Safety of future nuclear installations: An overview

Public confidence in nuclear plants is a major factor influencing developments

by Jeanne Anderer

From discussions at a recent workshop on nuclear plant safety sponsored by the IAEA and Argonne National Laboratory (ANL) in the United States, it was clear that most experts expect nuclear power to be deployed globally on a larger scale over the next few decades. Several explanations were given for this cautious optimism.

Many believe that the increasing concerns voiced by scientists, politicians, and the public about fossil fuel combustion and the threat to the environment posed by climate warming, stratospheric ozone depletion, and acid rain have prompted these groups to think again about the circumstances under which nuclear power might be part of an environmentally sustainable energy strategy. Others argue that the accelerating demand for energy and for electricity in particular, together with increasing societal awareness of the economic and lifestyle problems associated with every significant source of energy service (energy efficiency inclusive), will gradually lead people to opt for an energy mix that includes nuclear power.

The window of opportunity

For its part, the nuclear power community has recognized the international dimensions of nuclear safety, putting in place a wide range of international agreements for accident notification and emergency response, and for broad information exchanges to enhance the safety profile of nuclear power now and over the coming decades.

Gradually, the community is acknowledging the importance of properly addressing the concerns many people have about the health and environmental impact of radiation exposures associated with the varied uses of nuclear technologies.

Even so, the key question hanging over the nuclear community is whether it will be able to treat the current window of opportunity to (re)build broad public confidence in nuclear technologies as safe, well-regulated, and non-detrimental to human and environmental well-being. While the challenge of the 1980s was to ensure technologically the safety of nuclear power installations, the challenge of the 1990s will be to prevent societal rejection of nuclear power, an essential energy source. How the nuclear community could respond to this new challenge was at the core of the workshop discussions.

The need for nuclear power: A quantitative perspective

The 1989 Jülich "Carbon Dioxide Reduction Scenario for the Year 2030" developed by scientists in the Federal Republic of Germany offered a perspective on the magnitude of a possible future supply role for nuclear power in a global energy system constrained by internationally recommended reduction targets for carbon dioxide and driven by the forces of population and economic growth. While the scenario exhibits a number of features deemed impossible in today's terms, provocatively it addresses the question: how impossible is the "impossible". To this end, it assumes a shift towards the uses of hydrogen-rich fossil fuels, of recycled biomass and non-carbon alternative energy sources, of nuclear power, as well as the introduction of significant energy conservation.

The scenario findings point to an increase in the global contribution of nuclear power mainly for electricity generation but also for high-temperature process heat. Expressed in terms of total installed capacity, this

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would require the operation of some 2000 power reactors of 1000-megawatt size by the year 2030 — an increase by a factor of six over the existing installed capacity. Should all optimistic assumptions about supply from non-nuclear/non-carbon primary energy sources not materialize, the nuclear contribution would have to be even higher.

The expansion of the nuclear generating capacity along such lines would have major implications for the nuclear fuel cycle, such as the ratio between breeder-type reactors and burners, reprocessing capacities, and resource requirements. As a yardstick, the operation of some 2000 power reactors would necessitate an increase in the number of nuclear waste disposal facilities at the approximate rate of one facility per year indefinitely. Without the use of breeder-type reactors, by the year 2030 the amount of plutonium requiring storage could be in the broad range of 1000 tonnes. Accordingly, safeguards procedures would have to be re-evaluated. The findings of other energy demand scenarios considered — extending to the year 2060 — were essentially in accord with the above supply pattern painted for nuclear power over the coming decades.

Demonstrating safety

Substantially expanded use of nuclear power would call for a correspondingly higher level of safety at all nuclear fuel cycle installations worldwide. The reason for this lies partly with the large increase in the number of facilities and partly with societal expectation of lower risks for all nuclear technologies. In keeping with the theme of the workshop, attention focused primarily on safety issues associated with nuclear power production.

