take account of general international experience. Factors (i) to (vi) are each sufficiently important that they must all be judged acceptable.

In addition, there should be an overall consideration of the adequacy of the major safety systems,

- reactor protection,
- primary circuit integrity,
- emergency and decay heat removal,
- containment,
- essential power supplies,

taking account of their design, performance, maintenance and station staff capability.

(c) Exchange of experience

Countries should be encouraged to publish their experiences in addressing the issue so that other countries can benefit from their experiences, and any weaknesses or problems of the methods used can be reconsidered. This exchange of information should allow early recognition of generic issues and their resolution. Such exchanges should also promote good safety practices at all plants.

Where an operating plant is situated near a national border or an international river, neighbouring countries will be concerned with its level of safety. The host country should therefore make arrangements to keep its neighbours well informed concerning the safety of the plant, in a transparent manner, both at the conceptual stage and throughout operation. The level of safety of a plant is of sufficient public concern that neighbouring countries should be involved, and should ensure that they have adequate emergency arrangements and communication links with the host country.

(d) Site-plant acceptability

Original plant siting analysis may not have comprehensively addressed the natural phenomena which could affect the site. In addition man-made developments around a site since the plant was built, and such developments as the consideration of aircraft crashes and hazardous materials, could affect overall safety, including the emergency arrangements and the radiological effects of planned discharges. Guidance on their assessment and possible effects on plant operation is required.

(e) Staff

While plants remain in service there is a need to maintain a high standard of safety culture. To achieve this it is necessary to maintain motivation, be aware of developments in nuclear safety, and maintain a high standard of training. Emergency exercises and simulator training for abnormal events should be encouraged.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS

The issue of this paper should be addressed by carrying out a structured safety review for each of the older plants (see Section 4.1), in addition to the routine safety activities presently in place. Such a review should not only demonstrate that a plant is presently safe but also give confidence in its remaining safe with an adequate margin until at least the next review by consideration of ageing effects in the future period of operation. The scope should inter alia take account of the factors listed in 3(a) and also take into account the results of routine safety evaluations. Details of the manner of conducting these reviews should be determined by the individual countries, but it is recommended that these should have common objectives and fit within a common review framework. This paper proposes an outline of objectives and a review framework (see Section 4.3), which may be used for such safety reviews.

To carry out one comprehensive review of an old plant, and not plan for subsequent updating reviews, is unsatisfactory. The plant is likely to be required for several more years, during which time there will be changes that were not considered in the first review, and ageing effects may not conform with the assumptions of that review. However, once one comprehensive review has been held and relevant improvements to the plant have been made, subsequent reviews should be relatively simpler, more straightforward and inexpensive, since they will simply build on the first review and consolidate the subsequent relevant information. The reviews will also help to maintain a high standard of safety awareness at a plant.

There are of course alternative possible methods for addressing the issue of this paper. For example, when a new safety problem arises such as a component failure or as a consequence of an assessment using new data or a new or improved safety standard, it is normal practice to resolve it. Timely replacement and modernization of equipment as part of the maintenance regime can allow safety margins to be maintained or in some cases increased. If it is clear that a plant is subject to a systematic safety reassessment programme and hence is adequately upgraded in response to such problems, there may be no need for additional periodic plant safety reviews. However, the possible advantage of such a review as a stock-taking exercise may still be worth while. A middle course of action of occasional specific reviews of generic problems of several plants in a Member State may also be considered acceptable, and could be developed from the safety review framework given in

Section 4.3. Whatever method is adopted, the objective should be an overall assessment integrating all factors whether positive or negative within one coherent picture.

4.1 REVIEW PLAN

(a) A review plan should be developed by each Member State for its operating plants giving priority to those in service for 10 or more years or built to an outdated safety design concept. The consequent review should be completed within a reasonable time-scale.

Rationale: During a 10 year period it is expected that:

(i) safety objectives will have evolved and that analytical techniques will have improved;

(ii) the operational database for the plant will have been extended and new research information will have become available;

(iii) significant changes to the plant and its operational practices may have been introduced.

(b) The review plan should also address ongoing methods of review.

Rationale: See (a) above. In addition, the knowledge and experience gained during previous reviews should not be lost. This can best be ensured by involving a number of experienced staff who have worked on, and are familiar with, an earlier review. If the period between reviews is extended beyond about 10 years, it seems unlikely that such staff will still be available and, as a result, continuity will be lost. Documentation of the review process and results will be of particular value in such circumstances.

4.2 THE IMPORTANCE OF ESTABLISHING ACTUAL PLANT STATUS

If the record of actual plant status has not been maintained current, it should be determined at an early stage of the review and then regularly maintained current. This is of particular importance for plants which have undergone many modifications during their lifetime. Both plant hardware and documentation must be considered as well as staffing arrangements. This requirement could prove to be a major exercise involving many person-years of effort. Where data are lacking it will generally be necessary to generate or derive these. Special tests or inspections will probably be required. A detailed description of the elements which together form the actual plant status is given in Appendix I.

Rationale: Key design, safety and operational data are requirements for adequate operation.

4.3. REVIEW FRAMEWORK

This section gives a brief overview of the proposed framework for the review process. It is believed necessary to compare the actual plant status with the current safety objectives using up to date methods of assessment to identify any shortfalls and determine if safety enhancements are worth while. Only in cases where these current objectives cannot be met even with worthwhile enhancements being made, and the shortfalls are significant, will there be a need to compare with the original safety objectives. Thus, the review is in two stages:

(1) A comparison with current safety objectives using up-to-date methods and actual plant status;

(2) When current safety objectives are not fully met, a comparison with the original safety objectives using up-to-date methods and actual plant status may be made, unless the original safety objectives are clearly inadequate.

On this basis a logical framework for a review is shown in Fig. 2. The meaning of the terms is given in Appendix I.

An outline of the major steps is given below:

(a) A comparison with current safety objectives using current methods and actual plant status and operational history;

(b) Any shortfalls are identified;

(c) Once a shortfall has been identified, an evaluation is made immediately to determine if:
   (i) licence conditions are still being met;
   (ii) an unacceptable risk to the public during normal operation exists, or

(iii) there is a perceived unacceptable risk to the public under accident or fault conditions but not during normal operation;

(d) In case (i) action consistent with the requirements of the operating licence is necessary. In case (ii) the plant should be shut down (unless or until adequate safety enhancements can be made). In case (iii) plant operation may continue, but an evaluation of the safety significance of the shortfall must be carried out in an expeditious fashion;

(e) The evaluation of the safety significance of the shortfall may be carried out using a variety of techniques including deterministic analyses (both worst case and best estimate), PSA methods, operating records analyses, and comparisons with other plants (see Section 3, item (b));

(f) Where the safety significance is high, immediate adequate countermeasures should be taken. These could include enhanced maintenance, additional testing, reduced power level, etc.;

(g) Where the safety significance is demonstrably low, action is not necessary;

(h) Where the safety significance is not high, operation may continue but safety improvements should be made within a reasonable time-scale. Until these improvements can be made, it may be necessary that interim operational measures (e.g. power de-rating, or additional safety checks) be introduced to either eliminate or reduce the shortfall;

(i) Where improvements are either:

(i) impracticable, or
(ii) too expensive, or
(iii) cannot be made in a reasonable time-scale, or
(iv) do not completely eliminate the shortfall,

a comparison with original safety objectives may be made. If it is judged that there is no undue risk to the public, the condition of the plant may be judged satisfactory. However, where the original safety objectives are clearly inadequate, this procedure should not be used;

(j) There may be circumstances where a number of shortfalls are identified which are of low safety significance individually and require no action but when taken together represent an overall state which is unacceptable. In consequence, when assessments under paras (g), (h), and (i) above are being carried out, the sum effect of all shortfalls together should be assessed to ensure that an overall judgement of plant acceptability is made.

4.4 EXCEPTIONAL SOCIAL/ECONOMIC CIRCUMSTANCES

It is possible that the shutdown of a nuclear power plant will cause very severe economic or social hardship. It is, therefore, essential that premature or unwarranted plant shutdowns should not be ordered. The proposed review framework will prevent this as far as practicable. If however the review shows a plant to be unsafe then social and economic factors should not prevent shutdown of the plant.

If the social/economic consequences are exceptional then the more developed countries with strong nuclear power programmes and the international organizations should be prepared to give relevant assistance.

4.5 AGEING

The proposed review should demonstrate that a plant is currently safe, but may not demonstrate that a plant will remain safe with adequate safety margin until the end of its life or even the next review. It is therefore additionally recommended that a study of possible ageing effects up to the time of the next review be made. A study to determine the safe working life is also encouraged. If these studies indicate any failure of equipment or plant life limiting feature before the next review, this information should be used to define the future operating regime and the life of the plant.

4.6 FRAMEWORK FOR SUBSEQUENT REVIEWS

It is proposed, see Section 4.1, that reviews should be repeated at intervals of about every 10 years after the first review or a formalized programme is applied to ensure that changes in safety objectives, operational experiences or specific issues are adequately addressed as they arise. The framework for periodic reviews should be that discussed in Section 4.3 and outlined in Fig. 2 for the first review. However, the process will be considerably simpler and less expensive than that of the first review. The three major inputs are:

Actual Plant Status - the effect of changes since the previous review should be considered; such changes may be due to ageing, to enhancements of plant and to procedures and staff, which should all be on record.

Current Safety Objectives - have any changes occurred since the previous review?

Modern Analytical Methods - have any changes occurred since the previous review?

It can be seen that the work required for subsequent reviews is considerably reduced. It is probable that ageing and backfits will be the only major considerations; that is, assessment of the ageing that has occurred since the first review, prediction of ageing effects during the period to the next review and any safety implications arising from backfits.

5. RECOMMENDATIONS FOR IAEA ACTION

On the basis of this review, it is recommended that the IAEA give consideration to:

(i) The development of guidance on how to review the safety of a plant; for this purpose the framework proposed in this report is offered for consideration. The guidance should particularly consider the achievement of a consensus on the question of what is an acceptable standard of safety.

(ii) Encouraging Member States to undertake reviews of their operating plants;

(iii) Offering assistance and guidance to Member States undertaking reviews, with advice on appropriate standards to be used in their reviews, and provision of resources, in conjunction with other international organizations;

(iv) Encouraging Member States to publish the findings and experience of each completed review;

(v) Conducting workshops to exchange findings and experience and provide a forum for peer comments.

6. SUMMARY

At the time of initial commissioning, a nuclear power plant will have been safety justified to the then current safety criteria. As the plant ages, the plant design may change in response to safety and economic needs. It is essential to ensure that necessary changes are made and that any changes to the plant, for whatever reason, do not invalidate the safety case. Some form of safety review process is required to ensure that the reactor safety case remains current and valid. Concurrent with the physical evolution of the operating plant, safety criteria will also have evolved.

How should aged plant be treated when dealing with the justification of change? Is it sufficient to rejustify in accordance with the original safety criteria, or should current safety criteria be applied? Furthermore, what form should the safety review take?

This paper has identified and reviewed the issues relating to:

- how to determine that an operating plant is adequately safe;
- what is an acceptable level of safety;
- exchange of experience;
- site-plant acceptability;
- staff.

On the basis of this review, a number of recommendations for strategic action have been presented in relation to:

- development of a periodic review plant;
- establishing actual plant status;
- the framework for review;
- social and economic issues;
- plant ageing;
- frequency and nature of safety reviews;
- IAEA activities.

On the basis of these recommendations, an outline of a procedure for conducting a review has been developed and is presented for consideration in Fig. 2.

The proposed review process is a natural partner to the continual review of operation, maintenance, incidents, and specific safety issues which arise from time to time. The proposal is essentially one in which the operator and regulator stand back every 10 years or so and use all the accumulated knowledge of the plant and how it operates in a systematic and comprehensive review of all safety aspects against current standards. The "accumulated knowledge" should include developments in analytical techniques, results of research, effects of ageing, accumulated effects of design changes, changes to operating procedures etc. It would seem logical for the regulators of each Member State to decide on the review process and the interpretation of "current safety objectives", and for operators to undertake the reviews.

The need to address current safety standards varies considerably between countries. In some countries there are operating plants which have had no systematic and comprehensive review of their plant status as judged by current safety objectives. Other countries investigate immediately the relevance of a change in safety objectives or standards to each of their operating plants on an almost continuous basis. For these latter countries, a periodic review may be of lesser significance or not worth while. The approach given in this paper should also be used for new plants built to earlier safety standards.

It is proposed that the principle arguments presented in this background paper be addressed by the conference through discussion of the following significant topics:

1. How should reactors built to earlier safety standards be shown to be adequately safe?

2. Should an international consensus be sought to define a minimum level of safety to be met by reactors built to earlier standards?

3. What should be the role of the various international organizations (IAEA, OECD/NEA, WANO) in the implementation of recommendations on these topics?

4. What weight should be given to socioeconomic factors when making decisions on reactors built to earlier standards?

FIG. 1

Number of reactors in operation by age

(as of Dec.1990)

