Current Nuclear Power Plant Safety Issues: Preview of an International Conference

by M. Rosen and R. Schmidt

The Three Mile Island accident in the USA has led to extensive examination by many nations of the safety of their nuclear power facilities. The results of these investigations are becoming available and the safety issues of current concern are becoming clear. The more significant of these are: operational safety aspects, including qualification of the operating staff as well as the utility management, and man-machine interfaces; emergency planning and preparedness; siting policy requirements; plant design improvements and modifications; and various possibilities for international co-operation. In order to clarify, discuss and assess these important issues, the International Atomic Energy Agency will convene an International Conference on Current Nuclear Power Plant Safety Issues from 20–24 October 1980 in Stockholm, Sweden. This article introduces some of the subjects which will be treated during the meeting.

BACKGROUND

There are presently 22 countries with 235 operating nuclear power plants supplying 7% of the world's electricity. On the basis of plants now in various stages of construction, this will increase to 35 countries by 1990; about 15% of the electricity needed in that year will be supplied by 540 power reactors with a combined output of 400 000 MWe (see Figure 1). In the more than 20 years since commercial nuclear power was introduced, it has had no known detrimental effect upon the physical health of the public.

The radioactivity released in the small number of more serious incidents in these plants has generally been completely contained within plant boundaries. Indeed, at Three Mile Island the defense-in-depth concept, that is, multiple barriers between radioactivity and the environs, resulted in the almost complete containment of radioactive materials within the plant. Nevertheless, the accident on 28 March 1979 dramatically focused international attention on the fact that serious nuclear power plant accidents with the possibility of a radioactive release over the areas surrounding the plant can occur. As a result, nuclear safety has gained a most prominent position in the discussion of nuclear power. It is apparent that the extent to which nuclear power will be used on a world-wide scale in the future depends upon both the decision-making and public sectors being confident that nuclear power plants are designed, constructed and operated safely.

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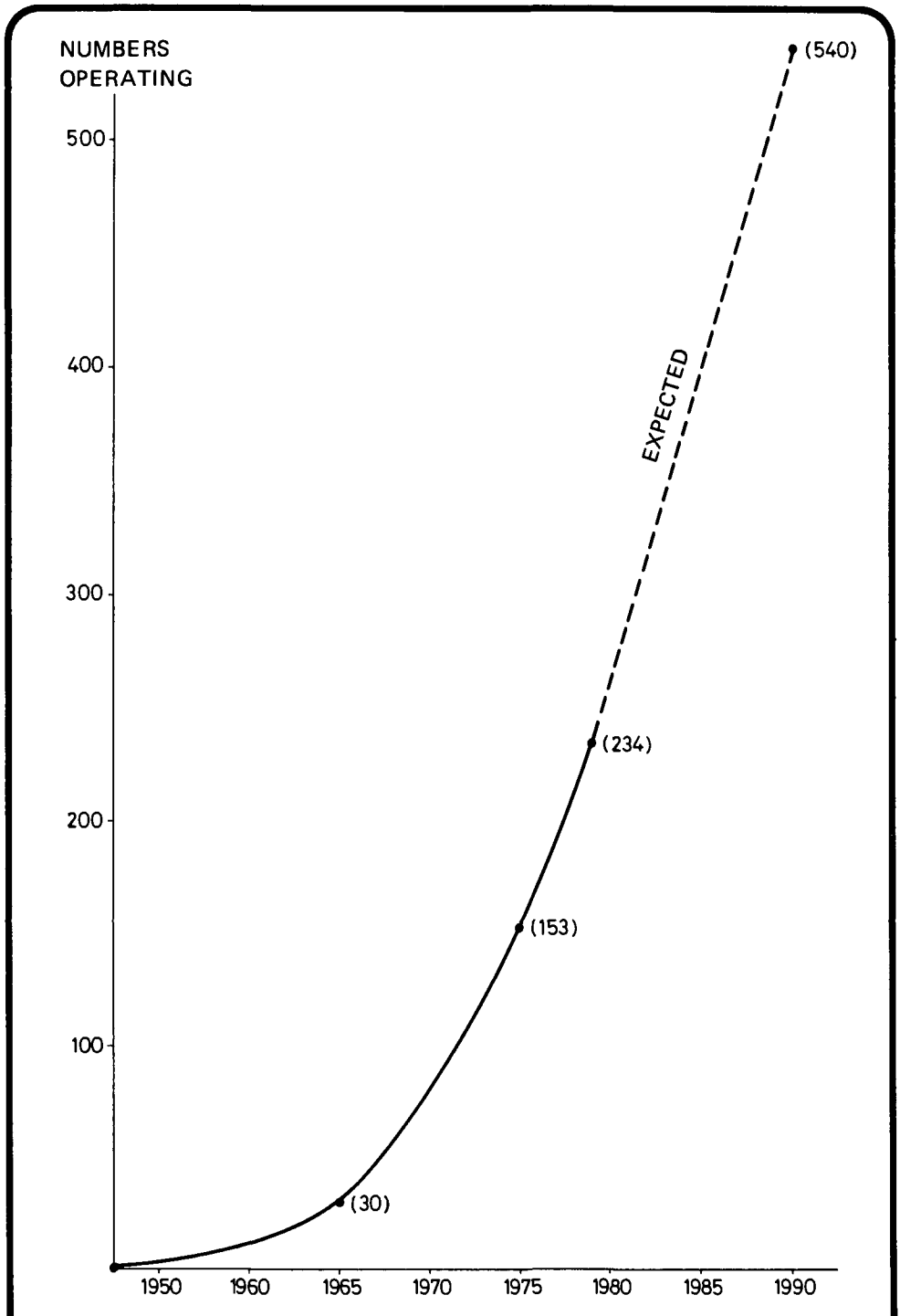

