Safety experts of the world write to Director General *IAEA*

The people listed below are nuclear safety experts from various countries who for many years have been engaged in research and development, design, construction, operation, management and safety regulation of nuclear power plants (NPPs). We express here our deep concern about the future of nuclear power in view of the consequences of the earthquake and tsunami at the Fukushima-Daiichi NPP in Japan. We are confident that only nuclear power that avoids being a threat to the health and safety of the population and to the environment is acceptable to society. Although comprehensive analysis of this tragic event is not feasible at the moment due to lack of complete data on the events that occurred, we wish to voice our opinion about severe accidents at civilian nuclear power plants and suggest additional measures to avoid them in light of the experience so far gained at Fukushima. First, we review the improvements made in safety following earlier severe accidents.

The accident at Three Mile Island Unit 2 (United States, 1979) did not cause injuries of the plant personnel or the population. There was no significant radioactive contamination outside the plant. Even so, the accident caused a reduction of investments in new NPPs due to a decreased interest from private investors. Studies of the accident confirmed the robustness of safety principles employed in the design of that type of NPP. At the same time, the accident revealed significant weaknesses in the implementation of those principles, including design of instrumentation and controls, operating procedures and the realism of the analyses supporting them, personnel training, and feedback of operating experience. Lessons learned from the accident allowed improvements with regard to human factors (how people and NPPs relate), design-specific probabilistic safety assessments, emergency preparedness, and safety systems. This accident also led the nuclear industry to design new NPPs that include passive safety features not dependent on the availability of electrical or mechanical equipment.

The accident at Chernobyl Unit 4 (Soviet Union, 1986) was the largest in history. The spread of the accident to the other reactors at the plant was prevented but cost the lives of thirty-one members of plant personnel and firemen. There was widespread radioactive contamination over large parts of Europe. Many thousand people had to be relocated from their homes near the plant. Regionally, the accident produced excess thyroid cancers and

other negative effects on human health and had a large psychological impact on the public. The accident also had significant political resonance. The design of the reactor at Chernobyl was very different from the light-water reactors at Three Mile Island and Fukushima. Studies of the Chernobyl accident highlighted significant design deficiencies (core instability, inadequate design of control rods, unsatisfactory characteristics of confinement) as well as deficiencies in safety culture in the former Soviet Union. In harmony with international guidance and in compliance with upgraded national safety standards, significant modernization was achieved in NPPs in the former Soviet Union. Moreover, the IAEA International Nuclear Safety Advisory Group (INSAG) issued reports on the accident and developed Guidance on General Safety Principles and Safety Culture for improving NPP safety worldwide. The nuclear industry created the World Association of Nuclear Operators (WANO) for a continuous review and feedback of nuclear power plant operating experience.

On learning the lessons from these accidents, the approaches to safety regulation and NPP design were upgraded, and an international nuclear safety regime based on the Nuclear Safety Convention and other international accords was established. The fundamental principle of safety culture has become a daily routine.

International cooperation was strengthened to improve the fundamental requirements and criteria to ensure safety of nuclear power and to incorporate them into the design basis of NPPs of the next generations. The Nuclear Safety Convention also called for reviewing the safety of existing NPPs to identify and implement reasonably practical improvements.

The importance of nuclear education and training was acknowledged, which led to the establishment of the World Nuclear University (WNU) and the creation of regional nuclear education networks in different parts of the world.

Severe nuclear accidents seemed to have passed into history. Nevertheless, another one has happened. Why?

A detailed analysis based on more data is needed to give a full answer, but some preliminary observations deserve to be made now. On one hand, the Tohoku-Taiheiyou-Oki Earthquake on March 11, 2011 shows that nuclear power plants are capable of withstanding some catastrophic natural events better than many manmade objects. On the

other hand, it appears that, in the siting and design of the Fukushima-Daiichi nuclear plants, an unlikely combination of low-probability events (historic earthquake plus historic tsunami leading to loss of all electrical power) was not taken sufficiently into account.

In fact, complex combinations of initiating events unforeseen in plant designs resulted in all the severe accidents described above. In addition, these accidents took emergency responders outside the range of circumstances for which they were trained and equipped. Moreover, hindsight shows that relatively inexpensive improvements, detectable by more extensive analysis beforehand, may have avoided these accidents altogether.

These observations lead us to conclude that more can be done to prevent severe accidents and to limit their consequences should they nevertheless occur. We know that due to a natural tendency of human beings for complacency, the nuclear safety regime can erode; i.e., if we do not continuously pursue safety, we can loose safety. There are occasional signs that national and international safety assessments and peer review missions are becoming more focused on demonstrating that safety is satisfactory and in compliance with national and international standards than on finding and correcting deficiencies, be they in design, operation, or the standards themselves. Therefore, we need to reinforce our dedication, not only in words but also in actions towards a questioning attitude, thereby assuring continuous improvement in the safety of NPPs.

Thus, there is a need to continue to audit and improve the safety culture at all levels of nuclear power management and regulation, achieve true attention to detail, implement effective programs to identify, analyze and correct safety deficiencies, and effectively manage nuclear knowledge.

Special attention should be paid to the quality of personnel training for nuclear power. To achieve this goal, NPP vendor countries should establish centers to train specialists for nuclear technology in recipient countries. Top professionals involved in nuclear power generation should not only "know what" and "know how" but also "know why" in order to deliver difficult and critical decisions in time to deal with unforeseen circumstances. In addition, regulatory organizations should improve the effectiveness of expert missions and inspections, and guarantee openness and honesty in reporting the findings of such inspections to the public. Routine inspections are important; however, even more important is the capability to recognize early indications of low probability incidents or circumstances.