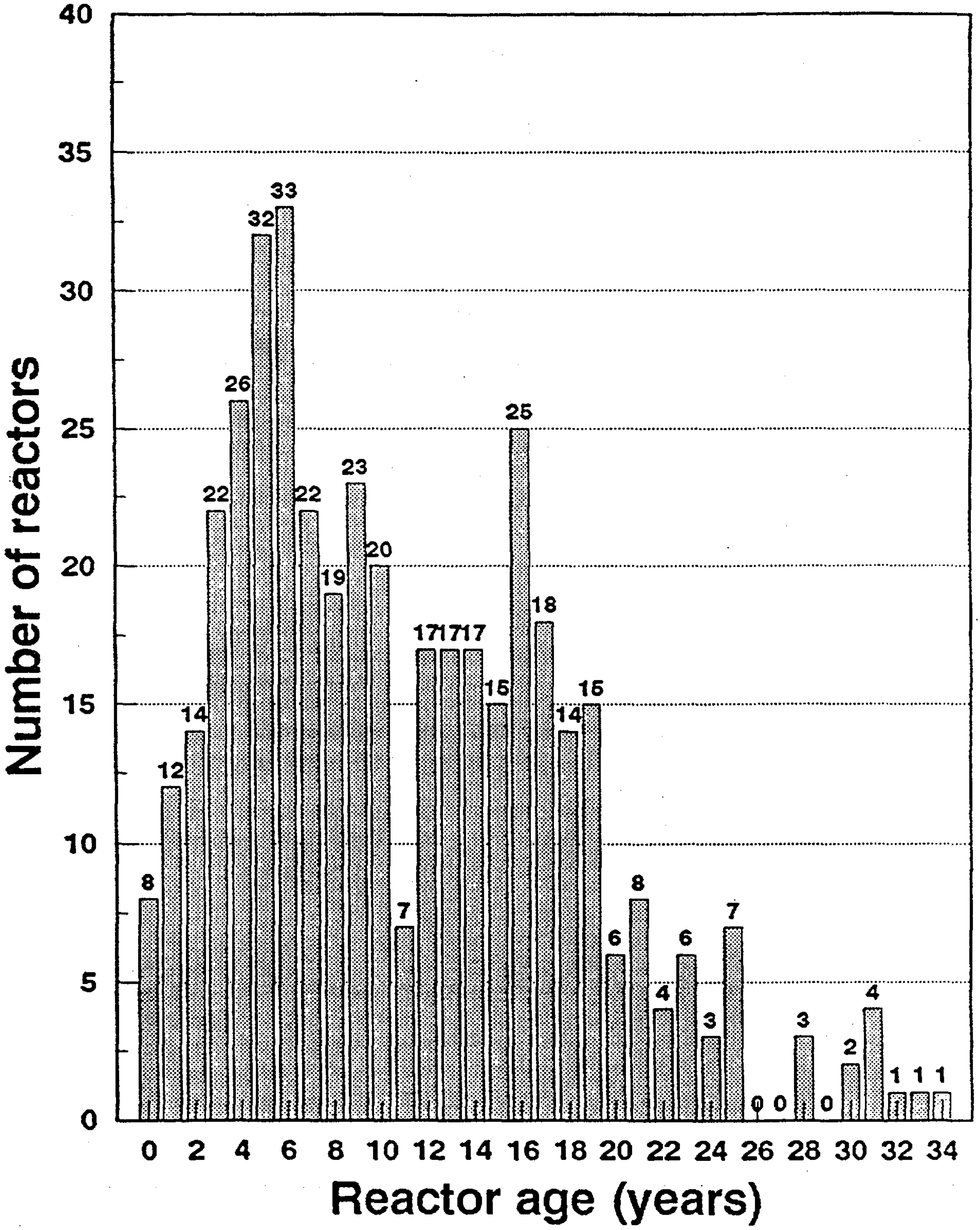
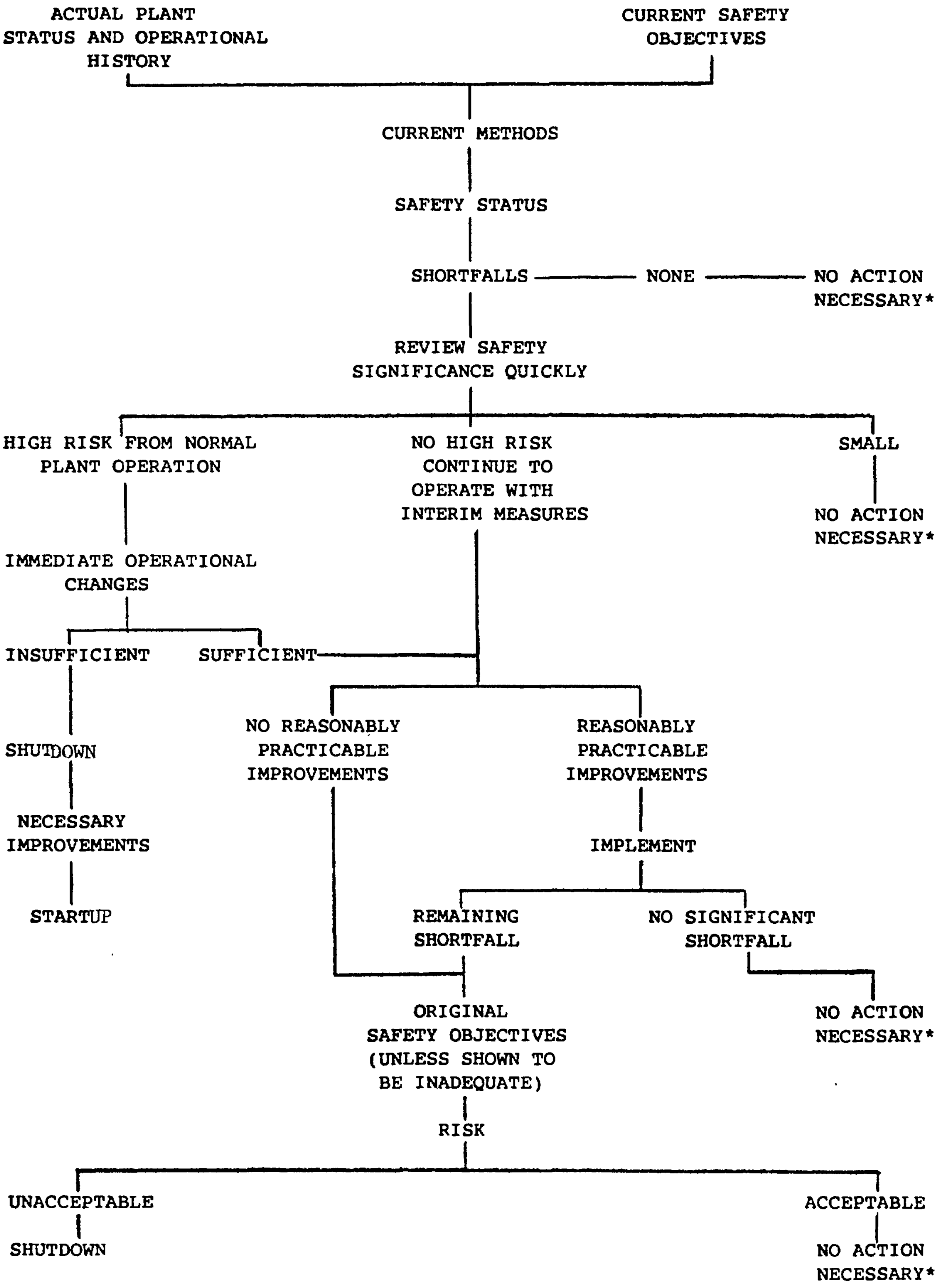


FIG. 2 Procedure for Conducting a Safety Review



* possible ageing effects up to the next safety review need to be taken into account

APPENDIX I

MEANING OF THE TERMS USED IN FIGURE 2

1. Actual Plant Status

This is a collective term for the following elements which together define the operational state of the plant:

(a) A detailed description of the plant as it exists at the time of the review, supported by layout drawings, system drawings and equipment drawings, which accurately describes the layout, systems, and major items of equipment;

(b) The functional specification of the plant, systems and major items of equipment;

(c) The findings of tests, including commissioning and routine tests and in-service inspection which validate the functional specifications;

(d) The results of inspections of primary circuit components;

(e) A fault schedule detailing the fault initiating events including hazards and means of protecting against them which have been considered for the plant in its design;

(f) Existing safety analyses, including PSA if available;

(g) The rules, instructions and procedures by which the plant is operated and maintained (including processes for configuration management and the maintenance of the design bases);

(h) A description of the present physical and operational state of the plant based on inspection (ultrasonic, visual etc.) or test including any equipment qualification information or theoretical analysis. Relevant ageing phenomena - neutron embrittlement, stress and pitting corrosion, fatigue, wear, etc. - and operational problems are to be taken into account;

(i) The maintenance status of the plant - outstanding plant deficiencies, compliance with maintenance instructions, any backlog of maintenance work;

(j) Plant staffing - structure, present staff, management arrangements, staff training and training facilities;

(k) Hazard data for seismicity, flooding, temperature variations, snow and ice, aircraft crash, and ultimate heat sink failure.

2. Operational History

This is a collective term for:

(a) Operational records giving the plant parameters since the plant raised power;

(b) The safety record - a record of abnormal events when the plant was not compliant with its operating rules and instructions, with information on cause and actions taken;

(c) A record of equipment and system failures - during operation or during test - and their probable cause;

(d) Records of the training given to members of the plant staff, original and refresher training to be included. The records should state how well an operator performed on each training course;

(e) The radiation dose records for workers and the public, individual and collective;

(f) Environmental release data - quantities and physical and chemical form of radioactive releases to the environment;

(g) Relevant operational experience with other similar plant.

3. Current Safety Objectives

This term means the safety objectives which are presently employed (nationally and internationally) for modern plants, and current objectives for radiological protection. There should also be consideration for any new national or international safety concept for a new plant and its staff which may not yet have been formalized into a safety objective but is nevertheless well founded.

4. Current Methods

The methods of safety analysis used currently for modern plants. International codes should in general be used. Probabilistic Safety Assessment (PSA) should be used to highlight any imbalance in the plant design, or sensitivity to particular equipment failure.

5. Safety Status

The result of a comparison of the actual plant status with current safety objectives, using up-to-date methods of safety analysis and research information.

6. Shortfalls

Those elements of the plant status which are not compliant with current safety objectives, given in the form of a summary which lists each element and its non-compliance.

7. Review Safety Significance Quickly

When a shortfall is identified there is an urgent need to determine its safety significance. Safety significance can usually be immediately assessed by experts as a "high risk from normal operation or major licence violation" or "small - no action necessary". If the former then "immediate operational changes", that are sufficient in the view of experts, are required or the plant must shut down. If neither of these two extremes applies then "interim measures" should be applied and the plant continue to operate whilst "reasonably practicable improvements" are sought.

8. Reasonably Practicable Improvements

Improvements which minimize or overcome "shortfalls" and whose cost is not unreasonable when compared to the benefit and the period of operation over which the benefit will apply.

9. Original Safety Objectives

The design and licensing requirements at the time that the plant was built where these remain valid. If the plant is not compliant with these objectives and cannot be sufficiently improved to minimize the resultant risk to the public to an acceptable level, then the plant cannot be considered adequately safe.

10. No Action Necessary

The plant is safe, but an assessment of ageing effects should be made to determine if any plant problems or equipment failures are predicted before the next review. If any are predicted, their effect on the future operating regime should be determined. For example, if a fatigue failure is predicted, one can either repair or replace the fatigue components, mount a more detailed inspection regime to monitor fatigue or take other countermeasures. Arrangements for the management of ageing effects will be needed if a reasonably long future life is required.

11. Shutdown

Putting the plant into a zero output state (reactor subcritical) without prejudicing further action leading to restart or decommissioning.

APPENDIX II

EXPERT GROUP PARTICIPANTS

This Background Paper was developed by the following experts:

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APPENDIX 4

Background paper for
document GOV/2541

Item 6(a) of the provisional
agenda (GOV/2537)

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

Vienna, Austria
2 - 6 September 1991

BACKGROUND PAPER

FOR

ISSUE NO. IV

THE NEXT GENERATION OF NUCLEAR POWER PLANTS

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

ISSUE NO. IV

THE NEXT GENERATION OF NUCLEAR POWER PLANTS

SIGNIFICANT TOPICS TO BE ADDRESSED AT THE CONFERENCE

Based on comments received to the Background Paper for Issue No. IV, together with discussions in the Steering Committee, the following topics are recommended for inclusion in the discussion on Issue No. IV. For each topic, there may be actions identified to be taken, by utilities, regulators, Member States, and international bodies, including the IAEA.

For each topic recommended for discussion, some comments are provided both to facilitate an understanding of the issues and to assist the reader with preparations for the discussion sessions at the conference.

Introductory Comment: Prior to discussing conference views on the next generation of nuclear power plants, a brief statement on nuclear power plants already in operation is necessary.

Based on using conservative principles during design, having high quality standards during construction and maintenance, and having intensive training and education programmes for operations and maintenance, a very high safety standard has been achieved in general for the current generation of reactors.

In spite of the high safety standard already achieved, a new generation of nuclear plant designs is being developed, taking into account the accumulated operating experience with existing plants and the results of the dynamic research and development process that exists in reactor technology. Although most current plants meet an adequate level of safety, these evolving factors should help address the need to achieve a higher degree of public acceptance for the next generation of nuclear power plants.

Topic No. 1

Next generation nuclear power plant designs will have incorporated design improvements for accident prevention. Although different designs take different approaches to accident prevention, are their overall objective and approach acceptable?

Examples of design approaches taken for accident prevention include improved component and system reliability, improved man-machine interface through design simplicity and human factors design improvements, increased design margins to safety limits, increased system redundancy and diversity including using passive systems, where appropriate (e.g. design improvements to reduce the probability of a station blackout event and to cope with such an event without plant damage) and improved accident management procedures. Also emphasized are design improvements that will enhance maintainability, quality assurance, and protection against outside threats. These improvements enhance both safety and plant availability, and are thus highly desired by nuclear plant owners and operators as well as the general public. Do these preventative measures contribute to a stronger basis for increased reliance on the nuclear option for future electricity generation?

Topic No. 2

> **Next generation nuclear power plant designs incorporate features for the mitigation of potential severe accidents. Is there a need for harmonization or consensus on different aspects such as design approaches, accident scenarios and analytical methods?**

Next generation nuclear power plant designs will have improved accident mitigation, with emphasis on the later barriers of the defence in depth concept. They will consider severe accident scenarios explicitly and systematically in design. The containment system will play a key role for the next generation of water reactors. Is this approach acceptable? Is there a need for or benefit in greater international consensus on design approaches (e.g., containment design parameters), on accident scenario selection and methods of analysis, and on how to treat severe accidents in the regulatory process? How might greater international harmonization be achieved?

Topic No. 3

> **What should be the role of emergency planning for future reactor designs? Do design improvements and recent severe accident research results provide an adequate technical basis for simplifying or eliminating emergency planning for future designs?**

Many advanced reactor designs have explicitly incorporated design features that would, based on current national policies and regulations, permit the technical demonstration of adequate public protection with significantly reduced emergency planning requirements, i.e. as a minimum, relief from the requirement for rapid evacuation and early notification of the public in emergency plans. Designers contend that realistic analysis and design improvements simplify or eliminate emergency planning. Potential future owners of these designs have encouraged these design features, and although no consensus has been established to totally eliminate emergency planning, many desire to eliminate the more onerous aspects of current procedures, particularly rapid action requirements. Should such modifications to emergency planning be considered?

Topic No. 4

> **What should be the role of the IAEA with respect to future reactor designs? Specifically, should the IAEA develop a set of desired safety characteristics for the next generation of nuclear power plants?**

Paper IV discusses many areas where increased international co-operation has been beneficial and could be expanded further. Many multinational efforts are already under way outside the IAEA to help define user needs, harmonize regulatory approaches, consolidate designer efforts, etc. The IAEA has started an effort to develop a set of desired safety characteristics covering all of the principle features for the next generation of nuclear power plants, irrespective of type. Will this effort contribute to better understanding and help facilitiate design assessments for the IAEA's Member States? How could this effort be further improved to better meet Member States' needs?

BACKGROUND PAPER NO. IV
THE NEXT GENERATION OF NUCLEAR POWER PLANTS

FOREWORD

GENERAL BACKGROUND

Today there are about 425 nuclear power plants operating throughout the world in both industrialized and developing countries, supplying 17% of the world's electricity needs. Four countries obtain more than half of their electricity from nuclear energy, while 13 countries obtain at least 20% of their electricity from this source.

During the accummulated 5600 reactor-years of operation the safety record of nuclear power has been marred by two accidents of particular concern, Three Mile Island in 1979 (with small public consequences) and Chernobyl in 1986 (with large public consequences). Mainly as a result, the risk and possible local effects associated with nuclear energy are perceived by some in government and in the public as being too great for nuclear energy to be accepted as a viable means of resolving the health and environmental effects caused by the other means of generating electricity, particularly the burning of fossil fuels.

The UN World Commission on Environment and Development (Our Common Future) indicated a number of specific items related to the use of nuclear energy that require international agreement including regulatory activities, standards (for operation, radiation protection, waste repositories, and decommissioning), operator training, site selection criteria, emergency response training, reporting, etc.

The Conference on the Changing Atmosphere: Implications for Global Security held in Toronto, Canada, in 1988, concluded that "If the problems of safety, waste and nuclear arms can be solved, nuclear power could have a role to play in lowering CO_2 emissions".

To help resolve these concerns the holding of an International Conference on nuclear safety was suggested and encouraged by European Community countries through the IAEA Board of Governors during the spring of 1990 and presented to the IAEA General Conference in September 1990. The General Conference in its Resolution 529 welcomed the holding of the conference, with certain financial stipulations.

CONFERENCE OBJECTIVE

The Conference is directed to decision makers on nuclear safety and energy policy at the technical policy level. Its objective is to review the nuclear power safety issues on which international consensus would be desirable, to address the concerns on nuclear safety expressed by the UN World Commission on Environment and Development, and to formulate recommendations for future actions by national and International authorities to advance nuclear safety to the highest level including proposals for the IAEA's future activities for consideration by its governing bodies.

The conclusions of this Conference, addressing safety issues only, will complement the conclusions of the Senior Expert Symposium on Electricity and the Environment held in Helsinki, Finland, May 1991 which address the comparative health and environmental effects of the various alternative means of producing electricity.

The conclusions of the Conference will also form part of the IAEA's contribution to the 1992 UN Conference on Environment and Development.

The Conference should promote more effective international co-operation between IAEA Member States on the safety of nuclear energy.

The particular issues selected for consideration by the Conference are:

(i) Fundamental principles for the safe use of nuclear power;
(ii) Ensuring and enhancing the safety of operating plants;
(iii) Treatment of nuclear power plants built to earlier safety standards;
(iv) The next generation of nuclear power plants;
(v) The final disposal of radioactive waste.

For each of these issues the present status, present and foreseeable problems, recommendations for future actions required to deal with these problems at both the national and international levels, and recommendations for the role of the IAEA in these activities are outlined.

This Background Paper deals with the subject of "The Next Generation of Nuclear Power Plants".

TABLE OF CONTENTS

1. RATIONALE FOR THIS PAPER

The purpose of this paper is to aid in understanding the expectations for the next generation of nuclear power plants by addressing the factors affecting nuclear power programmes. The objectives and hence the promise of the many development and design programmes for the next generation of nuclear power plants are to achieve enhanced safety, improved economics, increased reliability, enhanced investment protection, etc., and with these, to achieve greater public acceptability, more assured licensing, and less costly construction and operation. This paper will focus on the key factors that will help achieve the enhanced safety objective.