FIGURE 1. World's Nuclear Power Plants

It is almost one year after the Three Mile Island accident and the results of extensive re-examination by many nations of the safety of their nuclear power facilities are becoming available. To provide a forum for the presentation of the most current views on nuclear safety, the IAEA decided to convene an international conference to clarify, discuss and assess the major issues. The conference will bring together the knowledge and experience that the international community has acquired during more than two decades of commercial nuclear power. There will be plenary sessions with comprehensive presentations for senior officials and planners as well as topical sessions to provide more detailed supplementary and explanatory material (see Figure 2).

Of the many safety issues that could be selected for discussion, priority will be given to the most pressing and important. They surely include,

- Operational safety aspects
- Emergency planning and preparedness
- Siting policy requirements
- Plant design modification and improvements
- International co-operation

FIGURE 2. Topics for the International Conference on Current Nuclear Power Plant Safety Issues, 20–24 October, Stockholm.

Structure of the conference

- Plenary sessions with exclusively invited papers, round table discussions and parallel technical sessions with contributed papers.

Subject areas

- Evaluation of significant nuclear power incidents and their impact on nuclear power programmes
- Current trends in national nuclear power regulation and safety research programmes
- Trends in design philosophy and accident analysis to improve safety
- Conduct of nuclear power plant operations with increasing management responsibility and qualification, and training of the operating staff
- Preparedness for on-site and off-site emergencies
- International co-operation in dissemination of experience, standards development, safety research co-ordination and emergency assistance, and the present and future role of international organizations
- Specific contributions on a selected number of safety topics as aoutlined below.

Contributed papers for technical sessions on

- Details of incident and accident evaluation and related emergency response
- Advanced safety system design
- Design for operability in emergencies
- Operator training to prevent and mitigate emergencies
- Small-leak loss-of-coolant accidents
- Specification and qualification of equipment to ensure safety
- Developments in accident and post-accident instrumentation
- Radiological protection concepts in the light of new experiences

OPERATIONAL SAFETY ASPECTS

In terms of public safety, the 1800 reactor-years of operating experience accumulated by the world's 235 existing commercial nuclear power plants has been generally successful. As one can expect in any complex system, there have been failures of equipment and human errors. However, almost all the accidents that have occurred could be classified, from a radiological safety point of view, as having relatively little significance since they resulted primarily in operational problems and economic losses but produced no health consequences. On the other hand, these events provide valuable experience since their study can lead to a better understanding of the causes and the prevention of more serious accidents (see Table 1).

Table 1. Some Major Nuclear Power Plant Incidents

Year	Plant	Cause	Result
1966	Fermi (USA – 60 MWe)	Design Error	Core Damage
1969	St Laurent (France – 500 MWe)	Human Error	Core Damage
1974	Wurgassen (Rederal Republic of Germany – 640 MWe)	Human Error Equipment Failure Design Error	Containment Damage
1975	Brown's Ferry I & II (USA – 1100 MWe)	Human Error	Major Equipment Damage
1979	Three Mile Island (USA – 900 MWe)	Human Error Equipment Failure Design Error	Core Damage
1979	Oyster Creek (USA – 650 MWe)	Equipment Failure Design Error	Possible Core Uncovering

A common feature of many of the accidents which have occurred to date is the decisive importance of human factors. Human errors were in many instances the immediate cause of the accidents and were significant in determining the course of events. Although the accident at Three Mile Island was the result of a complex of factors (equipment failures, design errors, as well as operator errors) the primary deficiency in reactor safety identified by the accident was that inadequate emphasis had been given by all levels and all segments of the nuclear industry to safe operation, and perhaps in particular to the human element and its basic role in the prevention of and response to accidents. Previously, the overwhelming emphasis had been on producing a safe design.

