INSAG Note No. 4

Maintaining Knowledge, Training and Infrastructure for Research and Development in Nuclear Safety

A Note by the
International Nuclear Safety Advisory Group

INSAG

IAEA

The International Nuclear Safety Advisory Group (INSAG) is an advisory group to the Director General which provides him with advice on nuclear safety, radiation safety and the safety of radioactive waste from a global perspective. The functions of INSAG are:

(a) to recommend the underlying principles upon which appropriate safety standards and measures can be based;
(b) to provide a forum for the exchange of information on generic safety issues of international significance;
(c) to identify important current safety issues and to draw conclusions in the basis of results of safety activities worldwide, and other information such as research and development results;
(d) to give advice on safety issues in which an exchange of information and/or additional efforts may be required;
(e) to give advice, if requested, on the content of the Agency's programmes in the field of nuclear safety, radiation safety and safety of radioactive waste.

PREFACE

At its meeting in June 2001 INSAG approved this text and forwarded it to the IAEA Director General with a recommendation that it be published. The Director General has agreed that it should appear as an INSAG Note. It is hoped that this will make a contribution towards the enhancement of nuclear safety, radiation safety and the safety of radioactive waste.

INTRODUCTION

Like all major technological ventures, nuclear power owes its successful development to a strong underpinning of research and to keeping a constant pool of expertise, which has contributed to a good safety record around the world as well as economic success. Elements of this underpinning must remain robust if safe nuclear power is to remain an option. Safety in this context must be viewed in its broadest sense. Safety research and expertise should be directed not only to topics relating to the safety associated with plant performance and operation and with accident prevention, but also towards protection of workers and the public against radiation exposure and protection of the environment from accidental releases of radioactive material. This research should also be directed to the safety of nuclear fuel cycle facilities and other facilities which have the potential to cause radiation exposure, and to the management of nuclear waste at an acceptable level of safety in the short as well as the long term.

This statement derives from INSAG Reports addressing the need for and benefits derived from research and development. INSAG-12 stated the following principle:

> *"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."*

and developed the following conclusions:

> *"...research and development activities are needed to maintain knowledge and competence within organizations that support or regulate nuclear power plant activities."*

> *"Nuclear research and development is an essential element of nuclear plant safety and its continued support is very important... co-operative research on an international scale to reach a common understanding on major safety issues is an important way to avoid duplication of efforts and to reduce costs."*

In recent years, funding for long term strategic activities such as research and development, preserving corporate knowledge and maintaining technical expertise has been reduced in many countries. Industry funding by the designers and operators has been reduced as a result of the belief that the research needed for the initial design of plants has been completed, a lack of commitment to build new plants, the effects of deregulation and a highly competitive market place, and a preoccupation with short term profitability and shareholders' interests at the expense of long term programmes such as research.

Government funding has been reduced as a result of scepticism in some governments and among parts of the public about nuclear power as a sustainable source of energy and the belief by some governments that the nuclear industry, as user of a maturing technology, should be the primary source of research and development funding in the future. Because of the poor image that nuclear energy has had in some countries, teaching in nuclear technology and nuclear safety at universities has also diminished considerably. It follows that new researchers are not entering such programmes, raising concerns about the continuity of knowledge even in universities.

A nuclear power programme in any State represents a significant investment. That investment can be expected to be valuable to society for 60 years or more, provided that the plants are well maintained and upgraded throughout their operating lifetimes, that operating experience and new research results are utilized in continual improvement of plant safety and economics, and that the

safety authority retains the capability both to assess the plants' safety and to make soundly based decisions on their continued operation.

Nuclear power programmes have required a continued investment in safety research both by industry — to meet its responsibility for ensuring safe operation — and by government to ensure that the regulatory organization has the competence and independence to discharge its responsibility. If capabilities are not maintained by both the industry and the regulatory organization, the safety of nuclear facilities may deteriorate.