To be successful in achieving safe and efficient operation of the next generation of nuclear power plants, the constraints placed on the current generation need to be recognized, understood and overcome. As an aid to understanding those constraints, a review of the reasons for the hiatus in the deployment of nuclear power is presented in Section 2 of this paper. Additional factors which could affect the future revival of nuclear power programmes are outlined in Section 3.

In subsequent sections, this paper will discuss the following:

- the improvements to be expected in the next generation of nuclear power reactors, as a result of the expression of desired characteristics for these reactors from several groups. This discussion will be primarily safety oriented although other facets will also be mentioned;

- the differences that have become apparent in how various reactor systems are proposed to meet particular objectives;

- the limitations which should be anticipated concerning the likely degree of technological advancement;

- finally, some aspects which could assist in the realization of the next generation of nuclear power plants are considered, including possible future role of the IAEA.

The next generation of nuclear power plants refers to those designs for which a significant amount of development and design work is going on but for which few, if any, commercial orders have been placed. They represent a variety of reactor types, mostly light water cooled reactors, but also gas cooled reactors, heavy water cooled reactors, and liquid metal cooled reactors as described in Appendix I. Some, primarily of the evolutionary type*, are either available or close to being available commercially. Others, primarily of the innovative type, will probably require operation of a prototype. The commercial introduction of such plants may be more than a decade from now.

Finally, this paper attempts to reflect the judgements of nuclear experts on what might be achievable in future reactor designs. It is not intended to recommend requirements or standards on either a national or international basis.

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[*] A definition of the terms "evolutionary" and "innovative" is given in Section 8 of this report. Appendix I provides a description of the development and design work presently under way on the next generation of nuclear power plants and a classification of this work in terms of evolutionary and innovative.

2. REASONS FOR THE HIATUS IN THE DEPLOYMENT OF NUCLEAR POWER

The projections concerning the future growth in the deployment of nuclear power made in the early days of the nuclear era have turned out to be overly optimistic. The general picture is that the real growth on the average remains below even the more pessimistic earlier forecasts, despite growing concern over nuclear's alternatives.

No single cause for the lower growth rates and, in some countries, the complete hiatus in nuclear power deployment can be identified. Different causes also dominate in various countries. However, several causes do appear to rank among the highest.

In many countries, nuclear power growth forecasts were largely based on a corresponding rapidly growing demand for energy. Moreover, the growth rates for electricity within the energy supply sector were foreseen as being even larger than the overall energy growth rate owing to the already apparent shift towards electricity as the preferred energy source. However, the oil supply crises of the early 1970s led to the adoption of an energy conservation/ efficiency ethic in most industrialized countries. As a result, overall energy demand growth rates decreased to zero and even became negative in some countries. More specifically, the growth rates for electricity demand also decreased significantly, to levels clearly lower than previously expected. The need for new electricity generating capacity temporarily disappeared and with it the need to expand the deployment of nuclear power.

The potential expanding market for nuclear power in developing countries did not materialize for several reasons. Smaller nuclear power plants, which would better fit the needs of some of these countries, were not commercially available. Indeed, the development path taken by the industrialized countries was in the direction of larger plants in order to gain the benefits of specific capital cost reductions, i.e. costs per installed unit capacity. Irrespective of specific cost reductions, the overall capital costs increased and the ability to finance the construction of such larger plants, even if the need existed, became difficult or impossible. Moreover, in part owing to the larger sizes but also owing to other reasons to be discussed later, the need for an expanding infrastructure to cover all the facets of nuclear plant design, licensing, construction, operations and maintenance became beyond the near term capabilities of most developing countries.

Public acceptance became of crucial importance. Public concern regarding safety had already been expressed in many industrialized OECD countries during the infancy of the nuclear era. The accident at the Three Mile Island plant in 1979 strongly influenced public opinion regarding nuclear power plant safety, at least in OECD countries. Public resistance to nuclear power increased in several countries, despite the fact that there were no public consequences from the accident. The accident at Chernobyl did cause significant off-site consequences and exacerbated the public opinion problem on a worldwide scale. The public is only slowly recovering and is again beginning to look at nuclear power in a more balanced manner. The growing and more unified environmentalist movement over the past decade has also greatly contributed to the general public concerns.

Difficulties in licensing new plants have played an important role in several countries. The regulatory requirements have changed with time, generally in a more demanding and time consuming direction. In many cases it has been necessary to modify the design of nuclear plants already under construction as a result of the new requirements. Prolonged construction times and increased costs have resulted. In some cases, the operating licence has not been granted or has been delayed.

The legal system of licensing, for example in the USA, UK and Germany, offers ample opportunities for intervention by opponents to nuclear power. These interventions, based more often on formal deficiencies in the licensing procedure rather than on real safety issues, have sometimes caused long delays in the implementation of nuclear projects. The combination of long delays with high interest rates and large interest charges on funds already spent has resulted in disastrous economic consequences for a number of nuclear power plant projects.

3. FACTORS AFFECTING THE FUTURE REVIVAL OF NUCLEAR POWER PROGRAMMES

Many factors can affect the degree to which nuclear technology is used in the future. Foremost among these appears to be the need for new base load electrical generating capacity. In several countries, the large reserve capacities that became apparent when growth rates decreased, and as generating plants of all types which were already in the pipeline were completed, have now been depleted. The mandated shutdown and the termination of operations of several nuclear plants require replacement capacity. Some base load capacity plants, both nuclear and fossil, will be approaching the end of their original design lifetime within the next 1-2 decades, and must either be replaced or their lifetime extended. The environmentalist movement has raised concerns regarding new and existing fossil generating capacity and even new hydro-electric dams. Short term solutions such as using plants particularly suited to meeting peak load demands to satisfy base load requirements are not cost effective. Several utilities are finding that they need to start planning now for new base load capacity.

In recent years the environmentalist movement has increased the general public's awareness of the environmental effects of using fossil energy technologies. Among the most important concerns are those regarding global warming, ozone depletion and emission of pollutants from burning fossil fuel, which can affect both human health and the environment. Especially if it is perceived that the risks from nuclear technology are far less than from other energy technologies, a strong incentive for increased use of nuclear energy could evolve. In the future it is not impossible that environmental concerns, or other difficulties regarding fossil fuels, may even require a significant substitution of nuclear energy for that energy currently produced by fossil fuelled plants.

Another important factor is the economic performance of nuclear energy relative to competing technologies. The expected economic performance of nuclear power must be competitive with alternative sources of energy considering all life-cycle costs. Associated uncertainties must be small for nuclear technologies to survive in a free market. The size of future plants and the financing of the investment must also be addressed. Simplified designs, predictable licensing conditions and short construction times are all essential for minimizing the capital costs. Likewise, operating and maintenance costs must be controllable, long term complete fuel cycle costs including waste handling must be reasonably guaranteed and ultimate decommissioning costs must be included.

In many countries, especially in those where a nuclear moratorium is in force, regaining public acceptability is a necessary prerequisite for the revival of the nuclear programme. Although many factors have influenced public acceptability, enhanced safety is a key factor and is achievable with our increased knowledge and experience. In addition, future reactors should also be perceived as safe by the general public. Although current designs are generally considered safe by nuclear safety experts, some perceive that the goal of achieving public acceptability may require fresh thinking and new approaches. The safety features of the next generation of nuclear power plants of the evolutionary or the innovative type should be simplified and understandable to non-technical people. The public should also be given information to enable them to perceive that the new designs provide clear and straightforward solutions for the accident scenarios which happened in the past.

Organizations involved in nuclear power should exercise increased openness and candor in their interactions. Also, the public should be provided an elementary understanding of nuclear power and radiation. These efforts should enhance public trust and confidence in the nuclear enterprise.

Certain additional factors can also be expected to have an effect upon the future use of nuclear technology. These include the degree to which trouble-free operation of the existing nuclear energy plants is achieved worldwide and the degree to which international agreement concerning nuclear safety matters is achieved.

Finally, it should be kept in mind that the use of nuclear technology to alleviate global warming would imply a substantial increase in nuclear capacity worldwide. The implicit increase in uranium consumption associated with such an expansion would increase incentives for improved fuel efficiencies, for example by using high conversion or breeder reactors. It is worth noting that these plant attributes are currently not the top priority in most current advanced reactor development programmes, but are indeed supported as follow-on technologies.

Further into the future, non-electrical uses of nuclear energy could stimulate additional demand for new plants. Currently studied applications include district heating, process steam supply, desalination and, in the longer term, high temperature heat supply for various industrial processes, including hydrogen production.

4. SAFETY PRINCIPLES AND OBJECTIVES FOR ENHANCED SAFETY IN THE NEXT GENERATION OF NUCLEAR POWER PLANTS

Safety has always been uppermost in nuclear plant design and has been pursued not only through safe design and prudent system engineering but also by maintaining a high level of quality in plant manufacturing, construction, operation, maintenance and management. This high level of quality, the recognition of the importance of safety and the continuing quest for excellence within the entire system, including the technical infrastructure associated with both the design and the operation of nuclear power, have been given the special term "safety culture". The development of an adequate safety culture within any country would appear to be an absolute prerequisite to that country's deployment of nuclear power.

Current civilian nuclear power plants have accumulated over 5600 reactor-years of experience with only two significant accidents, only one of which led to significant off-site consequences. Plants currently in operation have, in general, a very satisfactory safety level, although at a number of plants some safety improvements appear to be advisable and relatively easy to implement. In a few cases, the necessary upgrading may not be a viable option and the permanent shutdown of these plants may have to be considered.

It is therefore important to note that the development of the next generation of nuclear power plants, with enhanced safety characteristics, does not disqualify the existing generation of nuclear power plants which already meet acceptable safety standards. The coexistence of different generations of plants should be accepted and understood by the public as a natural phenomenon occurring with all industrial activities. The acceptance of this principle is essential to the continued progress of any technology and to taking the maximum advantage of research efforts and the accumulation of operating experience.

Moreover, it should be recognized that there is a clear trend today, involving all types of industrial activities, towards a continuous improvement in public safety aspects and the environmental protection levels associated with these activities. This trend is a consequence of at least four factors:

- The public today is more sensitive to all environmental issues, not only those involving health and safety, but also those having negative effects upon the environment;
- The number of industrial plants is continuously growing, bringing increased risks due to the magnitude of industrial operations and to possible synergistic effects from different pollutants;
- Technological advances and operating experience make improvements in public and environmental protection possible, in some cases at little additional cost;
- The safety deficiencies of some operating plants.

In addition, the natural ambition of industry and the effect of competition among the vendors in the nuclear industry, as well as other industries, is to introduce design improvements, regardless of other factors, to enhance the marketability of their products.

From a user standpoint, utilities have high expectations for design improvements in many areas in addition to enhanced safety. Examples include design simplification, improved economics, improved investment protection, improved reliability, maintainability and constructability, etc.

In summary, to enable nuclear power to play an expanded role in the future, it appears that next generation plants should not only be at least as safe as the best plants operating at present, but should be expected to present some significantly enhanced safety and economic characteristics.

As intimated in Paper I, to improve the safety of the next generation of nuclear power plants will require the provision of designs which make the risks of a significant accidental release of radioactive material even more negligible. To do this requires a review of the characteristics of the many barriers which comprise the long-standing defence in depth principle associated with every nuclear power plant. These barriers and the protection of them serve two primary purposes: the prevention of accidents and the mitigation measures to reduce the effects of an accidental release of radioactive material.

Two factors are of special importance to public acceptability: what technical means are used to limit the off-site consequences of serious accidents and how the plants are designed to decrease the sensitivity of nuclear safety to human errors.

Regarding the first factor, irrespective of low probabilities for serious accidents, limiting off-site consequences of such accidents is important to public acceptability. The accident at Three Mile Island has shown that even a serious accident such as the melting of the core could proceed virtually without any off-site consequences, because of the adequate performance of the containment. The Chernobyl accident, on the other hand, has shown that some designs do not have adequate technical means to prevent or mitigate serious accidents. Overall there is thus a strong incentive to have design characteristics which, within the defence in depth principle, enable off-site consequences to be reduced to an insignificant level, irrespective of the seriousness of the accident.

The need to prevent and mitigate accidents, and to reduce off-site consequences, has had a significant impact on the design of the next generation of nuclear power plants. The impacts have ranged from arguments on the usefulness of probabilistic safety assessment (PSA) for low probability events, and on "how safe is safe enough?", to more changes in design than probably would have occurred had evolution and product improvement been the only incentives.

The second factor stems from popular belief, and perhaps a common sense conclusion, that human errors are a major factor of risk. Human error is an important factor in road and air traffic, in other industrial activities, and in a significant fraction of safety related and reported events in nuclear plants. The Three Mile Island and Chernobyl accidents involved human error by both designers and operators. There is thus a strong incentive to have design characteristics which would make future plants less dependent on human actions and to have the ability to be more forgiving of human errors.

These factors have led to desired safety features for future nuclear plants, such as less dependence on human actions, increased reliance on passive safety features, simplification, reduced occupational doses and reduced environmental consequences.

The objective of enhanced safety pertains to the next generation of nuclear power plants irrespective of their being termed evolutionary or innovative. The main difference between these two approaches is that the evolutionary designs emphasize improvement based on proven technology and experience already gained, whereas the innovative designs emphasize the use of new features, typically passive in nature, in meeting the enhanced safety objective.

Irrespective of the design direction taken, residual human errors, major external events (e.g. large earthquakes) and common mode failures will limit progress. These factors account for residual risks which are impossible to eliminate regardless of the particular reactor concept. However, efforts are being made to make even these risks negligibly small.

5. MAIN DESIRED CHARACTERISTICS RELATED TO THE OBJECTIVE OF ENHANCED SAFETY

Expanding on the discussion of the objective of enhanced safety in the next generation of nuclear power plants, this and the next section identify some particular characteristics which are felt to be important in addressing the objective. Within the context of interactions already held with potential users, it is believed that a consensus is likely to develop that these characteristics are desirable.

The characteristics proposed have the potential of being implemented to some degree in all of the next generation of nuclear power plants. However, only after the development has been completed, detailed designs have become available, and licensing reviews have been completed, will the degree of implementation be able to be assessed; and, more importantly, the degree to which enhanced safety has been achieved be determined.

Nevertheless, even though the "bottom line" may not have been reached for many of the designs, enough information is available on several of them to permit one to understand and comment on the emphasis being given in the design to the various characteristics believed desirable in achieving the enhanced safety objective. Moreover, there are several other desired characteristics for the next generation of nuclear power plants which, although not directly related to safety, may have indirect beneficial safety implications. Hence, although not extensive, the paper does contain some pertinent comments where appropriate.

5.1 DEFENCE IN DEPTH BARRIERS

The concept of defence in depth was introduced in Background Paper I, where the principles of accident prevention and mitigation were described. The implementation of the defence in depth principle involves the use of several successive levels of protection, including independent physical barriers to prevent the release of radioactive material to the environment.

Use of only a single barrier, even providing a very high level of protection against some kinds of accidents, is not considered acceptable. The design must include protection against accidents in which failure of one barrier could result in a significant radioactive release or could cause failure of other barriers; independence of systems protecting the integrity of each barrier must be carefully verified and strengthened where necessary. These statements are simply corollaries to the basic defence in depth principle.

In general, designers of the next generation of nuclear power plants are striving for enhancements in the characteristics of the barriers themselves, and in the level of protection provided for each barrier, so as to provide enhanced overall safety. But within this framework, it is not necessary that each barrier and its associated protection carry equal weight in achieving the objective. Clearly, enhancements in the characteristics related to the first barrier place less of a burden on the subsequent barriers; enhancement in the characteristics of the second barrier place less of a burden on the subsequent barriers and so on. Moreover, placing higher priority on the earlier barriers would provide greater assurance of preserving the plant investment, and keeping the radioactive material closer to where it is generated. This could lead to several attendant benefits.

Four levels of defence in depth barriers can be defined as follows:

a. preventing deviations from normal operation which require the intervention of safety systems. A robust design with large thermal inertia, and increased margins between operational parameter ranges and safety system actuation set points, is desired. It is noted that non-safety-related systems can also provide backup protection against most transients and incidents;

b. preventing the failure of the fuel cladding barrier. The use of cladding with a high temperature capability, plus provision of adequate cooling of the cladding by means of diverse and very reliable systems is desirable;

c. preventing the failure of the reactor coolant pressure boundary. Again a robust design and one which minimizes the extent of these boundaries and provides for easy inspection and maintenance is desirable;

d. containing the fission products within an adequate containment building, should preceding barriers fail. The plant design should be such that this last barrier, the containment, coupled with appropriate accident management measures provides the desired level of enhanced safety. In most designs this function is met by employing a leaktight containment building. This fourth barrier, the containment system, should play a key role for all next generation plants. Special care should be devoted ensuring the containment performs as required.