Therefore, the most important lessons learned are related to the general area of operational safety, including for example,

- the roles of utility management and its technical support staff,
- qualification and training of operating personnel,
- adequacy of emergency operating procedures,
- evaluation and feedback of operating experience, and
- the man-machine interface.

In most countries nuclear power generation is managed by the same utilities that handle the more conventional means of generating electricity. Nuclear power, however, requires special management attention and special operating qualifications as well as an extensive support system of technically qualified scientists and engineers. In a number of countries, the qualifications and training of reactor operators is currently under intensive review with consideration being given to more clearly defining the educational background requirements. Future operator training is to include an expanded role for reactor simulators which are to have a wider range of abnormal incidents in their programmes. In the man-machine interface area, recognition of the importance of control room design is resulting in consideration of such aspects as the adequacy of information presented to the operator, the grouping of displays and the layout of panels, and the communication between the control room and points outside. The question of manual versus automatic operation of safety systems is being re-examined in view of the Three Mile Island sequence of events.

EMERGENCY PLANNING AND PREPAREDNESS

In the event of a serious accident, the final measures to be taken against a radioactivity release should be specified in an effective emergency planning and preparedness programme. Yet, this activity has not had sufficient priority within the nuclear industry or at the governmental level. The resources and funds devoted to it as a percentage of the funds used to construct, operate and maintain nuclear facilities have certainly been relatively small. The reasons for this are varied, but needless to say, this situation is changing as a result of Three Mile Island.

Most nuclear power plants and their surroundings have been provided with various types of emergency plans. At Three Mile Island such plans existed within the utility and at federal, state, and local government levels. The plans included on-site emergency measures to protect plant personnel and equipment, and an off-site emergency response to protect the public and the environs. However, these plans were shown to be inadequate. The real life complexities of an actual nuclear emergency had not been fully anticipated. All the agencies with potential involvement had not been clearly identified, nor were their responsibilities and authority clearly defined. There were deficiencies in alerting procedures, communication capabilities and in the release of public information. There were problems in obtaining equipment and services and one clear lesson is that one must know in advance what is needed and where it can be found.

Efforts to develop efficient emergency planning and preparedness are now underway at both national and international levels. The IAEA has accelerated its programme to establish procedures for insuring that in the event of a nuclear accident, special resources (people,

Figure 3. Phases of a Nuclear Accident

Phase	Planning and Preparedness	Immediate Accident	Intermediate Assessment	Long-term Recovery
Time Period	years	seconds to several hours	minutes to several days	days to several years
Actions	Assess Resources: People Goods Services	Local Resources by Local Capability	Local and International Resources	

equipment, and services) which might be needed to assist in managing the emergency are made available with minimum delay. With respect to nuclear accident planning, four phases can be identified, as shown in Figure 3.

For these four periods the needed resources in terms of people, equipment and services can be clearly defined, and a programme can be developed to insure the availability and utilization of these resources, and to promote the proper management of the emergency.

SITING POLICY REQUIREMENTS

Countries which have developed commercial nuclear power programmes began by selecting sites generally in regions away from highly populated areas. With satisfactory operating experience and with technological improvements, some of these countries chose sites closer to areas of higher surrounding population densities Different siting policies evolved as is shown in Figure 4. Some countries have established exclusion zones in which resident population is not allowed and restricted zones in which resident population levels must remain low. Limits placed on potential individual and total population radiation doses can be factored into these criteria.

In general the siting of nuclear power plants has been considered more carefully and has been more restrictive than has the siting of other types of industrial facilities For nuclear plants, the potential radiological impact on the inhabitants in the region around the plant is evaluated for normal operation as well as for possible accident conditions. The consequences of a serious release of radioactivity are dependent not only on the population distribution, but also on the meteorology, topography, and the economic and social activities in the area surrounding the plant. The siting evaluation must consider not only the total number of inhabitants in close proximity to the site but also the number of inhabitants in adjacent areas, particularly in the sectors downwind in the prevailing wind direction. Traffic, communications and the presence of schools, hospitals, prisons or other large institutions near the site become important considerations for the implementation of emergency measures in the event of a serious accident