PURPOSE

The purpose of this INSAG Note is to emphasize the importance of maintaining capabilities for nuclear research and education, especially with regard to safety aspects, so that nuclear safety may be maintained in IAEA Member States, and to alert Member States to the potential for significant harm if the infrastructure for research, development and education is not maintained.

DISCUSSION

Throughout the development of nuclear power, safety considerations have been of paramount concern. Thus, efforts in safety research have been widely supported by governments, design organizations and electrical utilities, operating organizations, research institutions and universities. The results gained from research have been used to form important technical bases for new designs, safety developments and regulatory programmes. Therefore, many safety research programmes have been supported and organized by several IAEA Member States.

Progress of safety research

Safety research has never lost its importance, but its scope and emphasis have changed as challenges to safety have arisen. Past successes in safety research have permitted the nuclear industry to grow, maintaining public confidence through well founded designs and operating limits and, particularly, through sound regulatory practices. Examples of the enhancement of the regulatory process as a result of research in several countries include: the research on emergency core cooling in the 1970s; the research on probabilistic safety assessment in the 1980s that led to technical advances and the use of probabilistic techniques in decision making on safety; and, in the 1990s, ageing research which improved the understanding of material properties and behaviour and provided a knowledge base for considering the safety implications of long term operation of plants, sometimes beyond their initial design lifetimes. Other examples include: the improved understanding of thermal-hydraulic phenomena that led to the approval of advanced light water reactor designs; understanding of severe accident source terms; the improved process of reactor inspection and oversight; and effective accident management schemes and emergency plans. Research has enabled sound design, operational and regulatory decisions and the provision of strong oversight of licensees' activities. However, in the absence of growth in a number of countries where significant development of nuclear power has taken place, there is a significant danger of stagnation or even decline in the research and educational infrastructure.

We must be concerned about potential complacency in our approach to plant safety. While there is ample evidence of improving performance of the industry, we are also experiencing dynamic

changes resulting from an increasingly competitive economic environment and an unchanging or declining infrastructure, with margins between electrical supply and demand shrinking and electricity demand rapidly increasing in some IAEA Member States. This situation is aggravated by the downward trend in research funding. Additional challenges to the infrastructure stem from renewed interest in reactors and fuel cycles that are 'proliferation resistant', the use of simple passive systems to enhance safety, the implementation of emerging technologies (for example, digital instrumentation and control) and the potential for new plants utilizing novel concepts (for example, new fuel materials). All of these challenges require research by designers and operators to develop the concepts, and action, including research if necessary, by governments to enable safety authorities to ensure that safety is thoroughly considered before approval is granted.

International experience also indicates that the more utility staff are involved in the application of the knowledge gained from research to the design, operation and maintenance of an individual plant, the more safety is enhanced. This application of knowledge gained from research is a way to improve staff competence and to maintain the knowledge base at the plant.

Requirements of safety research

Safety research by both industry and regulatory organizations can only develop and thrive where several conditions are satisfied. Although the challenges may be changing, these requirements remain critical to maintaining the necessary research infrastructure:

(1) Necessary technical expertise in all safety disciplines must be maintained through a vigorous educational process. This is particularly true of those disciplines which are specific to nuclear facilities, such as nuclear science and engineering, reactor physics and radiation related health physics, and studies of the unique problems associated with the chemistry, materials and thermal-hydraulic performance of new and existing reactors.

(2) Analytical tools and techniques must be maintained and further enhanced to better quantify safety margins and thus to facilitate better decisions.

(3) Experimental facilities must be maintained to provide data to elucidate basic physical processes, to confirm and validate mathematical models used in analytical tools, and to respond to new problems as they arise.

(4) The development of a constant pool of safety experts requires educational institutions firmly rooted in the pursuit of excellence with current knowledge of research in all disciplines relating to safety. This can be kept up only if research institutions are maintained and are active at the forefront in research activities, and if employment opportunities exist. In some cases, this may be achieved by in-house training of scientists and engineers who lack direct education and training in nuclear safety. Unless the need to maintain a cadre of safety experts is made clear and the facilities necessary for this purpose are maintained, the infrastructure will wither and the talent pool will be continuously depleted.