As was previously stated, the various future designs place varying degrees of emphasis on these four barriers. All nuclear power plant designs provide some protection at each stage. From available design information, it is apparent that the evolutionary designs have been critically examined and have improved all four barriers. The innovative designs also critically examined all four barriers, but some designs have given major emphasis to the second barrier, i.e. preventing the failure of the fuel cladding. The owners' interest in protecting their investment and limiting fission product transport emphasizes prevention of accidents, which also tends to place more emphasis on the earlier barriers.

5.2 DESIGN IMPROVEMENTS FOR SEVERE ACCIDENTS

Current plants meet conservative design requirements within a defined set of accidents called the licensing design basis. Future plants will meet this same licensing design basis; and in addition, even lower probability events will be considered explicitly and systematically in the design. This will result in next generation plants with improvements in both prevention and mitigation of severe accidents.

Over the past two decades severe accident research programmes, particularly for LWRs, have provided valuable data, and analytical tools have been greatly improved.

Specific severe accident scenarios will be reactor type dependent. Identification of credible scenarios will involve engineering judgement, deterministic analysis, use of PSA results, analytical tools, and review of applicable operating experience.

Many aspects of severe accidents remain too uncertain to permit the modelling of the phenomena and the corresponding loads with the desired accuracy (e.g., the conditions governing, and consequences of, high pressure core melt ejection in LWRs). In these cases, efforts should be made to remove the effects of these uncertain phenomena by design. In most cases, however, the phenomena present physical limitations in the possible effects, and some upper limits can be used in the design. Because of the limitations and uncertainties just discussed and the very low probability of severe accidents, both the design approach and the regulatory reviews should be based on best estimate assumptions, data and calculational methods. Also, the treatment and review of severe accidents should consider accident management measures, including use of non-safety-related systems.

In addition, a more general review of designs may be justified on the basis of the available operating experience data and the insights from the large number of PSAs already completed.

Future plant designs should include, or at least not prevent, plant protection against credible external events and allow for easy plant design upgrading if required. However, a limit to the degree of feasible safety improvements is imposed by the possibility of, for example, very large earthquakes, even though they may be extremely unlikely.

In general, forgiving, robust and simple plants may be expected to promote increased protection against all types of severe accidents, including external events. However, it must be emphasized that absolute safety cannot be achieved.

5.3 PROBABILISTIC SAFETY ASSESSMENTS

Since the beginning of the 1970s probabilistic techniques for assessing the safety of nuclear power plants have increasingly been used. Their use is very important in identifying vulnerabilities in the design, in particular those related to systems interactions. They also provide valuable insights into the likelihood of accident scenarios. Despite the limitations of PSA discussed below, PSA targets have been proposed in several instances by different groups. For example, INSAG-3 proposed the following targets for future plants:

- likelihood of occurrence of severe core damage of not more than about 10^{-5} per plant operating year;

- likelihood of occurrence of large off-site releases of not more than 10^{-6} per plant operating year.

These targets are goals for designers to pursue in terms of expected performance. It has not yet been established that they can be met by each design in practice, but they are generally considered feasible. These goals were not postulated to be interpreted as performance requirements.

One should recognize that use of absolute values of results from PSA to validate the safety of plants has often been overemphasized. For example, INSAG-3 qualified the above targets as not constituting regulatory requirements. Deficiencies in equipment reliability data and in mathematical models and the imperfect knowledge of phenomena in some accidents limit the accuracy of risk estimates. Human error probability values are uncertain owing to the intrinsic uncertainty of human behaviour. Designs with little operating history are particularly difficult to evaluate with PSA owing to insufficient equipment reliability data and limited practical understanding of operating conditions and responses. Absolute values of risk results obtained from PSA often serve to confuse the public rather than educate. For these reasons, PSA results should not be emphasized in trying to convey an understanding of the safety level of a design to the public, nor should they be used as regulatory acceptance criteria.

In addition to the continued use of PSA as a tool for designers for the reasons already given, non-probabilistic methods, as discussed in Section 5.2, should be used to the greatest extent even though PSA might indicate a very low level of accident probability.

5.4 OFF-SITE CONSEQUENCES

As indicated in Section 4 under principles for enhancing safety, there is a strong incentive to reduce off-site consequences of a potential accident to an insignificant level, irrespective of the seriousness of the accident. It must be pointed out that this principle has always been part of the basic safety philosophy for nuclear plants. Within the design basis framework, credible serious accidents were thoroughly analysed and the plant was designed with sufficient barriers to mitigate the consequences of such accidents. In recognition of the fact that there could perhaps be less credible sequences of events, very large design margins were required, and rapid sheltering and/or evacuation of people beyond the nearby exclusion area around the plant was also mandated to further allow for uncertainty.

As a result, emergency plans for nuclear plants, as opposed to emergency plans for other industrial activities, were obligated to include complex provisions for rapid sheltering and/or evacuation. Such provisions and associated rapid notification requirements placed onerous responsibilities on the plant owner and on various public agencies whose rapid actions were also required. Also, some recent studies and evaluations of nuclear accident scenarios indicate that rapid evacuation may not be necessary for public safety, and that a more orderly approach is preferred.

Hence, designers and users of the next generation of nuclear power plants have focused on more realistic analyses of accident scenarios, environmental parameters, and protection strategies, and on prevention and mitigation features in the design which address these concerns, i.e. delaying the need for sheltering and/or evacuation for a reasonable period (at least 24 hours has been suggested) and, if possible, establishing a strong technical basis for not requiring any sheltering or evacuation at all. Similarly, because of the Chernobyl event, there has been a recent focus on assuring no health significant contamination of surrounding land and water bodies or at least limiting this contamination in space and time. In particular, it has been emphasized that contamination should not require the long term relocation of a large number of people.

The provision of enhancement of all of the barriers associated with the defence in depth principle, including appropriate accident management in combination with incorporating modern research results and more realistic accident analysis, has now provided the technical basis for minimizing and delaying releases of radioactivity. This should provide the technical basis for simplifying emergency planning for the next generation of nuclear power plants. Better appreciation of these measures should lead to greater public acceptability for nuclear power.

Within this framework, it is recognized that there is a need for a greater international harmonization of calculational methodologies and of the policies concerning permissible limits relating to the need for sheltering and evacuation and to land and water contamination. The objective of enhanced safety for the next generation of nuclear power plants and their potential worldwide application would appear to warrant consideration of such harmonization.

5.5 THE HUMAN FACTOR

The plant should be designed to be easy to operate so that the behaviour of the plant can be readily understood and, as a result, the possibility of human error can be reduced. However, if a human error (errors of omission or commission) should occur, the plant should be "forgiving" or "fault tolerant".

The design should provide for automatic responses to abnormal situations to the maximum extent, with a sufficient period of time (grace period) during which no operator action is required. This would allow the operators time to either identify the event or to assess the plant state and, thus, after careful consideration, to initiate appropriate actions, including intervention, if warranted.

Many studies have shown that with a grace period of about 30 minutes the probability of operator errors becomes very low. Moreover, the probability of correct protective or recovery actions by the operators increases as the time available before actions become necessary increases. Grace periods longer than 30 minutes appear to be within the capability of several next generation reactors. If, after this period, only simple and preplanned actions are needed, correct performance of these actions would be highly likely. On the other hand, operators should play an active role in gaining an overview of the plant status and systems response during the grace period and assume full control later on. They should never be prevented from using non-safety-related systems, but should not have to interfere with the operation of safety systems during the grace period, once such safety systems have been actuated, and while the actuation signal is present.

The man-machine interface can also be improved by taking advantage of advances in modern electronic, digital and computer technology, for example microprocessors, video displays, multiplexing, fibre optics, etc. Organized and hierarchical alarm displays and controls, "expert systems", and improved diagnostic systems are available technology that should be used to best advantage in advanced nuclear designs. Future designs should consider improvements to cater for human factors throughout the design process.

In order for the operators to be able continually to assess the plant's condition, it is essential that comprehensive instrumentation be included in the plant design. Also, with regard to assuring operator capability, a representative, full scope simulator facility should be provided or adequate training provided in another identical plant.

Accident management is another area that should be planned at an early stage of reactor design in order to include all necessary features to facilitate the action of plant personnel and also external organizations which could be summoned to the plant to provide, for example, backup cooling water and electrical power.

5.6 PASSIVE SAFETY FEATURES

Passive safety features, by definition, do not rely on human actions and, to some extent, also do not rely on external mechanical and/or electrical power, signals or forces. Passive safety features rely on naturally available sources of motive power, such as natural circulation; and on actuation mechanisms, such as check valves. Several levels of "passivity", as defined in IAEA TECDOC-626 on Safety Related Terms for Advanced Nuclear Plants, exist including systems which are actively initiated but may operate passively. The use of passive safety features in a nuclear power plant is a desirable method of achieving simplification and increasing the reliability of the performance of essential safety functions, i.e. reactor control and shutdown, core and containment cooling, and retention of fission products.

Passive systems also tend to reduce redundancy requirements, operational complexity and need for operator actions. Passive systems have the potential of achieving higher reliability and presenting fewer performance uncertainties than active systems. An important aspect of passive systems is their sole dependence on stored, readily accessible sources of energy and, hence, their capability of operating in a station blackout condition. Use of passive features should be encouraged whenever they can provide an adequate level of functional performance for the intended purpose. The use of passive features, already incorporated to a limited extent in present plants, should be expanded in both evolutionary and innovative designs, where appropriate.

Proper attention should be given, in the assessment of the functional performance of passive features, to system reliability and testing possibilities. It is also necessary to verify the availability of proper and validated computer codes and correlations to support the expected performance of the passive safety systems and components. A careful review of potential failure modes of passive components and systems should also be performed in order to identify possible new failure mechanisms such as those which do not arise with active components and systems.

6. OTHER DESIRED CHARACTERISTICS INDIRECTLY RELATED TO SAFETY

Several other characteristics, which might be viewed as having an indirect impact on enhancing the safety of the next generation of nuclear power plants, have arisen in discussions.

6.1 SIMPLIFICATION

The goal of plant simplification is shared by all potential users and designers. Current plant designs have proven to be unnecessarily complex to operate, inspect, maintain and repair. Unnecessary complexity is a root cause of a wide range of problems in existing plants, and therefore design simplification should be pursued with high priority, particularly when operational safety is enhanced.

Simplification should be pursued in every aspect of plant design and operation, even though it may be necessary to define some priorities. The basic spirit of simplification is to only include systems in the design that perform essential functions, and to reduce complexity by adding design margin or by performing the essential function passively, thus reducing the need for complex controls.

First priority should therefore be simplicity in plant operation. This will help make the operator's tasks easier, and may also help reduce operator error. Simplicity in manufacturing and construction should be considered, as second priority.

The design engineers should seek simple layouts and endeavour to eliminate unnecessary components and systems. This does not mean that numbers of components and systems should always be minimized, because excessive zeal in reducing the number of components can run counter to safety, e.g. by reducing the overall reliability. It does mean that good reasons should support the presence of each component and system. Choices should be sought that support simplicity in later formulations of normal operating procedures, emergency operating procedures, inspection, testing and maintenance.

6.2 PROVEN TECHNOLOGY AND OPERATING EXPERIENCE FEEDBACK

Feedback of experience from the prior operation of existing nuclear power plants plays an important role in the design of the next generation of nuclear power plants. Both the evolutionary and the innovative designs have factored in prior experience to the extent possible. The innovative designs, by definition, incorporate some design features or other facets for which a large amount of prior experience may not be available.

Any plant design or feature within a design that is not previously demonstrated should only incorporate components or systems that are introduced after thorough research and prototype testing at the component, system or plant level, as appropriate. Proof of performance including safety of some of the innovative designs may require a full scale demonstration plant.

6.3 OCCUPATIONAL DOSES

The plant should be designed to reduce occupational doses. Reduction of these doses through proper component design, materials selection, shielding, layout and accessibility should take into account not only normal operation and maintenance activities but also possible actions needed during the handling of any abnormal situation including accident management.

Attention should be given to prevention of activated corrosion product generation, transport and accumulation in areas where maintenance activities are expected.

Of particular interest with regard to the reduction of occupational doses are two facets of the next generation of nuclear power plants previously discussed. One is the use of design features which may require less maintenance and hence involve less potential exposure to radioactivity. The other is the manner in which enhancement of the barriers related to the defence in depth principle is achieved. Clearly, enhancement of the factors related to providing and protecting the first barriers provides greater assurance of localizing radioactive materials, particularly fission products, in fewer, more protected areas of the plant for any abnormal situation. It should also be noted that such emphasis might also result in the generation of less low and medium level waste.

6.4 WASTE GENERATION

The important steps to be addressed from the standpoint of next generation designs are the minimization of waste generation, volume reduction and final conditioning of low and medium level wastes. Proper design, materials selection and fluid chemistry should be utilized to minimize waste generation.

Low and medium level waste volume reduction and conditioning systems should be included in the plant to minimize waste shipping problems and to produce waste packages suitable for disposal. If centralized facilities for waste disposal or storage are not available, adequate space should be provided on site to store all low and medium level wastes produced during plant life. If necessary, storage facilities for spent fuel generated during the entire plant life should be provided on site, as well.

Plant decommissioning, at the end of plant commercial life, should also be facilitated in the design. Most of the provisions needed to comply with this goal are the same as those necessary to minimize radioactive waste production and occupational doses. However, attention should be given in the design to the need for dismantling large components during decommissioning.

7. STANDARDIZATION AND LICENSING

Standardization, where it has been implemented (France, Germany, Japan), has proven to be very beneficial in terms of both safety and overall life-cycle costs. Benefits for safety stem from a greater concentration of resources and effort by designers, regulators and utilities/users on fewer designs, and from greater stability in the design and licensing process resulting from earlier and more definitive resolution of safety issues. Also, standardization permits a much greater volume of feedback of common experience from the standardized units and permits standardized training, maintenance, etc. for fewer designs. Benefits in terms of cost come from the sharing of information and engineering resources during all phases of design, construction, and operation, and the potential sharing of spare parts, training facilities, etc.

Licensing criteria and procedures should be harmonized to the greatest possible extent based on worldwide scientific resolution of technical issues and generally accepted standards of safety adequacy. Such harmonization would foster more stable regulations and licensing procedures and allow vendors to offer standardized designs to a wider range of utilities. Further, licensing standardized designs prior to construction will increase the probability that the utilities would to be able to achieve a streamlined and more predictable licensing process. As mentioned previously, international harmonization of calculational methods and safety policies would result in clearer and more widely accepted quantitative targets for enhanced safety.

8. STRATEGIES FOR THE INTRODUCTION OF THE NEXT GENERATION OF NUCLEAR POWER PLANTS

The early developments in nuclear power took place mainly on a national basis to meet an individual country's needs. As the technology has matured, more co-operative approaches to achieving improvements are now proceeding on an international basis:

- several vendors have undergone transnational mergers or implemented international co-operation agreements to develop a common product for a broader market;
- utilities, on an international basis, are developing common requirements which are intended to be met by vendors and accepted by different governmental licensing authorities; co-operation agreements already exist between some utilities in Europe, the USA and Asia for this purpose;
- the recently formed World Association of Nuclear Operators (WANO) is gathering and collating operational experiences on a worldwide basis;
- there are a growing number of co-operation agreements between national regulatory bodies, and a general recognition that the risks of transboundary effects warrant the harmonization of at least some regulatory approaches;
- the IAEA has in place several advisory and information gathering groups which have international participation and are intended to provide worldwide dissemination of information concerning advanced reactors. INSAG provides advice specifically on nuclear plant safety principles.