Figure 4. Typical National Siting Practices

Country	Exclusion zone	Restricted zone	Remarks
Canada	1 km		Individual & Collective dose limits also used
CSSR	0.5 km		Typical value
India	1.6 km	5 km	No population centre of 16 000 within 16 km in the main wind direction
Italy	0.8–1 km		Typical value adopted
USA	0.65 km	5 km Low Population Zone	Acceptable value for plants licensed in 1960's and early 1970's
USSR	3 km		Typical value

There are some questions regarding siting which still remain. For example, since people are potentially afforded additional protection by being distant form a nuclear plant, should plants be located far from population centres? We must recognize that remote siting is not possible in many countries. Should plants be designed to protect against accidents more severe than those for which present plants are designed, that is, for releases of radioactivity larger than the current design bases? Should safety design be improved to incorporate such ideas as a burst-proof reactor coolant system to prevent large loss-of-coolant accidents and further reduce accident risks? We will always be faced with the question of how safe is safe enough.

Answers to these questions depend somewhat on the basic question of risks and benefits. Zero risk is not possible, since all human activities to some extent involve risk. Risk calculation is difficult, and so is the determination of what type and degree of risk is acceptable to the public. The theoretical risk to human health from nuclear power plants has been calculated to be far less than that of many other large-scale industrial activities and of other means of producing electrical energy such as with fossil fuel plants and hydroelectric sources.

PLANT DESIGN MODIFICATIONS AND IMPROVEMENTS

The safety systems used in nuclear power plants have been designed to control and to mitigate the consequences of even the most severe accidents, the so-called design-basis accidents, which can lead to extensive core damage and radioactive release from the fuel. To date, after 1800 reactor-years of operation, no accident has occurred which has followed the course of what can be called the classic design-basis accident, that is, a large break in

the leak-tight primary system leading to a rapid loss of the essential coolant. In fact, there have been only a few incidents where safety systems have been called upon to operate. On the other hand, the accident at Three Mile Island has demonstrated that several apparently minor events when combined with deficiencies in instrumentation and operator error, can lead to serious accidents. It is now apparent that the implications of the more minor incidents at nuclear power plants had not been adequately investigated.

There will be increased emphasis on the analytical understanding of accidents (this having been traditional for nuclear power plant safety) with an increase in the scope and breadth of the analysis. These new analyses will focus on the consideration of a wider and more detailed spectrum of possible initiating events and consequential failures and on the important area of man-machine interactions. Increasingly sophisticated probabilistic analyses as well as computer simulation methods will be used. To assist in these efforts, the actual experience from operating plants will be used more extensively. This experience is now being processed into computerized data banks for evaluation.

The new information obtained from these studies will be factored into safety reviews so as to improve features of operating and future plants. Although no dramatic changes are expected in the nuclear power plants now in operation, there will certainly be changes in operating procedures, instrumentation and automation schemes and improved quality assurance techniques to increase the reliability of equipment. There are, however, some plant improvements and modifications which have to be considered. These are provision for venting of hydrogen gas from the primary system, returning radioactive effluents to the containment, improved instrumentation (type and range), post-accident hydrogen control, and controlled venting from the containment to handle major radioactivity releases. More specific to the Three Mile Island design are items such as emergency power to feedwater heaters, containment isolation signals, and quality assurance outside the containment, especially of safety-related systems.

INTERNATIONAL CO-OPERATION

Many safety-related activities have been assisted by bilateral and multilateral agreements among nations and through the auspices of international organizations and committees such as the IAEA, CMEA, NEA, CEC and ICRP. There are areas which are especially suited for international co-operative efforts, such as the exchange of safety-related information, safety research and emergency assistance.

As operating experience accumulates and the quantity of safety-related information increases, its dissemination throughout the international community will allow it not only to be incorporated into design improvements but also to assist in safe operation. The 19 developing countries which will be operating nuclear power plants in the year 1990 certainly will need easy access to information on operating experience. Data banks containing this information can be developed only if it is exchanged openly by all nations, and this may be assisted through international organizations.

International co-operation in the area of safety research can be obviously beneficial not only in the joint performance of safety research projects but also in the sharing of safety research information. Periodic meetings of experts from various countries can be convened to discuss results and propose new projects.

The emergency assistance aspects of nuclear accidents offer another opportunity for co-operation. The large, varied and complex job of securing emergency resources in the form of people, goods and services can be facilitated by adequate preplanning. These resources can be identified and the means of making them available defined. The internationally agreed-upon safety criteria and standards being developed by the IAEA are a good example of co-operation to assure a minimum acceptable safety level worldwide Other active programmes to assist Member States include dispatching safety advisory missions and long- and short-term safety experts and conducting training courses and seminars on the various safety and regulatory aspects of nuclear power. These programmes can continue to be a major element in the international safety effort.