The expert consensus was that existing nuclear power plants are safe, although not all plants have as of yet met in full detail the basic safety principles for nuclear power plants established by the IAEA's International Nuclear Safety Advisory Group (INSAG) in its pioneering report, known as INSAG-3. There was also broad consensus that, in line with the above arguments for higher safety levels, the next generation(s) of nuclear power plants would have to be "demonstratively safer" in the eyes of the owner utilities, regulatory bodies, politicians, and the public. The challenge of demonstrating safety would call for concerted action at both the technological and institutional levels.

For summary purposes, technological developments applicable to nuclear power plants have been broadly classified into the following three groups. While such groupings are convenient for discussion, in practice it is difficult to make such clear-cut distinctions, particularly for evolutionary and innovative reactor designs.

- The first group comprises the current generation of operational nuclear plants or those under construction. These are characterized by large-sized power reactors of various types which exploit the benefits of widespread operational feedback for improvements in safety and performance.
- The second group is made up of evolutionary reactors which represent modifications of current reactor designs and which could be available in the near term. These include pressurized-water and boiling-water reactors that achieve an enhanced margin of safety generally through lower power densities, smaller size, and simplier design features than current ones, as well as through passive safety systems such as gravity and heat convection for delivering emergency coolant to the core and for containment cooling in the event of an accident. Also included in this group are the modified designs of the liquid-metal fast reactor (LMFR) being developed, for example, in France, Japan, USSR, and the United Kingdom. Generally, these evolutionary reactors rely on proven components and systems.
- The third group consists of advanced reactors characterized by revolutionary or innovative designs, which might show promise after a longer period. The reactor concepts that drew the most attention at the workshop were the advanced modular high-temperature gas-cooled reactor (MHTGR) systems being developed in the Federal Republic of Germany, Japan, USA, and USSR; the Swedish process inherent ultimate safety (PIUS) reactor based on the principle of entirely passive safety systems; and the mid-sized innovative power reactor inherently safe module (PRISM) being developed in the USA. Most of these advanced reactor concepts are modular designs that would promote engineering and manufacturing simplicity, economy, and demand-response flexibility. By their very nature, these advanced reactors are not proven by testing and experience, and it will be many years before applicable safety analysis, experiments, codes, and standards become available. As design work continues and additional designs are proposed, the open question is whether existing safety criteria would cover all features of the new designs or whether more stringent criteria will be necessary to handle issues raised by these advanced technologies. One possible implication of the INSAG-3 report would be the need for prototype testing of new reactor designs before regulatory approval and utility commitment. Indeed, the proponents of these revolutionary reactors face a dilemma: designers need funding now, which may be difficult to obtain until funders have greater confidence that innovative reactor designs can meet stringent safety criteria.

The importance of the defence-in-depth strategy for achieving international safety objectives at all nuclear power plants was underscored at the workshop. The subject of maintaining containment integrity — the last safety barrier in a defence strategy — figured prominently in the discussions of safety targets for limiting significant environmental releases of radioactivity and the concurrent need for off-site emergency response. Several countries reported progress in the development of sturdy containment systems capable of maintaining their function even in the event of hydrogen detonation, steam explosions, or other causes of extensive overpressure. Many of these developments would also apply to breeder-type reactors.

There was strong support expressed for the use of probabilistic safety assessments (PSAs) in defining safety issues for the next generation(s) of nuclear plants, especially with methodological advances in human reliability assessments and in treating common-cause failures and uncertainties of external events. The example was given of how the combined application of deterministic and probabilistic safety analyses has promoted design consistency for the new European Fast Reactor (EFR) project and also allowed for flexibility in response to different national safety requirements.

At the institutional level the goal of higher safety levels for future nuclear installations would require an even firmer commitment to safety on the part of the "safety culture" — the designers, manufacturers, operators, maintenance personnel, regulators, and the host of other professionals whose work bears directly or indirectly on the safety of nuclear power plants. Education and training were considered the key to this all-pervasive safety thinking, so that the strategic planning of training programmes was strongly endorsed, not only for maintaining existing skills and capabilities but also for meeting the anticipated heavy demand worldwide for qualified personnel at nuclear power plants.