Within this increasingly international framework, two approaches have developed regarding the design of the next generation of nuclear power plants:

- Some consider that the next generation of nuclear power plants should primarily evolve from the present generation. Such plants would make maximum use of proven technology and accumulated experience. They would include safety improvements and new safety features, some of which would be passive, to meet the enhanced safety objective. These plants appear presently to range in size from around 500 MW(e) to 1500 MW(e) output. They are called evolutionary designs and may be further categorized as requiring no prototype for proof of performance. These designs are typically water cooled, and generally will be available for operation by the end of this decade;

Others consider that more drastic changes in plant design are necessary to achieve greater public acceptability. In these designs increased emphasis is placed on passive features; in particular, features that protect the fuel and the fuel cladding - the first barriers in the defence in depth principle. Mostly owing to the nature and capability of these passive features, these plants are smaller in power output, ranging in size from around 100 MW(e) to the order of 500-600 MW(e). Those plants with the smaller power output have been termed modular with the thought that a single nuclear plant site would consist of several such identical standardized modules as necessary to meet a higher total output. Such designs are called innovative designs, although some have used the term "revolutionary". Proof of performance by way of a first-of-a-kind or prototype plant would probably be required. In general, innovative designs will be available in a later time frame than evolutionary designs, and consist of the more highly innovative water cooled reactors, as well as gas cooled and liquid metal cooled reactors.

Most of the development and design work on this next generation of nuclear power plants is taking place in industrial and government organizations in countries that already have a large background in nuclear power development and typically have several operating nuclear power plants. It is natural that such countries prefer the evolutionary approach in the near term, in order to take full advantage of their experience, to have designs available within the short term and not to have to depart radically from the industrial practices adopted so far. Even though radical departures might be construed as an indication of significant problems with the present generation of nuclear powers plants, which is certainly not the situation, some of these same industrialized countries are actively pursuing the more innovative designs as either future alternatives to evolutionary designs, or as plants with a unique "niche" in their energy future.

Some countries, often ones with few if any operating plants, are more favourably disposed towards either smaller evolutionary or the innovative plants. Many factors appear to be contributing to this disposition. Many countries see smaller plants as better fitting their load growth patterns. Some believe that, irrespective of evolution, more of a fresh start is necessary to overcome present public attitudes. Others believe that what is now available is becoming overwhelmingly complex, and lack confidence in the ability of evolutionary designs to significantly reduce complexity of design and infrastructure. They believe that the approach taken by the innovative designs regarding enhanced safety does offer significant advantages, some of which have been covered in this report.

It has also been suggested that either the smaller evolutionary or innovative plants may be suitable for use in the developing countries. This is due to the fact that the smaller power outputs of these designs better meet the needs of the developing countries. Some of these countries also foresee possible eased public acceptability, eased regulatory licensing and oversight, and eased infrastructure requirements with the innovative designs. It must be recognized, of course, that such possibilities will only be realized with the industrial maturity of the innovative designs and the clear evidence that such benefits can be obtained. This will obviously be a long term process. Further, there is some doubt that regulatory licensing and oversight for designs unfamiliar to regulatory authorities will necessarily be easier. Hence, in the near term of at least the next decade, the more appropriate technologies for all countries will probably be of the evolutionary type. Further, it is generally agreed that developing countries must be particularly sensitive to their need for an adequate safety culture and ability to handle the technology.

It is becoming increasingly evident that international co-operative approaches, such as those previously listed, help to forge a broader consensus, on the need for and the benefits of nuclear power. Moreover, expansion of these international approaches, whether through more government to government agreements, increased joint venturing by industry or involvement of a broader utility/user base, could lead to greater harmonization of the total nuclear enterprise. The commercial introduction of the next generation of nuclear power plants on a worldwide basis could be facilitated by such expansion. Standardized designs which fit the needs of a broader international market are being designed to meet the requirements of a broader international utility/user consensus, and to meet a broader set of safety criteria and regulatory policies.

It is also becoming evident that realizing the first step in the commercialization of the next generation of nuclear power plants, i.e. accomplishing the required engineering effort for certification and standardization, is an expensive venture for any single industrial entity or single national government. The probable need for full scale prototype plants to demonstrate the performance facets of the innovative designs is an additional burden. Hence, multinational support for national efforts to design and build such prototypes may be needed for these designs to achieve commercial availability.

9. ROLE OF THE IAEA

Related to the safety of current plants, the IAEA already has a broad safety programme including the establishment of international safety principles through the International Nuclear Safety Advisory Group (INSAG), the review of operational safety of present plants through Operational Safety and Review Team (OSART) reviews and other co-ordinated safety related assessment efforts.

In the future, the IAEA should continue to work with Member States towards developing an international consensus on the safety targets that could be attained by the future generations of nuclear power plants. This should be complemented by the development of appropriate safety principles and safety characteristics which could be applied to these future plants. These activities should be based on the work of INSAG on this subject.

Related to the broader objective of promoting nuclear power technology development, the IAEA co-ordinates technical information exchange between Member States, related development programmes, and the publishing of reports for the information of all interested Member States. The IAEA activities are co-ordinated by three standing committees, called the International Working Group on Fast Reactors, International Working Group on Gas Cooled Reactors and International Working Group on Advanced Technologies for Water Cooled Reactors.

Mainly through the existing structure of these International Working Groups, the IAEA has started to bring together utilities and energy users on an international basis to establish a set of desired characteristics for the next generation of nuclear power plants. These characteristics are independent of the specific reactor type and enable the entities within any country to assess and determine which type of next generation plant best meets its needs.

The IAEA could also be a catalyst for the creation of forums to discuss opportunities for multinational co-operation on joint projects.

10. SUMMARY

A new generation of nuclear power plants is being developed, capitalizing on the accumulated experience of current generation systems, plus the incorporation of the results of research and development. These designs offer a future where safety enhancements and improved economic return are achievable together.

These designs make possible enhancement of the barriers associated with the defence in depth philosophy, giving the potential for achievement of reduced off-site consequences with simplification of emergency planning. Additional benefits of the new designs include:

- reduced occupational doses;
- minimization of waste generation;
- design simplification; and
- standardization.

The success of these various designs depends not only on their technical excellence, but on the ability of the nuclear industry to redress the balance of understanding and acceptance of nuclear power by the public and decision makers.

Within the evolution of the designs for the new plants, there are still a number of issues to be addressed. These have been discussed in some depth in this Background Paper. For the purpose of debate at the conference, four significant topics are proposed for consideration:

1. Next generation nuclear power plant designs will have incorporated design improvements for accident prevention. Although different designs take different approaches to accident prevention, are their overall objective and approach acceptable?

2. Next generation nuclear power plant designs incorporate features for the mitigation of potential severe accidents. Is there a need for harmonization or consensus on different aspects such as design approaches, accident scnearios and analytical methods?

3. What should be the role of emergency planning for future reactor designs? Do design improvements and recent severe accident research results provide an adequate technical basis for simplifying or eliminating emergency planning for future designs?

4. What should be the role of the IAEA with respect to future reactor designs? Specifically, should the IAEA develop a set of desired safety characteristics for the next generation of nuclear power plants?

APPENDIX I

STATUS OF NUCLEAR POWER PLANT DEVELOPMENTS

A1. INTRODUCTION

It is evident that nuclear power has an important role to play in supplying the growing world population with energy. The desire to conserve fossil fuels, which at the same time are valuable raw materials, the commitment to decrease CO_2 emissions below certain levels and the limited prospects of large scale use of renewable energy sources tend to emphasize the contribution of nuclear energy. This form of energy will be successful only under certain conditions: it must meet increasingly exacting safety requirements, it must be acceptable to the public and it must be economically competitive. The nuclear industry is faced with a demanding challenge in attempting to fulfil these requirements.

Much development work is going on in several countries, with participation of both governmental and private bodies.

The efforts are directed along two different lines, both putting emphasis on achieving enhanced safety. One line is striving at improved reactors by further developing existing types on an evolutionary basis, avoiding significant departures from well proven designs. The other line involves reactor designs which, at least in some respects, differ considerably from existing reactors. In these designs the main emphasis is on passive safety features. This line implies innovative designs, and may require construction of prototype or demonstration reactors before commercialization.

A2. NUCLEAR POWER DEVELOPMENT TRENDS

Increased attention to these developments is being given not only by the governments and industrial entities in nations with an already well developed nuclear power infrastructure, but also by those nations seriously considering an expansion of or entering into nuclear power implementation. The development trends for all reactor concepts are clearly reflecting the influence of past experience and the revised development goals for the future.

A2.1 LIGHT WATER COOLED REACTORS

The current Western light water cooled reactor (LWR) technology has proven to be economic, safe and reliable. The LWR has a mature infrastructure and regulatory base in several countries. Over 75% of all current operating plants are LWRs. LWRs also have the highest percentage of the total world reactor operating experience. Most industrialized countries continue to develop large size units, with power outputs above 900 MW(e), as advanced LWRs (ALWRs) for the 1990s. These evolutionary ALWR designs result from a continuous upgrading and improvement based on experience gained from current models. For example, the N4 model (1400 MW(e)), which is now under construction in France, derives directly from the standardized P4 series (1300 MW(e)), while achieving a reduction of 5% in cost per installed kilowatt compared with the P4 series. In Germany the "CONVOY" plants are a group of three standard pressurized water reactors of the 1300 MW(e) size. The advanced features of the "CONVOY" plants are mainly in the engineering and project management associated with nuclear power plant construction. The Westinghouse-Mitsubishi Advanced Pressurized Water Reactor (APWR-1350 MW(e)), the British "Sizewell-B" PWRs (1250 MW(e)), the ABB-Combustion Engineering "SYSTEM 80 PLUS" (3800 MW(th)) and the General Electric-Hitachi-Toshiba Advanced Boiling Water Reactor (ABWR-1360 MW(e)) are further examples of the large size evolutionary ALWR.

Medium size ALWRs are also being developed in the 600 MW(e) range that place greater emphasis on incorporating passive safety features. Within the context of definitions in this paper, both the larger and medium size ALWRs are considered to be evolutionary designs, in that none will require a prototype. Examples of these medium size passive ALWRs include the

Westinghouse Advanced Passive PWR (AP-600) and the General Electric Simplified Boiling Water Reactor (SBWR).

An important aspect of the United States programme was initiated in 1984 by the Electric Power Research Institute, an organization of US utilities. Several foreign utilities have also participated in the effort. A comprehensive set of user requirements was compiled and the designs of ALWRs to meet these requirements are being developed. This design work is being partly supported by the US Department of Energy. Utility requirements were established for both BWRs and PWRs, of both large (outputs around 1200 MW(e)) and medium size reactors (outputs around 600 MW(e)). Design certification from the US Nuclear Regulatory Commission is a key feature of this programme and it is contemplated that standardized units could be commercially offered in the 1990s as design certification is obtained. Certification for the larger sizes (typified by the ABWR and SYSTEM-80 PLUS) is expected first, with the smaller sizes, typified by the AP-600 and the SBWR occurring later.

All of these ALWRs incorporate significant design simplification, increased design margins, and various technological and operational procedure improvements, including better fuel performance and burnup, better man-machine interface using computers and improved information displays, greater plant standardization, improved constructability and maintainability, and better operator qualification and simulator training. The result of these improvements will expand on the already manifested improvements in availability and the lower number of challenges to safety systems.

Further work along these lines is being done in Europe. Initiated in 1989 by Electricité de France, the REP 2000 programme should lead to the specification of European utilities' requirements. On the vendor side, Framatome and Siemens established a joint company, Nuclear Power International (NPI), which is developing a new product with enhanced safety features, and intend to have it reviewed jointly by the French and German safety authorities. This procedure will provide strong motivation for the practical harmonization of the safety requirements of two countries with major nuclear power programmes, which could later be enlarged to a broader basis. In Sweden, ABB Atom, in co-operation with the utility Teollisuuden Voima Oy (TVO) of Finland, is developing the BWR 90 as an upgraded version of the boiling water reactors operating in Sweden.

In the USSR, design work on the evolutionary VVER-92, an upgraded version of the VVER-88, has been started and another design, the VVER-91, is being developed in co-operation with Finland. The USSR is also developing the evolutionary VVER-500 design along the same lines as the AP-600 and a more innovative, integral design, the VVER-600.

An innovative approach for next generation light water cooled reactors is being taken by the developers of two "integral" PWRs, the PIUS reactor (ABB-Atom), and the SIR reactor (ABB-CE).

The conceptual design for PIUS is for a medium size power unit of about 600 MW(e), although smaller sizes are certainly possible. The approach to enhanced safety in this reactor is based on the principle that the ability to shut down the reactor and provide continuing core cooling to remove decay heat after accidents could be entirely passive. The PIUS principle is based on having a large volume of borated water available to shut down and cool the reactor core. This borated water is separated from the primary water coolant by density locks during normal operation but naturally convects through the core during any shutdown. Several other innovative designs, both of the boiling and pressurized water reactor types, using the PIUS passive core shutdown and cooling principles, are also being considered. The ISER (University of Tokyo) and the SPWR (Japan Atomic Energy Research Institute) concepts use the PIUS principle on smaller units inside steel vessels. Proof of the PIUS principle would probably require a demonstration plant, although considerable loop type verification work has already been performed.

The SIR (Safe Integral Reactor), being jointly developed by ABB-Combustion Engineering and Stone and Webster in the USA together with Rolls-Royce and the Atomic Energy Authority in the United Kingdom, is another example of an innovative approach to enhanced safety. The SIR also places all of the primary system components (core, pumps and steam generators) inside of a steel vessel.

With delays apparent in the large scale deployment of breeder reactors, mostly from cost considerations, improvement in uranium resource utilization has become another element in the evolutionary development of LWRs. Relatively limited changes in existing water reactors could provide attractive alternatives for such improved utilization strategies. These changes could range from plutonium recycling to new core designs specifically aimed at significant improvements in fuel utilization. Some of these approaches would have low economic risks and could be incorporated easily and rapidly. Confirmation of technical and economic feasibility and safety is expected shortly from validation studies and development work in progress in several countries, including the USA, Japan, Germany and, in particular, France. Many of these modifications, if proven satisfactory, could be applied to existing reactors within the next three to five years.

A2.2 HEAVY WATER COOLED REACTORS

Heavy water cooled (HWR) technology has also proven to be economic, safe and reliable. A mature infrastructure and regulatory base have been established in several countries, notably in Canada, the pioneer in the development of the HWR concept. Approximately 7% of all current operating plants are HWRs. Two types of commercial pressurized heavy water cooled reactor (PHWR) have been developed. Both the pressure tube and pressure vessel variants have been fully proven. Sizes in the output range of a few hundred MW(e) up to 900 MW(e) are available. Lifetime capacity factors of most of them have been among the best of all commercial reactor types. Safety performance has also proven very good. The promise of low fuelling costs arising from the inherent neutron economy of heavy water moderation has been demonstrated. This inherent neutron economy offers prospects for a wide range of fuel cycles including low enriched uranium, use of reprocessed uranium from LWRs (offering a synergism between LWRs and HWRs), plutonium recycle, and thorium high conversion cycles. Plutonium utilization in HWRs has been established in Japan. The others are being investigated.

The continuing design development programmes for HWRs in Canada are primarily aimed at reduction of plant costs and an evolutionary type of enhancement of plant performance and safety along lines similar to the LWR programme. These designs include the 480 MW(e) CANDU 3 and the 800 MW(e) CANDU 6 MK2. Also under development are the 500 MW(e) reactor in India and the 380 MW(e) ARGOS under joint development by an engineering firm in Argentina and Siemens in Germany. Work is also proceeding in Japan on 600 MW(e) and 1000 MW(e) ATRs, a heavy water moderated, boiling light water cooled, pressure tube reactor.

A2.3 GAS COOLED REACTORS

With the completion of the Heysham 2 and Torness stations in the United Kingdom, the Advanced Gas Cooled Reactor (AGR) programme, pioneered by the UK, appears to have come to an end. Further development work on this carbon dioxide cooled system will be concentrated on improvements in plant performance and life extension studies of existing plants.

The experience with the early High Temperature Gas Cooled Reactors (HTGRs), the Dragon in the United Kingdom, the AVR in Germany and Peach Bottom in the USA, was very satisfactory and proved the capability of several of the unique features of this type of system. The experience with the later HTGRs, Fort St. Vrain (330 MW(e)) in the USA and the THTR-300 (300 MW(e)) in Germany, has not been entirely satisfactory. The problems which resulted in the termination of operation of these plants were not related to the basic reactor concept of helium cooling, graphite neutron moderation or the use of graphite as a structural material, but were primarily related to first-of-a-kind systems and components. The development of the helium cooled reactor line is proceeding in the USA, Germany, the USSR and Japan. Most of the effort is concentrated on small modular designs with an individual power output capability of 80 MW(e) up to about 170 MW(e).