(5) Major nuclear research projects play a significant role. They are of prime importance for attracting capable scientists and engineers who may otherwise be absorbed by faster growing technologies that appear more attractive.

(6) Achieving the public confidence necessary for continued development of nuclear technology demands a mature regulator possessing the necessary tools and expertise to

monitor performance and assess the potential for unintended consequences in order to ensure that there is no undue risk to the public. These tools must address concerns relating to long term waste management and radiation effects as well as reactor safety. The public must also be confident that operators and workers at nuclear facilities are competent and expert in both generating power and maintaining safety.

NEW CHALLENGES

Even though a good safety level for nuclear facilities and applications has been achieved in most countries, there are also areas where improved knowledge will be necessary to regulate and operate current reactors efficiently and effectively as they age, and to provide the scientific and technical basis for the development of innovative nuclear reactors and novel means for management and disposal of high level waste. Experience indicates that new issues will continue to emerge from operational experience, and an enterprising and dynamic industry will continue to propose innovative initiatives to improve economics while maintaining safety. A questioning attitude is necessary in industry and in regulation to evaluate and resolve problems as they arise. Furthermore, new designs are being proposed which have many characteristics that differ from those of current plants. Knowledgeable and well trained personnel are necessary to sustain and enhance the safety of nuclear power and to provide effective regulation through all its phases from research and conceptual design through operation to waste management and decommissioning.

Examples of areas where novel emerging issues of these types have already been identified are provided below. For each example listed, and for all other areas that may be identified in a comprehensive evaluation, emphasis must be placed on understanding the uncertainties and highlighting those needing attention, as well as on the role of information on the contributors to the risks in identifying safety related and regulatory related needs.

Economic conditions are leading to extension of the operating cycle, higher fuel burnup and increasing of power levels. Initiatives have been taken in several IAEA Member States to explore the use of mixed oxide fuel, either because of considerations relating to non-proliferation or to recycle fuel to use it more efficiently. These are being evaluated by regulatory bodies in Member States. The combined effects of these considerations must be evaluated to determine the overall impact on safety.

Economic deregulation has had many influences on plant performance and may have the potential to lead to departure from extant safety principles if the impacts of deregulation on plant performance, including the performance of both equipment and operators, are not fully understood and monitored by the plant operator and an independent regulator to provide early warning of a change in organizational culture. Similarly, extending the effective operating lifetimes of nuclear power plants will bring great economic benefits but requires effective programmes for mitigating or managing the deleterious effects of plant ageing.

Extension of plant operating lifetimes, decommissioning, the introduction of new technology and ageing of the workforce all pose unique challenges in the area of human performance. We must be prepared to understand these challenges and to develop means to measure, monitor and trend organizational and management performance with regard to safety as well as individual human performance.

New reactor concepts (for example, the pebble bed modular reactor or advanced light water reactors) are under development which appear to have advantages in terms of both economics and safety over existing plants. Where there is a reasonable prospect that such new designs may be proposed to a State's regulatory authority, it is essential that the regulatory authority prepares in advance for such a proposal, ensuring that it has the proper mix of technical skills and experimental facilities to evaluate thoroughly the safety of such new designs.

Similarly, in the fuel cycle, new concepts are under consideration for both the enrichment of new fuel and the disposal of radioactive waste, and research expertise is needed. The application of techniques of risk analysis to manufacturing and processing facilities for nuclear materials is well under way, but these facilities differ from reactors and it may be necessary to adopt a different technique for risk assessments.

Analysis of the risk associated with both the interim above ground storage of spent fuel and the transport of high level waste to final repositories requires detailed analyses of cask designs and evaluation of material behaviour. Similarly, the long term storage of radioactive waste will require monitoring as operational information begins to be compiled. Experience from reactors and from other industries using advanced technology indicates that operational observations may necessitate 'mid-course corrections' by the regulatory body as well as by the operator of the facility to maintain safety.