Irrespective of these developments, participants agreed that the best strategy for gaining utility and regulatory acceptance of the next generation(s) of nuclear plants should be a consistent global track record of safe, reliable, and cost-effective operation of today's plants. In contrast, the strategy for gaining public acceptance would have to go beyond these criteria.

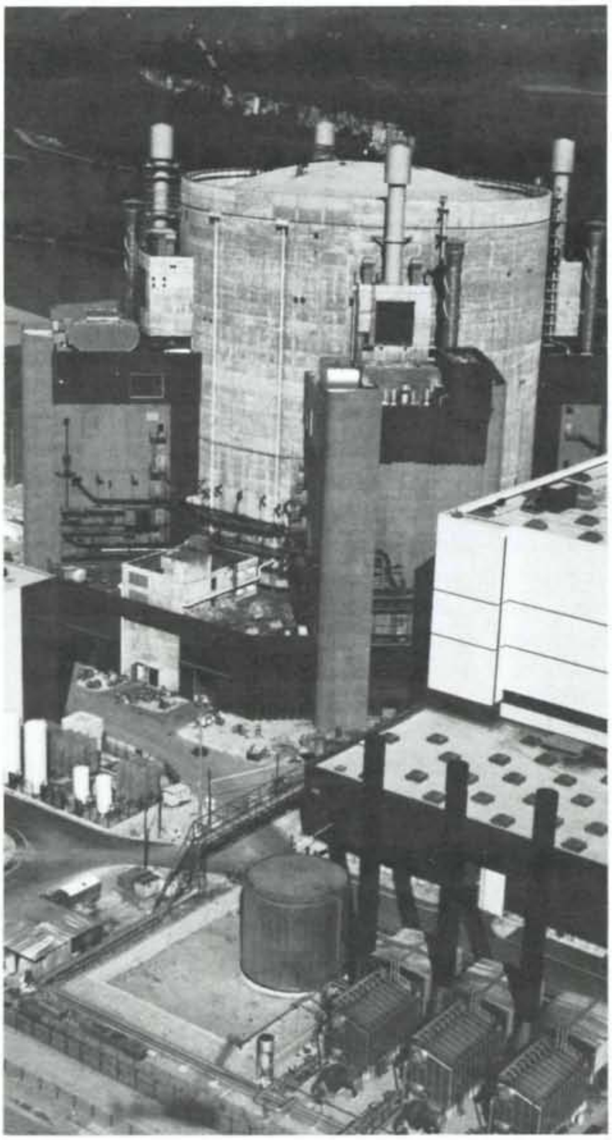
The IAEA/ANL workshop

The International Workshop on the Safety of Nuclear Installations of the Next Generation and Beyond was held from 28–31 August, 1989, in Chicago, USA, and sponsored jointly by the International Atomic Energy Agency and the Government of the United States of America through Argonne National Laboratory. More than 200 professionals participated, representing nearly two dozen countries with existing or emerging nuclear power programmes.

The workshop served as a timely international forum for examining the basic safety concepts and objectives that should underlie a possible future large-scale deployment of nuclear energy. There were 30 invited presentations and a number of panel discussions that addressed issues including the environmental impact of fossil-fuel energy technologies; future needs for nuclear power; and safety aspects of existing and advanced types of nuclear power plants. Additionally, 10 exhibits featured advanced reactor design concepts and other safety advances for nuclear power plants that are being pursued in several countries. Special addresses were presented by Mr Frederick M. Bernthal, Assistant Secretary, Bureau of Oceans and International Environmental and Scientific Affairs, US Department of State; Mr Kenneth C. Rogers, Commissioner, US Nuclear Regulatory Commission; and Mr Chauncey Starr, President Emeritus, Electric Power Research Institute, Palo Alto, California.

Workshop proceedings are being published by the IAEA; further information may be obtained from the IAEA Division of Publications.

The Superphénix fast-breeder reactor in France.



Building public confidence

From discussions it was evident that members of the nuclear community are well aware of problems frustrating a constructive dialogue with the public about the future of nuclear power and are bent on resolving these. Less clear is how to (re)build the confidence of an increasingly sceptical public in the uses of nuclear technologies.