The motivation for the present effort comes almost entirely from a critical examination of the requirements evolving from the objective of enhanced safety for future nuclear plants. Satisfying these requirements formed the basis for the smaller power output of individual power-producing modules and the reactor core configuration of each module. Emphasis has also been placed on other modular features of the design with a maximum use of factory fabrication, as opposed to field construction, for better quality control and time and cost savings. Separation of the HTGR nuclear systems from the majority of the plant is intended to yield significant cost savings.

The key features of the HTGR which permit these characteristics are the benign helium coolant, the large mass of graphite moderator (hence, low power density) closely coupled to the fuel, the always negative power coefficient and, particularly, the fuel itself, which is in the form of small particles individually coated with multiple layers of ceramic material. This fuel is capable, along with the graphite moderator, of withstanding very high temperatures without losing integrity.

It is recognized that the unique features and characteristics of the modular HTGRs will likely require prototype demonstration prior to design certification and commercialization and hence programmes in the USA, Germany and the USSR are proceeding accordingly. With the relatively small size of each power-producing module, it is possible to contemplate such a demonstration with just one module with a later expansion into a multimodule plant at the same site for commercial purposes.

The HTGR programme in Japan, although recognizing the potential for higher quality steam production and higher efficiency electricity generation, is nevertheless aimed primarily in the direction of proving the capability for even higher core outlet temperatures for the helium coolant (up to 1000°C) with the view to a large number of industrial process heat applications. A small test reactor, the 30 MW HTTR, is presently being constructed in Japan for tests related to this objective.

A2.4 LIQUID METAL COOLED REACTORS

The deployment of liquid metal fast reactors (LMFR) as breeder reactors as well as for electricity generation has not gained the momentum expected, owing to the availability of adequate low cost uranium resources to meet near and mid-term demands. Nevertheless, there is an awareness in the industrialized countries that breeder reactors will be needed in the early decades of the next century particularly if nuclear power implementation regains momentum.

In the interim, experience continues to be gained from the more than 200 reactor-years to date of operating experience from experimental and medium size LMFR power units. The design development of advanced versions is also continuing, with due recognition of the requirements for the next generation of nuclear power plants. Work is also continuing on fuel cycle development with emphasis on extending fuel burnup and demonstrating fuel cycle closure. Most of the fuel cycle development is on mixed oxide, but recent developments in the USA on the use of ternary metallic (U-Pu-Zr) fuel and the associated pyroprocessing of spent fuel are showing promise. A notable feature of pyroprocessing is that the majority of the long lived actinide elements which accompany plutonium through the process are subsequently recycled and thereby removed from the waste stream.

Design development in Europe, Japan, the USSR and India is following the traditional path of considering large designs fuelled with mixed oxides. In Europe and in the USSR, 1500-1600 MW(e) units are being developed with component design, plant design and fuel cycle following an evolutionary pattern from the operation of the Phénix and Superphénix in France, the PFR in the UK and the BN-350 and BN-600 in the USSR. Major efforts are under way at this time to make better use of the philosophy of passive safety in these designs. One example is the European Fast Reactor (EFR) design, which includes a passive decay heat removal system via air coolers.

The efforts in Japan and India are concentrated on smaller units as the next step in design evolution. With the 280 MW(e) MONJU prototype reactor expected to go critical in 1992, Japan's next step is the development of a loop type demonstration reactor. India is proceeding from its Fast Breeder Test Reactor (FBTR) with the follow-on design of a 500 MW(e) pool type prototype (PFBR).

With the demise of the Clinch River Breeder Reactor (CRBR) in the early 1980s, the liquid metal reactor programme in the USA initially proceeded down many advanced design avenues. The main thrust of the programme is now on a modular type concept, PRISM, developed by the General Electric Company. Each power block of the proposed system is comprised of three 471 MW(th) reactor modules connected to a single 465 MW(e) turbine generator. The plant has many innovative characteristics, including the use of the ternary metallic fuel cycle, inherent reactor shutdown by thermal and reactivity response, passive decay heat removal, and other construction and operational type characteristics claimed for such modular concepts. The programme is proceeding with the conceptual design, pre-licensing stage on this concept with the intent of obtaining design certification following extensive testing of a full scale prototype module.

APPENDIX II

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APPENDIX 5

Background paper for
document GOV/2541

Item 6(a) if the provisional
agenda (GOV/2537)

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

Vienna, Austria

2-6 September 1991

BACKGROUND PAPER

FOR

ISSUE NO. V

FINAL DISPOSAL OF RADIOACTIVE WASTE

INTERNATIONAL CONFERENCE ON THE SAFETY OF NUCLEAR POWER: STRATEGY FOR THE FUTURE

ISSUE NO. V

FINAL DISPOSAL OF RADIOACTIVE WASTE

SIGNIFICANT TOPICS TO BE ADDRESSED AT THE CONFERENCE

Based on comments received to the Background Paper for Issue No. V, together with discussions in the Steering Committee, the following topics are recommended for inclusion in the discussion on Issue No. V. For each topic, there may be actions identified to be taken, by utilities, regulators, Member States, and international bodies, including the IAEA.

For each topic recommended for discussion, some comments are provided both to facilitate an understanding of the issues and to assist the reader with preparations for the discussion sessions at the conference.

Topic No. 1

How should the developed strategy for the final disposal of radioactive waste be implemented?

As in many other practices (e.g. the chemical industry) the production of nuclear energy gives rise to waste products. The general approach taken in the nuclear energy field is to finally dispose of the wastes after appropriate conditioning and packaging. Near surface repositories for low and intermediate level radioactive wastes have been in operation for many decades. For high level waste (HWL) the final disposal has not yet been achieved in any country. There are however ongoing programmes in many countries with a nuclear programme aiming at disposal of HLW at the beginning of the next century.

The collective opinion of experts in waste disposal is that the long term safety of waste disposal can be adequately evaluated by methods available today. Also, there seems to be no impediment from a scientific and technological point of view to proceeding with ongoing programmes.

There are however in some countries discussions on extended storage, human intrusion, retrievability of waste after sealing of a repository etc. New techniques are also discussed, e.g. transmutation of long lived nuclides to shorter lived products by irradiation in specially designed facilities (reactors or accelerators).

One important aspect in the achievement of waste disposal is the public involvement and public acceptance.

Topic No. 2

What role should the regulatory body have in relation to the implementing organization with regard to the programme for disposal of HLW?

According to national legislation in the field of nuclear power and nuclear waste, the role of the body responsible for regulation and licensing is to give guidance to the organization responsible for waste disposal (the implementor) on the regulatory procedures to be followed. No experience exists in the development of deep geological repositories. Especially in the early stages (site selection and site investigations) the regulatory requirements seem to be vague.

The implementor must have guidance during the long period of time needed for site selection, site investigation and repository design that precedes a licence application. Because of lack of experience it is premature for a regulator to define detailed criteria. An alternative strategy could be an iterative approach, where regulators assess the R&D activities and performance assessment studies periodically performed by the implementor. Guidance on future licensing could then be given.

One important aspect in the realization of a final repository is the involvement and acceptance of the public. The implementor and the regulator have different roles in the achievement of a repository. The implementor is an advocate for the repository while the regulator should be seen only as a promoter of safety. If the regulator is seen as a promoter of the repository his/her credibility could be destroyed.

An enhanced dialogue between regulators to develop and harmonize safety approaches in different countries could be valuable. Such dialogue between implementors is also needed but such co-operation under the auspices of international organizations already exists, while there is still a need to strengthen co-operation between regulators.

Topic No. 3

International co-operation, how can it help? What should be the role of the IAEA?

International co-operation in nuclear power and nuclear waste is long established through international organizations such as the IAEA, OECD/NEA and CEC. There are many good reasons for that. The safety aspects of repositories for HLW cover a very long time-scale for which national borders may no longer have a meaning. It is obvious that co-operation in science and technology for the development of repository systems will be beneficial. It is also a great advantage if the development of criteria, safety standards and performance assessment methods can be performed in an international framework to achieve harmonization in regulatory requirements between countries. The work on geological disposal is being actively co-ordinated between the international organizations, e.g. by IAEA and CEC representation on the OECD/NEA Committee on Radioactive Waste (RWMC) and by OECD/NEA and CEC representation on the IAEA International Waste Management Committee (INWAC).

A relatively new IAEA programme (RADWASS, Radioactive Waste Management Safety Standards) has as its goal the development of a comprehensive set of waste management standards applicable to handling and disposal of all radioactive wastes, contributing to the international harmonization in Member States.

The role of the IAEA regarding the benefits of international co-operation and in relation to the OECD/NEA and CEC could be further discussed to define a proper international structure for co-operation in the sphere of nuclear waste disposal.

BACKGROUND PAPER NO. V

FINAL DISPOSAL OF RADIOACTIVE WASTE

FOREWORD

GENERAL BACKGROUND

Today there are about 425 nuclear power plants operating throughout the world in both industrialized and developing countries, supplying 17% of the world's electricity needs. Four countries obtain more than half of their electricity from nuclear energy, while 13 countries obtain at least 20% of their electricity from this source.

During the accummulated 5600 reactor-years of operation the safety record of nuclear power has been marred by two accidents of particular concern, Three Mile Island in 1979 (with small public consequences) and Chernobyl in 1986 (with large public consequences). Mainly as a result, the risk and possible local effects associated with nuclear energy are perceived by some in government and in the public as being too great for nuclear energy to be accepted as a viable means of resolving the health and environmental effects caused by the other means of generating electricity, particularly the burning of fossil fuels.

The UN World Commission on Environment and Development (Our Common Future) indicated a number of specific items related to the use of nuclear energy that require international agreement including regulatory activities, standards (for operation, radiation protection, waste repositories, and decommissioning), operator training, site selection criteria, emergency response training, reporting, etc.

The Conference on the Changing Atmosphere: Implications for Global Security held in Toronto, Canada, in 1988, concluded that "If the problems of safety, waste and nuclear arms can be solved, nuclear power could have a role to play in lowering CO_2 emissions".

To help resolve these concerns the holding of an International Conference on nuclear safety was suggested and encouraged by European Community countries through the IAEA Board of Governors during the spring of 1990 and presented to the IAEA General Conference in September 1990. The General Conference in its Resolution 529 welcomed the holding of the conference, with certain financial stipulations.

CONFERENCE OBJECTIVE

The Conference is directed to decision makers on nuclear safety and energy policy at the technical policy level. Its objective is to review the nuclear power safety issues on which international consensus would be desirable, to address the concerns on nuclear safety expressed by the UN World Commission on Environment and Development, and to formulate recommendations for future actions by national and International authorities to advance nuclear safety to the highest level including proposals for the IAEA's future activities for consideration by its governing bodies.

The conclusions of this Conference, addressing safety issues only, will complement the conclusions of the Senior Expert Symposium on Electricity and the Environment held in Helsinki, Finland, May 1991 which address the comparative health and environmental effects of the various alternative means of producing electricity.

The conclusions of the Conference will also form part of the IAEA's contribution to the 1992 UN Conference on Environment and Development.

The Conference should promote more effective international co-operation between IAEA Member States on the safety of nuclear energy.

The particular issues selected for consideration by the Conference are:

(i) Fundamental principles for the safe use of nuclear power;
(ii) Ensuring and enhancing safety of operating plants;
(iii) Treatment of nuclear power plants built to earlier safety standards;
(iv) The next generation of nuclear power plants;
(v) The final disposal of radioactive waste.

For each of these issues the present status, present and foreseeable problems, recommendations for future actions required to deal with these problems at both the national and international levels, and recommendations for the role of the IAEA in these activities are outlined.

This Background Paper deals with the subject of "The Final Disposal of Radioactive Waste".

TABLE OF CONTENTS

1. RATIONALE FOR THIS PAPER

Nuclear fission is an established technology that has been used for several decades, not only in electric energy production, but also to produce radioactive materials for use in medicine, research and industry. During this time, radioactive waste of different categories has been produced. The quantity of radioactive waste, which is dominated by waste from the nuclear fuel cycle, is expected to increase as a result of nuclear energy's continuing development and nuclear reactor plant decommissioning. Compared to the quantity of chemically toxic wastes produced by other technologies, the volumes of radioactive waste to be disposed of are only a very small fraction of the volume of toxic waste. Disposal of both types of wastes may require isolation over very long periods of time, as in the case of chemical waste having permanent toxicity, such as heavy metals, or as in the case of long lived radioactive waste and spent nuclear fuel.

It is a matter of international consensus that countries using nuclear energy should make adequate provisions for the disposal of the resulting waste arisings. Even though safe interim storage strategies are available and provide flexibility in action, it is deemed reasonable that provisions for disposal should be made by the present generation, which benefits directly from the exploitation of nuclear energy. It should bear the associated burden, notably to make available and finance appropriate solutions for safe disposal of the waste.

However, a significant mismatch exists between these principles and the present situation. While the disposal of low level radioactive waste is being practised at an industrial scale in some countries, programmes for disposal of long lived, highly radioactive waste are continuously delayed, increasing the financial burden, and, paradoxically, raising doubts about the possibility of achieving solutions.

A gap exists between the confidence which most waste management specialists have in disposal technologies and the impressions of the general public that waste disposal presents unacceptable hazards and environmental risks. Reasons for this situation are found in the understandable apprehensions of the public about the effects of ionizing radiation associated with the peaceful use of nuclear energy. These apprehensions are aggravated in the case of long lived waste disposal by the fact that some of the radioactivity contained in the waste will last for extremely long periods of time for which it is impossible to provide absolute proof of repository performance. This is perceived as a danger which cannot be mastered, putting at risk not only the present generation, but also generations to come. These apprehensions are also caused by a lack of perspective in judging radiation risks compared to others, such as those arising from chemically toxic wastes, which present similar hazards. The contamination of large areas by the waste arising from pioneering facilities, most of them military, during the early years of nuclear energy development, and the possible need for long and costly environmental restoration programmes, give support to these views. A typical product of such a sociological situation is the "not in my backyard" syndrome, i.e. an a priori refusal of disposal in one's own region, neighbouring regions always being better. The selection of a site, even for research purposes, appears nowadays, in most cases, to be a focus for opposition in the decision making process intended to lead to the fulfilment of the principles described above.

The consensus of experts in the field, worldwide, that feasible and safe options for disposal do exist - notably disposal in deep geological repositories - has not alleviated these fears, at least up to now. The confidence which experts have in their ability to dispose safely of radioactive wastes is based on the large amount of knowledge and experience gained during recent decades as the result of national and international research and development programmes. This confidence is also based on an improved understanding of the safety requirements of radioactive waste management. The task, as the specialists see it, is now to properly select disposal sites and construct disposal systems to isolate the wastes until any releases which may eventually occur are within internationally agreed safe levels that are a small fraction of the natural background radiation that already exists in the environment. Since many natural systems exist around the world which have isolated uranium and thorium and their daughters for millions of years, such isolation is considered to be scientifically achievable and demonstrable for a number of key radionuclides.

The expert group for this Background Paper has identified a number of technical and scientific issues that need to be addressed, in order that the goal of safe isolation can be achieved. It has also pointed out a number of areas where regulatory developments, decisions and guidance are needed in order that waste disposal programmes can proceed. Finally, it has considered the area of public understanding and perception of waste disposal issues and has made some suggestions for bridging the gap between the waste disposal specialists and the public.

This paper gives a brief description of the disposal options currently being followed worldwide, concentrating on high level waste, spent fuel, and long lived waste. It then discusses issues that the expert group has identified as requiring further consideration and agreement to enhance the progress of national radioactive waste disposal programmes. The paper makes recommendations in specific areas, identified in three categories: scientific and technical, regulatory matters, and public acceptance. It brings to the attention of the conference the need for a lead to be given in the political arena to permit national waste disposal agencies to realize established goals. International co-operation and peer review between agencies, regulators and researchers are seen as a valuable means of achieving this objective.

2. PRESENT STATUS OF WASTE DISPOSAL

2.1 FUEL CYCLE OPTIONS AND WASTE DISPOSAL

Fuel Cycle Options

Various options are available to countries having nuclear power programmes for management of the spent fuel from nuclear power plants. These options lead naturally to radioactive waste arisings which differ for each fuel cycle in nature, volume, and radioactivity content, with differing consequences for their safe management and disposal.