New approaches to enrichment and recycling as well as consideration of transmutation of high level waste will require careful evaluation of the need for safety research in parallel with developmental analyses.

The complexities of these techniques and the complex concerns relating to safety, non-proliferation and operations will require a cadre of safety experts to evaluate future research needs. Adequate research must be conducted to understand these new technologies, their associated risks to public health and safety and the uncertainty in risk estimates, and to evaluate where controls are needed for the protection of public health or where further research is needed to reduce uncertainties.

Support of the educational infrastructure is a specific and primary responsibility of government. Industry can and does support educational institutions in partnership with government. This pattern can be seen in aeronautical engineering, chemistry, electronics, biochemistry and other fields of endeavour in high technology which may be vital to long term national interests. Nuclear engineering is no different in principle; it is, however, passing through a difficult period, and these concerns need to be addressed promptly and with vigour.

CONCLUSION

If the infrastructure for nuclear safety is not maintained, there will be a steady decrease in expertise, and thus in capability to respond to new challenges. The lead time in developing replacement educational opportunities is very long, because most institutions will require an indication of a number of enthusiastic potential students before investing in new infrastructure, and potential students may look elsewhere in the absence of an exciting analytical and experimental programme and a growing career field. Once lost, it would require massive inputs of resources from many IAEA Member States to attempt to re-establish the infrastructure, as it did to establish it when nuclear technology was new. The result could be a downward spiral in which expertise is lost, influence of the technical community on the decision making process is diminished, and

complacency, fed by diminished technical capability, begins to exert a strong effect. If such a situation were to arise, it could be a harbinger of future accidents. In this context, it should also be recalled that governments that are parties to the Convention on Nuclear Safety are committed to taking "the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety related activities in or for each nuclear installation, throughout its life" (Article 11.2 of the Convention). Maintaining the necessary supporting research infrastructure for nuclear safety is indeed, in the opinion of INSAG, such an appropriate step.

In view of the above, INSAG has the following recommendations:

— *In order to maintain and further enhance the safety of nuclear facilities and to protect workers and the public and the environment from radiological consequences, the infrastructure for safety research (experimental facilities, highly competent staff and modern analytical tools) must be maintained and supported by the responsible governmental organizations as well as by the operating organizations and manufacturers. This support should include international networking and co-operation, including joint funding of centres of excellence that have facilities and equipment for use in nuclear research.*

— *Education in nuclear science and technology needs to be stabilized in order to maintain sufficient human resources in sciences and engineering relating to nuclear safety. Part of the research infrastructure should be maintained at universities. There is a concern that deterioration of the research infrastructure may lead over time to a deterioration in safety which the public will not tolerate. National and international bodies have a key role to play in ensuring that the skills and capabilities required by the nuclear industry and its regulators are available and that the infrastructure required for this is provided for.*

— *Maintaining the safety of nuclear facilities, a pool of expertise and the level of safety research is a common concern of IAEA Member States and therefore, to the extent practicable, research facilities and research data should be shared in joint research programmes by IAEA Member States.*

— *The Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) is actively engaged in this effort. It has recently published two important reports dealing respectively with research capabilities and facilities and with major research programmes at risk. Following up on the conclusions of these reports, the OECD/NEA continues to review safety research needs and organizes and sponsors internationally funded projects which contribute to maintaining key research facilities and teams. However, it is important that such efforts encompass all countries having nuclear power programmes. The IAEA and OECD/NEA could explore this possibility further.*

— *More frequent interactions among research managers in Member States should be considered to ensure that full advantage is being taken of the joint expertise and equipment available around the world. Results of national research programmes should be made public and broadly shared. This will increase public confidence and help to ensure that regulatory processes reflect the state of knowledge.*

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