The nuclear industry's communication effort has often been guided by utility organizations, which in many countries operate both nuclear facilities and coal-fired plants. Thus many organizations have adopted a rather delicate approach to informing the public about the relatively high health and environmental risks posed by coal combustion and the use of coal by-products.

The technical jargon of nuclear specialists has served as a barrier to communication with the public. Frequently, terms used to describe safety improvements for nuclear power plants, such as "inherently safe", "walkaway safe" and "transparently safe", have been misinterpreted by most of the public who are not well versed in this terminology. When used indiscriminately, these terms have painted a negative picture of the safety performance of today's plants and held out the promise of a "perfectly safe" or "zero-risk" technology that is impossible for any industry to keep, no matter how far it goes in its safety pursuits.

The well-intended use of PSA findings as a vehicle for communicating the safety message to the public has been largely counterproductive. Based on their experiences with communication on nuclear issues, several participants reported that people want reliable and comprehensible information about what is being done to prevent accidents and to respond to a radiological emergency, not bland statements about the mathematical improbability of occurrence. Indeed, the severe accidents at Three Mile Island and Chernobyl represent the improbable actually happening, for which the consequential environmental impacts and mitigating measures taken have mattered most to people. For many participants, the practical answer to the public's question of "how safe is safe enough" would depend on whether the institutions involved could foster confidence in their ability to manage an accident and mitigate its consequences, and not on any quantitative assurance derived from safety assessments.

To (re)gain credibility and trust, the nuclear industry will also have to properly address people's misconceptions about the radiobiological and radioecological impact of nuclear power, and nuclear accidents in particular. In effect, the realities of the radiation environment must become part of the public consciousness.

Towards a higher radiation literacy

Many people, and even some scientists and engineers, were believed to lack a broad picture of radiation as an inherent part of life, one that encompasses the patterns and magnitudes of exposure, the defined radiobiological risks, and the tangible benefits from the seemingly unlimited uses of radiation. And yet, paradoxically, people have always lived in a radiation environment. The paradox extends further: nuclear power, a negligible contributor to the average dose of radiation people receive, is the target of most public concern, whereas radiological medicine, the largest and increasingly most common man-made source of radiation exposures, is calmly accepted for its acknowledged benefits. There is even less public apprehension about the most prodigious and least controlled sources of exposures, such as the naturally occurring radionuclides in soils and dwellings.

A proposal was made for accelerating the communication process about the realities of the radiation environment through a concerted international effort. Three complementary objectives were advanced that would provide an informed basis for individual and collective decision-making about a given radiation practice. First, low-level radiation should be viewed as a fact of life. The second objective would be to help people understand that the real impact of low-level radiation on human health and the environment is so minor that it should have little relevance for the individual and society as a whole. This may require acknowledging that the costly philosophy now governing radiation safety decisions is not necessarily the best for the public interest.

The third and most encompassing objective would address the comparative health and environmental impact of nuclear power along with those of its viable alternatives. It would require demonstrating that while nuclear power in normal operation is environmentally benign, this is not so for the alternatives. Specifically, it would address many people's excessive anxiety about a nuclear accident by showing that the real consequences of a severe accident are tolerable both in terms of health effects and environmental contamination and the resultant need for evacuation and relocation.

For its part, the IAEA is seriously considering a new activity devoted to radiation acceptability, an area not yet properly explored at the international level. A first step would entail establishing an advisory group composed of credible scientists and scientific communicators who would openly and comprehensibly explain risk-related statistics and comparisons and aid in the formulation of practical radiation safety principles. Their work could help lay the foundations for a major international conference on radiation, health, and society. A profitable second step would have this group, with some haste, reassess the past and on-going suitability of the radiation safety response to the Chernobyl accident, within the framework of a fuller and more comparative view of the effects of low-level radiation, with the full benefits of hindsight. A new IAEA programme on comparative assessments of nuclear power with alternatives aims to establish a reliable and authoritative repository of information on the human health and environmental risks posed by the total cycle of the global energy system.