Two principal options are being developed and/or implemented:

a) The spent fuel itself can be disposed of as waste, after a suitable period of storage for radioactive decay (usually a few decades). The high levels of heat and radiation and the presence of long lived transuranic (TRU) radionuclides and fission products in the spent fuel dictate that measures such as deep geological disposal are required for safe isolation.

Such a "once-through cycle" for nuclear fuels does not produce significant secondary waste streams. Spent fuel requires special consideration in the design of an underground repository because it generates heat for long periods of time and safeguards measures are required to prevent the diversion of fissile material.

b) Alternatively, the spent fuel can be chemically reprocessed to recover plutonium and uranium for recycle; the high level liquid waste remaining after the reprocessing operation contains transuranic elements and fission products that are highly radioactive, long lived and heat generating. They must be conditioned for disposal by encapsulation in a solid matrix. Industrial vitrification facilities for this purpose are already in operation in some countries. As with spent fuel, conditioned high level waste must be disposed of by a method such as deep geological disposal providing long term isolation. In addition, secondary waste streams are created, notably transuranic wastes (also called TRU or alpha bearing waste) which are contaminated with enough long lived alpha emitters to make surface disposal unacceptable.

A variation of the reprocessing option is receiving increased attention recently. It considers partitioning the high level liquid waste from reprocessing to remove long lived products for transmutation into shorter lived products by irradiation in specially designed facilities (reactors or accelerators). This has the potential to reduce the quantity of certain long lived products to be disposed of, with possible benefits for the safety of disposal and public acceptance of waste disposal. However, the additional separation steps and irradiation facilities may result in larger volumes of TRU and low level radioactive wastes, together with some additional occupational exposure and discharges to the environment.

The feasibility of this option and the net gain in terms of radiation protection has not yet been demonstrated and is currently the subject of scientific research in some countries, and the issue has been proposed as a subject for international co-operation through the NEA.

All these options require their specific waste arisings to be disposed of. All of them produce low level (LLW) and intermediate level (ILW) waste in various quantities directly or through the associated nuclear facilities, notably the nuclear power plants. LLW contains primarily short lived radioactive materials and only small amounts of long lived radionuclides, and is also produced in industry, medicine and research. ILW contains lower levels of radioactivity and heat content than HLW, but must be shielded during handling and transport.

The general requirement to dispose of the waste does not demand that it be done immediately; this would be technically unsound in the case of spent fuel and high level waste, owing to the intense heat and radiation they emit initially. In addition, countries may prefer to store the waste for an interim period of several decades or more for short term economic, social or other reasons. Interim storage for an extended period is only a temporary measure that allows flexibility in managing spent fuel and high level waste, but is not a substitute for final disposal.

Waste Disposal

Terrestrial repositories for radioactive wastes can broadly be categorized into two groups:

- near surface disposal facilities;
- geological disposal facilities.

The first group is suitable for disposal of LLW and short lived ILW only. The second group is suitable in principle for all waste, and especially required for disposal of long lived ILW, HLW, TRU wastes and spent fuel.

Ocean disposal of radioactive wastes is another technical option, with the following two alternatives:

- sea disposal of packaged wastes;
- deep seabed disposal using penetrators or drilling techniques.

An OECD/NEA Working Group concluded in 1988 that sub-seabed burial of HLW was technically feasible, but added that its long term safety assessment required further research to reduce the uncertainties before the option is used.

Although scientific studies have concluded that sea disposal is safe, sea disposal of radioactive wastes has not been practised since 1983, owing to a non-binding moratorium agreed to by members of the London Dumping Convention. This situation is not likely to change in the foreseeable future. Sea disposal is not considered further in this Background Paper.

In addition very advanced options have been considered such as space disposal; however, the feasibility of safety of such an option is questionable, on the basis of the present state of technology.

2.2 CONCEPTS AND PRINCIPLES OF WASTE DISPOSAL

A radioactive waste repository is a disposal system the objective of which is to isolate the radioactive substances it contains from the human environment (that is, the biosphere) sufficiently well that releases, during the period when a significant hazard remains, are within acceptable levels. The isolation provided by the disposal system must be effective in any plausible situation and without any human intervention (control, maintenance) beyond some pre-established control period.

The isolation capability of the repository depends on a system of barriers between the radioactive wastes and the biosphere for deep geological disposal. For deep geological disposal, it is usual to distinguish three components of the waste disposal system:

- The waste package, which safely contains the wastes during handling and emplacement and assures the protection of the radioactive materials against leaching by groundwater during a limited period. The radioactive substances to be disposed of must be in a solid form of themselves or made so by means of a solidification process;

- Other engineered barriers, which fill the voids after the emplacement of the waste packages and reduce the hydraulic or mechanical perturbation of the geosphere, and can both delay contact of groundwater with the waste packages and retard migration of radionuclides released from waste packages;

- The geological barrier, which consists of the host rock and surrounding strata.

The selection and design of the barriers must permit the disposal system to play a dual role:

- to delay the release of the radioactivity which is contained in the waste and minimize the possibility of occurrence of human intrusions;

- to retard the transfer of the released radionuclides to the biosphere for a period long enough and to keep the amounts low enough to allow radiological risk to remain within acceptable levels.

The multibarrier concept ensures that the safety of the disposal system does not depend on only a single barrier, but on a combination of them. The barriers play complementary roles, the relative importance of which depends on the geological medium and disposal system design. Usually, the geological barrier provides the final protection in the long term.

The quality of the system of engineered and natural barriers is the basis for the safety of the repository. The demonstration of adequate safety must rely on this quality.

General principles and qualitative objectives for the selection, design and realization of these barriers have been defined for underground disposal of high level radioactive wastes, by national as well as international organizations, for instance in IAEA Safety Series No. 99. There is a general consensus on these principles and qualitative objectives. Quantitative objectives for the performance of the individual barriers depend on the type of repository, are generally site specific, and thus cannot be proposed in a general way. Each barrier must be selected (natural) or designed (engineered) to contribute effectively to the overall waste isolation system. Demonstration that the performance of the system of engineered and natural barriers is sufficient, in order to have an acceptable radiological impact, is to be obtained through safety assessment using site specific data.

Overall repository performance criteria for long term radiological protection are available and have been agreed to internationally (e.g. IAEA Safety Series No. 99). Problems may arise in their practical implementation, and there is a need for agreement on how to interpret the period of time for which it is necessary to demonstrate that the basic radiation protection criteria are met.

A concept that is often raised in connection with siting, design and closure of final repositories is whether to provide for future retrieval. Retrievability may affect safety and safeguards requirements for a repository. The concept and issues related to it are discussed further in Section 4.

2.3 *STATUS OF WASTE DISPOSAL PROGRAMMES*

Countries involved in nuclear power activities have been carrying on radioactive waste disposal programmes for many years.

For disposal of low and intermediate level radioactive wastes, near surface repositories have been operating for several decades, for example in France, the United Kingdom, the Union of Soviet Socialist Republics and the United States of America. The experience gained has permitted significant technological progress to correct problems experienced with shallow land burial in the early years of nuclear programmes. Improved disposal techniques for the protection of man and environment are now practised in many countries. These techniques involve, for instance, the construction of concrete structures placed in trenches excavated into the surface geology. The structures are then filled with conditioned waste and backfilled with an engineered barrier such as cement. When full, the structures are covered by a further impermeable cover. Institutional control is foreseen during a period corresponding to the decay of the buried radioactive materials, that is, a few centuries. During this period, various drainage systems are usually employed for the management of rainwater runoff from the site. In some cases, improved shallow land burial is practised with greater care given to site selection, conditioning and packaging of the radioactive wastes, operation of the facilities, and the allowable amounts of long lived radionuclides, in order to achieve greater protection.

Geological disposal is a concept for isolation of waste at a much greater depth than near surface. For LLW and ILW, examples of geological repositories are the Swedish SFR repository in a mined rock cavity at Forsmark, which began operation in 1988, the Konrad facility for non-heat-emitting waste in Germany, which is almost complete but has not yet been approved for operation, and the Morsleben facility in Germany.

It is generally recognized that the necessary degree of long term isolation, for wastes containing significant amounts of long lived radioactivity, is best obtained in deep geological repositories. Repository concepts are currently being developed, including technologies for construction and sealing. The national disposal programmes are thus focused on research, development, demonstration and safety evaluation activities on deep geological disposal of long lived and high level waste (TRU, HLW, spent fuel). This waste poses a special challenge owing to its toxicity, the significant heat it generates by radioactive decay, the high levels of radiation it emits, and the long periods of isolation it requires.

National and international programmes (IAEA, CEC, NEA) have investigated, among others, the following considerations regarding geological repositories and their host environment:

- The feasibility of a geological confinement system. The knowledge acquired over the past 20 years has covered rock mechanics, geochemistry, geology and hydrogeology, mining engineering, repository design, instrumentation and backfilling of shafts and galleries. Various geological media (e.g. salt, crystalline rocks, clays, schist and tuff) and designs have been investigated by means of laboratory experiments, in situ drilling of boreholes and use of abandoned mine galleries. The old iron mine of Stripa (Sweden), which was the first international underground research laboratory, is an example of the use of an abandoned mine.

- The confinement properties of the various components of the repository system itself. The leaching of the waste by underground water and the resulting migration of radionuclides through the various barriers (waste container, surrounding engineered barriers, and host rock) have been extensively studied. Full scale experiments with radioactive products are limited for safety reasons. Therefore, numerous and sophisticated experiments have been performed in the laboratory with representative groundwaters and materials, including studies of colloids and complexes which may serve as vehicles for the radionuclides to pass through the geological barrier.

Field and laboratory studies have the difficulty that they can be conducted only for time periods which are short compared to the time-scales required for the containment of HLW in the repository. However, materials and processes analogous to those expected in a repository exist in nature. Examples are uranium or thorium deposits (Cigar Lake, Canada; Alligator River, Australia; Pocos de Caldas, Brazil), fossil reactors (Oklo, Gabon), and fossil forests (Dunarobba, Italy). These "natural analogues" are extensively studied, mostly in international co-operation (CEC, OECD/NEA), as a useful way of obtaining evidence of the cumulative effects of the migration of radionuclides over tens of thousands of years or longer. The comparison of "natural analogues", together with the results of laboratory studies, improves understanding of isolation related processes and confidence in the capability of models to assess performance of geological repositories.

A very important task, being performed at national and international levels, is to assess the performance of a disposal facility in relation to safety and acceptability criteria using pertinent information from field and laboratory studies. Since long term performance cannot be demonstrated directly (time periods covering tens of thousands of years being involved), indirect methods have been developed, by the use of mathematical models which describe disposal systems and simulate physical and chemical processes of importance for predicting the behaviour of the repository over long time periods. Models for such purposes must be verified for numerical accuracy and validated, to the extent feasible, for their ability to predict physical processes correctly. The validation of such models is carried out by comparing the results of the predictive analysis with laboratory and field observations and measurements (underground laboratories, natural analogues). Several models are at present available for performance assessment of waste disposal facilities. Progress in performance assessment was discussed at an international symposium in Paris sponsored by the IAEA, OECD/NEA and CEC in 1989.

Safety evaluation projects, carried out at national level during the last ten years (e.g. the KBS project in Sweden, and the Gewähr project in Switzerland) or international level (the PAGIS project in the European Community) have all concluded that the radioactivity released from an appropriately designed repository at a properly selected site would not reach the biosphere for at least several thousand years, and would remain much below the level which would attract regulatory concern or below the natural background radiation level.

It is stressed that site specific investigations (surface and underground) and underground laboratories, especially built for this purpose, are the most important tools to obtain the data needed to assess the suitability of a particular site for deep geological disposal. There is a need to directly verify laboratory results and in situ results obtained from either surface, borehole, or abandoned mine investigations with systematic observations from shafts and tunnels down to the depth of and in a similar host rock to that of a final repository, in previously undisturbed areas. Underground laboratories are in operation in some countries like Switzerland and Canada (granite), Belgium (clay), and Germany (salt). Several of them are the subject of some bilateral or multinational co-operation. International organizations (IAEA, CEC, OECD/NEA) are very active in this field with a view to promote co-operation and consensus. For example the Belgian and German facilities are within the framework of the CEC programme. Others are under construction or foreseen (Sweden, France). In addition, Germany is developing a full scale, industrial, deep repository in a salt dome at Gorleben. The USA is preparing to characterize a site in tuff to determine its suitability as a repository (Yucca Mountain, Nevada). Other countries have plans to build industrial repositories in the next 15 to 50 years.

The choice of when to begin operation of a repository for disposal of spent fuel or conditioned high level radioactive waste is a matter of national policy and economics. There are benefits to storing the wastes to take advantage of radioactive decay and decreasing heat generation rates with time. Improved technologies may also become available or spent fuel now considered waste may in the future be considered a resource. If a government decides to adopt a strategy to delay disposal, safe interim storage technology for spent fuel and conditioned high level waste is available. However, it is only an interim measure that allows governments flexibility in implementing the most efficient national strategy to achieve final disposal.

2.4 INTERNATIONAL CO-OPERATION

Nuclear waste disposal is clearly of relevance to all countries with nuclear power programmes. It is also a complex field with many technical and political aspects and with extensive research and development programmes. For these reasons, it is an area with intensive international co-operation at various levels. The international organizations IAEA, CEC, and OECD/NEA provide suitable forums for discussions of common areas of concern and for reaching international consensus on particular issues. (Reference "On International Collective Opinion" - Paris 1991). One important area for international co-operation is that of standards and criteria for disposal. Recommendations from the International Commission on Radiological Protection (ICRP), as further developed by the IAEA and OECD/NEA and others, serve as guidelines for radiation protection criteria in most countries. Recent achievements in the development of methodologies for safety assessments have been promoted by international organizations, in particular within the OECD/NEA and CEC. The programmes of the IAEA, CEC and OECD/NEA have important roles in promoting co-operation between countries for the co-ordination of research in a number of fields.

Several of the issues related to the scientific basis for demonstrating safety, and described in Section 4.2, require the use of different experimental and modelling approaches. Within these research areas, international co-operation has been shown to be especially fruitful and effective. Such co-operative projects are under way within the OECD/NEA, CEC and the IAEA but also as multinational projects set up by special agreements.

3. ISSUES RELATED TO WASTE DISPOSAL

Extensive radioactive waste disposal programmes performed by all interested countries with the support of international organizations have led to the conclusion that it is technically feasible to safely dispose of high level waste in a geological repository. However, the development of these repositories still faces three types of issues:

a) Issues of a scientific or technical nature, which require detailed site specific data from real sites for their resolution.

b) Issues involving regulatory matters.

(c) Public perception, which can delay the necessary site investigations for the improvement and qualification of repository technology and safety assessment methods.

This section reviews and prioritizes these issues and Section 4 makes recommendations for future actions to address them within a framework of international co-operation.

3.1 SCIENTIFIC AND TECHNICAL ISSUES

General

All studies and reviews have pointed out that a key step in disposal programmes is to perform site specific studies and to obtain site specific data. Only in this way can it be confirmed that the options chosen, the generic data used, and the assumptions made in feasibility studies, will be valid for real repositories.

The Scientific Basis for Performance Assessment

The acceptability of a proposed repository at a specific site to licensing authorities, as well as to the general public, depends on the confidence they have in its predicted long term behaviour. In the safety evaluation, the complex system with the waste matrix, engineered barriers and movement of groundwater and radionuclides in the geosphere, as well as the transport and dilution of the nuclides in the biosphere, is described by mathematical models. The process of deriving the scenarios and the basic concepts for the models, performing the calculations and evaluating the results against safety standards, is called performance assessment.

During recent years the methodologies for performance assessment have been greatly developed and there is now international consensus that these methodologies, coupled with sufficient information from proposed disposal sites, are suitable for evaluation of repository safety. However, further development of models is still justified in some areas because better modelling could clarify or reduce uncertainties associated with assessment results. It could also contribute to further improvements in disposal system designs. However, in order to improve the models, to be able to conduct performance assessments for a particular site, it is necessary to obtain site specific data at the proposed repository depth.

An important area is validation of models for groundwater flow and radionuclide release and transport in the geosphere. Experimental data on different scales, including laboratory experiments and natural analogues, can play an important role. This validation of the applicability of these models to a particular site cannot be concluded without site specific information.