In addition to further measures to prevent severe accidents, more must be done to limit the consequences of such accidents if they occur. It is important to finalize the in-depth safety assessments of severe accident vulnerabilities for each NPP plant design and to develop severe accident management provisions for all operating nuclear reactors. Measures for accident management should be supported with robust technical capabilities, backup equipment, and procedures for restoration of core heat removal before the onset of fuel melting. Plant staff should be well trained in flexible severe accident management.

Renewed attention should be given to general safety requirements for plants built to earlier safety standards in view of the considerable remaining operating time envisaged for many such plants. A more internationally harmonized approach in this area should be sought. In light of the common mode failure of redundant safety systems (electric power) caused by the tsunami at Fukushima, authorities should ask to what extent this failure and other common mode failure vulnerabilities in operating plants might be revealed by current technology.

The safety requirements for future NPPs should be refined to assure that their backup cooling systems are able to operate for a long enough time following a complete loss of on-site and off-site power. These future NPPs should be able to promptly restore or compensate for lost power. Passive systems and advanced technologies for system engineering, materials, information management and communications should be applied to new NPPs. New plants should be sited away from areas of extreme natural and manmade hazards. Risk assessments and risk governance should be used for optimization of plant design and operation but not substitute for deterministic safety justifications. The next-generation NPPs should ensure safety even if operating personnel are not able to provide immediate response in an emergency.

The responsibility and qualifications of government and corporate officials involved in nuclear safety-related decision-making should be reviewed and enhanced by national authorities where needed. National nuclear institutions in all countries, including nuclear safety regulators, should be accountable for their actions and transparent in nuclear safety communications so that they receive and deserve the trust of the public. It is necessary to ensure that national nuclear safety regulators in all countries are fully independent in their decision-making on nuclear safety and to assure their competence, resources and

enforcement authorities. Insurance premiums for all NPP owners should be tied to plant safety performance.

The safety of nuclear power goes beyond national boundaries. Appropriate measures to further strengthen the international nuclear safety regime should be identified and implemented after proper discussions, whether it will be within the framework of the Nuclear Safety Convention, the IAEA, regional bodies like the EU or industry organizations like WANO. A critical question should be what measures would be most effective in further promoting a high level of nuclear safety worldwide. Would it be to create new international frameworks, for example in the shape of an international regulatory agency entrusted with issuing binding international safety standards and performing compulsory inspections, or would it be to further develop and strengthen existing frameworks, emphasizing national responsibilities in combination with rigorous international peer reviews? It is to be expected that the international conference to be convened at the IAEA in Vienna in June of this year will provide a starting point for discussions of such measures.

Requirements for new countries wishing to start using nuclear power should be developed and incorporated into the international nuclear safety regime. Such countries must demonstrate their ability to uphold high international standards with regard to safety, security and non-proliferation over the lifetime of their nuclear power programs.

We hope that our recommendations will be accepted for consideration by national authorities and international organizations and that concerted measures will be developed. We are always ready to share our experience and expertise to assist in developing and implementing these and other recommendations to reach our common goal - to "Never Again" experience severe accidents in the future and, as defense in depth, to effectively respond to them should they nevertheless occur.

The following people assisted in the formulation of this Statement and concur in its issuance.

Adolf Birkhofer, Germany, Professor Emeritus, Technical University of Munich; member, INSAG; former chair, German Reactor Safety Commission; former chair, Committee on Safety of Nuclear Installations of OECD

Agustin Alonso, Spain, Former member, INSAG; former member, director and commissioner of Spanish Regulatory Institution; vice chair, Committee on Safety of Nuclear Installations of OECD

KunMo Chung, Republic of Korea, former member, INSAG; former minister, Science &Technology, Republic of Korea; former president, Korean Academy of Science & Technology; former president, General Conference, IAEA; former vice chair, World Energy Council

Harold Denton, USA, Former director, office of nuclear reactor regulation, US Nuclear Regulatory Commission and President Carter's representative at TMI during the accident

Lars Högberg, Sweden Former member, INSAG; former director general, Swedish Nuclear Power Inspectorate; former chair, steering committee, OECD Nuclear Energy Agency

Georgy Kopchinsky, Ukraine, Former head, nuclear power and industry department, USSR Council of Ministers; former vice chair, Ukrainian nuclear regulatory authority

Jukka Laaksonen, Finland Vice-chair, INSAG; director general, Finnish Radiation &Nuclear Safety Authority

Salomon Levy, USA Former member, INSAG; former design and manufacturing manager, General Electric Atomic Power Equipment Division; honorary member, ASME

Roger Mattson, USA, Former director of reactor systems safety and leader, TMI Lessons Learned Task Force, US Nuclear Regulatory Commission; working group co-chair, INSAG-3

Victor Murogov, Russia Professor, National Nuclear Research University (MEPHI); director, Russian Association Nuclear Science and Education; former director, Institute of Physics and Power Engineering (IPPE); former deputy director general for nuclear power, IAEA

Nikolai Ponomarev-Stepnoy, Russia, Member, Russian Academy of Science; former deputy director, Kurchatov Institute

Victor Sidorenko, Russia, Correspondent member of Russian Academy of Science; former member, INSAG; former deputy director, Kurchatov Institute; former deputy Chairman of the USSR nuclear regulatory authority; former deputy minister of nuclear power of the USSR and Russia

Nikolai Steinberg, Ukraine, Former member, IAEA Standing Advisory Group on Nuclear Energy; former chief engineer, Chernobyl NPP; former deputy chairman of USSR nuclear regulatory authority; former chairman of Ukrainian nuclear regulatory authority; former deputy minister of fuel & power of Ukraine

Pierre Tanguy, France, Former member, INSAG; former inspector general of nuclear safety, Electricité de France

Jurgis Vilemas, Lithuania, Member of Lithuanian Academy of Science; former director, Lithuanian Energy Institute