Application of Criteria

Considerable progress has been made in the development of systematic procedures for the identification of scenarios to be used in performance assessment. However, practical problems may arise when applying the procedures in particular performance assessments. The radiological safety principles formulated in IAEA Safety Series No. 99 use individual dose and risk criteria intended to apply, respectively, to the expected evolution of the system, characterized by a gradual release from the repository, and to exceptional situations, for which releases result from hypothetical disruptive processes. The probabilities of occurrence of some of these disruptive scenarios can be estimated, but others cannot. The requirement to assess these two different possible situations reflects the intention to consider the range of possible radiological consequences of a repository, knowing that events far in the future can never be predicted in absolute terms.

To overcome the difficulties associated with assessing performance over very long times, various approaches, including complementary safety standards, have been suggested and discussed. For example, it has been proposed to introduce calculated activity inflow to the biosphere from the repository as a complementary criterion.

Another approach to the problem of setting long term performance criteria and showing compliance with them is to use the established standards, recognizing that accurate predictions cannot be made for time-scales in the order of thousands of years, then to use the outcome in terms of calculated dose for different scenarios as performance indicators. By variation of the scenarios evaluated, it is expected to cover the actual future evolution of the repository system within the envelope of calculated scenarios.

To address our limited ability to predict future developments in geological processes and in human practices, a "time cut-off" is another approach that has been proposed. Up to this time limit, a quantitative demonstration would be necessary that the dose standards are being met. After this time limit only a qualitative approach would be required.

The limitations in our ability to make long term predictions are especially evident for the biosphere, notably because of uncertainties in human behaviour. To take this into account, the use of a set of "reference biospheres" for the calculation of individual doses from activity releases from the geosphere is being discussed at an international level. Various efforts are under way by international (IAEA, OECD/NEA), regional (Nordic countries) and national organizations to obtain consensus on these issues.

Human Intrusion

Should records of the repository be lost, breaches of the geosphere surrounding a repository, whether deliberate or not, can be considered as human intrusion. The radiological risks associated with such intrusion are being considered as part of the repository safety assessments of many countries. However, there is considerable uncertainty associated with the prediction of future human activity and it is an area for further research and development of ideas. Working parties have been set up to reach international consensus on scenarios and their probabilities.

3.2 REGULATORY ISSUES

Legal and regulatory frameworks for nuclear safety and radiological protection exist in all countries having nuclear power programmes. Countries having a programme to dispose of radioactive waste have defined the basis for the licensing process which they intend to use for repositories. For deep geological repositories, developments are currently under way in several countries to define more detailed safety criteria. Because deep geological disposal has not yet been established, it is difficult for:

(i) the applicant to propose quantified performance objectives for the various systems of a repository, including barriers; and

(ii) the regulatory bodies to fix detailed and quantitative safety standards for these systems.

Developers and regulators need to communicate in the development of these criteria.

Many forums exist for repository developers to exchange technical information on their programmes. On the other hand, discussions at an international level between regulatory bodies should also be conducted. These would be of benefit to the process of defining the bases for national safety assessment and should also permit closer proximity in regulatory approaches between countries and thereby facilitate public acceptance.

Areas for exchanges between national regulatory bodies include the following:

(i) definition of steps in the licensing process starting very early in the programme: for example, site preselection, site selection, beginning of operation (partial or global), closure (partial or global), monitoring;

(ii) identifying the nature of the safety studies required at each step of the licensing process and the way of managing uncertainties at each step;

(iii) determination of scenarios to be taken into account in the safety studies provided at the different steps of the licensing process; providing adjustments of the scenarios as a function of reduction of uncertainties;

(iv) determination of the methodology and its implementation within the applicant's safety demonstration at each step of the licensing process (e.g. time cut-off, deterministic-probabilistic approaches);

(v) necessity and extent of cross-comparisons of applicant studies with independent studies using independent methods;

(vi) role of regulatory bodies in assessing R&D programmes carried out by the applicant in support of its safety demonstration.

There is a large volume of material with very low content of radionuclides that can be safely disposed of outside the regulatory framework for radioactive waste. While radiological principles for exemption of such material from regulatory control have been published by the IAEA and OECD/NEA, numerical exemption levels remain to be developed for different groups of radionuclides, depending upon their radiotoxicity. These levels should be based on international benchmark exercises on the evaluation of radiological impacts associated with a sufficiently large number of scenarios describing representative ways for the release of waste to the biosphere. The methods of controlling compliance of waste with the proposed "exemption" levels should be addressed together with the justification of these levels. These levels should be established in sufficient time to allow countries to consider them in planning for decommissioning of the present generation of nuclear fuel cycle facilities that will reach the end of their design life early in the next century.

Retrievability

Deliberate retrieval of waste from a sealed repository could be considered in the future for three reasons: 1) because improved disposal technology may become available in the future; 2) because of unexpected poor repository performance; or 3) to use today's waste as a resource for other operations in the future. In any case, retrievability would be practical only if adequate measures are foreseen at the stage of the design of the repository. These measures, however, may compromise the integrity and safety of the repository and oppose safety oriented natural phenomena like the sealing of cavities by creep of salt or clay, or measures like the sealing of tunnels by engineered barriers. In each case retrieval would involve increased radiological exposure both during the retrieval operation and the subsequent handling of the waste material. For all of these reasons, retrieval of wastes from a sealed repository is to be avoided.

Safeguards

Direct disposal of spent fuel and wastes containing large quantities of fissile materials (uranium and plutonium) may lead to a safeguards issue, notably in relation to deliberate human intrusion into a repository. The requirements regarding safeguarding nuclear material in a repository are not yet defined by the competent international bodies. Consequently, the safety implications deriving from necessary safeguards measures for the layout of a repository and its operational and post-operational phases cannot be sufficiently evaluated at present.

3.3 PUBLIC ACCEPTANCE

Public reaction to the siting of a radioactive waste repository or underground research facility is another major obstacle to gaining information needed for repository development. In some cases, the public demands that further research be carried out on waste disposal, but then attempts to deny access to individual sites for research purposes. This often manifests itself as a political difficulty in obtaining the necessary authorizations to begin site investigations. This can induce long delays to development programmes and in extreme cases it can involve direct action to prevent work being carried out.

It is felt that the reaction by the public is due partly to a misunderstanding of the mature status of waste disposal philosophy and research and the high standards of safe performance demanded by regulatory bodies. This lack of understanding is in some cases due to poor communication on the part of repository developers regarding their programmes and active communication by repository opponents. The public's concerns are often misunderstood by the repository developers as well. The public may contribute to a sharper focusing on safety aspects of the repository.

Some agencies have overcome public opposition by giving assurances that research at particular sites will not lead to that site being used as the final repository. This was so at the Stripa iron ore mine in Sweden and the Underground Research Laboratory in Canada.

4. RECOMMENDATIONS

The expert group has identified three types of issues: scientific and technical, regulatory, and public acceptance. Consideration of the foregoing illustrates that these problems are interrelated, e.g. lack of public acceptance makes it impossible to conduct site investigations that are needed to resolve the technical issues that would satisfy the regulatory agencies and resolve public concerns about safety. These interrelationships make resolving these problems more complicated and need to be taken into account in adopting strategies for problem resolution.

Based on the above identification of issues, the expert group has a number of recommendations for strategic actions that should be taken by Member States and international organizations.

4.1 SCIENTIFIC AND TECHNICAL RECOMMENDATIONS

(i) Site Selection and Investigation

Within the regulatory process the applicant has to demonstrate that the safety requirements are met in the operational and the post-operational phase of the repository. This demonstration must be performed for the particular site intended for development, making use of the results of the site specific investigation programme, including in situ tests at repository depth.

Safety assessment cannot be achieved without site specific data. Confinement properties of barriers and the radiological impact of a repository depend on site specific data (e.g. geochemical and hydrogeological data). The type and features of the scenarios to be evaluated in safety assessments are dependent on site characteristics. Therefore, site specific investigations are needed for efficient progress in research and safety assessment. All these reasons have led the expert group to recommend that unnecessary delays in site selection programmes should be avoided. It is a matter of national strategy whether to investigate one or more sites for site selection purposes, but this strategy is for the purpose of selecting an acceptable site in a timely fashion, not the "best" site.

(ii) Repository Construction and Sealing

Technologies for the design, construction, operation and sealing of repositories must be demonstrated, taking into account (1) potential negative effects on the geological barrier that could come from repository construction and waste emplacement, and (2) the need for effective sealing of boreholes, excavations and shafts that can be assured over very long times.

(iii) Validation of Safety Assessment Models

The ability of models used in safety assessments to describe actual processes in real repository systems (e.g. the movement of groundwater and radionuclides) in the geosphere, in many cases, needs to be further validated. This can be done with a more systematic and comprehensive use of information from experimental programmes and studies of natural analogues, together with model development and new experiments. Improvements in the models could also lead to a more realistic analysis by reducing unduly conservative assumptions. Efforts in this direction need to be further enhanced at both national and international levels.

(iv) Implementation of Safety Evaluation Methods and Radiological Criteria

Basic radiological protection standards and criteria are available and internationally agreed. In the practical application to nuclear waste disposal, these established criteria are considered implementable for safety assessments over periods of thousands of years. However, problems do arise, concerning the limits of applicability of such safety assessments. The limits of applicability of safety assessment methods for very long periods are being discussed at an international level.

4.2 REGULATORY ASPECTS

(i) The Role of the Regulator

Regulatory bodies must be given sufficient and independent resources for in-depth review, in order to identify critical issues that require further investigation by the operators of disposal programmes. This is also an important factor in demonstrating the integrity of the regulators, which is necessary for public confidence in the licensing procedures.

(ii) Regulatory Guidance

There is a great deal of work involved in site selection, investigation and design before a developer can be in a position to make an application for construction of a repository. The operators of the programmes must be given regulatory guidance during this time. One possible procedure for this is that the operator present updated safety assessments to the regulator at certain decision steps in the programme. On the basis of reviews of such assessments, the regulators can make the operator aware of requirements and give ongoing guidance for future steps in the licensing process.

(iii) Exchanges between Regulatory Bodies

Exchanges between regulatory bodies, under the umbrella of international organizations, should be further enhanced in order to discuss and harmonize safety approaches in different countries, especially as concerns the following aspects:

- definition of steps in the licensing process;
- nature and content of safety studies required at each step of the licensing process, management of uncertainties;
- agreement on scenarios to be evaluated, including human intrusion;
- methods to satisfy radiological protection objectives over very long time periods;
- role of cross-comparisons between independent safety studies;
- definition of the minimum safety levels;
- role of international peer reviews;
- role of regulatory bodies in assessing R&D programmes carried out by waste management organizations.

(iv) Retrievability

In the interest of safety, disturbances of the barrier system after the disposal of radioactive waste should be avoided. The facility should be sealed as soon as is appropriate and no special measures for later access should be taken.

(v) Safeguards for Repositories

After emplacement of waste in a repository, present day safeguards methods are no longer applicable. It is recommended that the application of safeguards requirements to particular types of waste be clearly defined by the competent bodies as quickly as possible, and that measures be used which are in compliance with safety requirements for the repository. This should be done in close co-operation with experts in charge of the safe disposal of radioactive waste.

4.3 PUBLIC PARTICIPATION AND UNDERSTANDING

Decisions on the development of a repository should involve public information and participation at an early stage. However, information limited to scientific and technical aspects is not sufficient. It is also of great importance that the regulatory process and the safety implications of the work be made transparent to the public, and that regular information on the progress of repository development be made available to the public.

4.4 GENERAL RECOMMENDATIONS

(i) Flexibility

Nuclear waste management programmes should retain flexibility, to take into account long term R&D results, and other issues such as new fuel cycle options, and new reactor or fuel concepts, which give rise to new waste streams.

(ii) New Fuel Cycle Options

The partitioning-transmutation option should be considered as a long term alternative strategy. Research should be pursued to ascertain its potential to reduce the quantity of long lived products to be disposed of, to identify the cost, and to determine its impact on the overall safety of the fuel cycle. Research programmes should be implemented by individual countries in the framework of international co-operation.

(iii) Quality Assurance

As in any large industrial project, quality assurance procedures should be applied at all stages of development (site investigation, design, construction, operation, and closure) and to all components (waste packages, repository and engineered barriers, investigation of the geological barriers) of a disposal system. It is recommended that measures be taken - if this has not already been done - to that effect, with a view to verifying the safety features. The ability to demonstrate the quality of the design, and the data on which decisions are based, is essential if the industry is to increase confidence among decision makers and the public.

(iv) Continuity of Disposal Efforts

The continuity of all activities related to disposal as recommended in this paper, should be ensured as efficiently as possible without undue time pressure; in fact, the possibility of interim storage, the relatively limited volume of the waste under concern, and the continuing technological progress provide the necessary flexibility.

(v) International Co-operation

International co-operation on nuclear waste disposal has been carried out for many years, most notably in many R&D activities. Such cooperation efforts are extremely valuable in providing a means to develop international consensus in areas of concern. They are also a necessary and efficient means with which to carry out research projects which require the use of different methodologies and extensive experimental work. International organizations can also provide peer review to give detailed and informal consideration of particular aspects of a programme.

5. ROLE OF THE IAEA

The IAEA should work with Member States and other international organizations (CEC, OECD/NEA) to provide a suitable forum for discussions of common areas of concern and for reaching international consensus on issues related to the long term safety of waste disposal. One important area for international co-operation in which the IAEA should play a key role is the development of standards and criteria for waste disposal. These should cover the entire spectrum of waste disposal, from standards for disposal of high level waste and spent fuel, to those for wastes of very low levels of radioactivity that can be exempted from disposal under regulatory control. The IAEA should assist the progress towards international consensus on the application of radiation protection criteria over very long time-scales. Within the last year, the IAEA has initiated the RADioactive WAste Safety Standards (RADWASS) programme, which has as its objective to demonstrate the harmonization, at the international level, of the approaches which exist for safe management of radioactive wastes.

In order to address the regulatory problems identified by the expert group, more exchanges between national regulatory bodies are recommended. The IAEA should help to promote, facilitate and provide a forum for such exchanges to improve the development and harmonization of safety approaches in different countries. An area of great importance to regulators as well as developers of radioactive waste disposal facilities is that of safety assessment. Additional efforts are recommended to ensure the validation of safety assessment models at both the national and international levels, and the IAEA should continue its work to foster information exchange and technology transfer between Member States in this rapidly developing area. Through its WATRP programme, the IAEA can organize international peer reviews of relevant aspects of national waste disposal programmes.

The requirements regarding safeguards measures for nuclear materials disposed in a geological repository need to be defined promptly by the competent international bodies. The IAEA, in its programmes to develop these requirements, should work closely with waste disposal experts to ensure that requirements can be developed which are compatible with safe, long term isolation of the radioactive materials in the wastes.

6. SUMMARY

Radioactive waste must be managed properly to protect public health and safety, for as long as a significant radiological hazard persists. Near surface disposal is practised in many countries for disposal of low and short lived intermediate level radioactive wastes. Most countries have concluded that deep geological disposal, using a system of engineered and natural barriers, is the preferred method for disposing of spent fuel and solidified HLW. While no repositories for disposal of HLW are now in operation, several countries have constructed underground test facilities, while others have identified sites to be characterized, or are in the process of selecting candidate sites. International consensus exits on the principles for radiological protection that, when applied to repository performance, would provide adequate protection of health and safety of this and future generations. International consensus also exists on the general principles and criteria to achieve safe disposal of HLW (IAEA Safety Series No. 99). Because of the need to protect future generations, decisions concerning whether safety criteria are met will involve performance assessments of future behaviour of the repository. There is much international co-operation on development and validation of performance assessment models, on development of methods to measure geological and hydrological data, and to develop performance data for various engineered barriers. The collective opinion of experts in waste disposal is that long term safety of waste disposal systems can be adequately evaluated by methods available today, and that these methods provide a technical basis to decide whether specific disposal systems offer society a satisfactory level of safety for current and future generations. Additional efforts are needed to demonstrate the long term safety of geological disposal of high level wastes and spent fuel, to improve the regulatory process for licensing long term disposal and to achieve public understanding. The IAEA has a significant role to play in these future efforts.

To facilitate a focused discussion of the issues at the conference, the following significant topics are presented for consideration:

1. How should the developed strategy for the final disposal of radioactive waste be implemented?

2. What role should the regulatory body have in relation to the implementing organization with regard to the programme for disposal of HLW?

3. International co-operation, how can it help? What should be the role of the IAEA?

APPENDIX I

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