



The IAEA has established safety standards for nuclear reactors and provides expert review and safety services to assist Member States in their application.

Promoting Safety in Nuclear Installations

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More than 430 nuclear power plants (NPPs) are currently operating in 30 countries around the world. The nuclear share of total electricity production ranges from about 20 percent in the Czech Republic and United States to nearly 78 percent in France and Lithuania. Worldwide, nuclear power generates about 16% of the total electricity.

The safety of such nuclear installations is fundamental. Every aspect of a power plant must be closely supervised and scrutinized by national regulatory bodies to ensure safety at every phase. These aspects include design, construction, commissioning, trial operation, commercial operation, repair and maintenance, plant upgrades, radiation doses to workers, radioactive waste management and, ultimately, plant decommissioning.

NPP operators and regulators have achieved an impressive safety record by making safety their top priority. But how does this work in practice? What are the guiding principles that nuclear safety specialists follow? What is the regulatory framework that operators have to adhere to? And what is the role of international organizations such as the IAEA?

Safety Fundamentals

Defence-in-depth

Nuclear safety measures are designed and implemented to protect workers, the environment and the public at large. The fundamental principle applied to the safety of nuclear installations is the concept of **defence-in-depth**, which means having in place multiple levels of protection.

Different plant activities may be organizational, behavioural or equipment-related, but they are all covered by layers of overlapping safety provisions. In this way, a deficiency or

failure at one level can be compensated for or corrected at another level.

Regulatory Responsibility

Every country operating nuclear facilities has to establish a legal framework for regulating the use of nuclear technology. These laws cover plant and equipment, materials and personnel. There is also a clear assignment of responsibilities for nuclear safety in a wide range of fields such as power generation, medicine and research.

The government is responsible for adopting the necessary legislation. Within this legal framework, the operating organization — which might be a power company or research institute — has the prime responsibility for nuclear safety. In addition, legislation establishes a regulatory body, responsible for inspection work and for enforcing the legal requirements established at national level.

Communicating with the Public

The regulatory authority and the plant operating organization have a responsibility to inform the public about safety matters in a transparent manner. The regulator is independent of the operator, and is therefore recognized as a reliable source of impartial and factual information. Regulators around the world use the IAEA International Nuclear Event Scale (INES) to give the news media and the public a clear account of the significance of problems at nuclear facilities.

International Convention

An important step in the international oversight of nuclear safety was taken in 1994, with the adoption of the IAEA Convention on Nuclear Safety, first international legal instrument dealing directly with the safety of nuclear installations. The Convention is essentially an incentive instrument. It is not designed to ensure that obligations are

met by control and sanction. It is based on a common determination to develop, promote and achieve higher levels of safety through regular meetings of the parties.

The Convention obliges the parties to draw up reports on the implementation of their obligations and to submit these documents for 'peer review' by all countries, which are part of the correction at meetings, held every 3 years.

IAEA Nuclear Safety Standards

The IAEA produced the first comprehensive, non-national set of publications on safety standards for nuclear power plants. A revision of the standards is being developed to reflect current trends and challenges facing the nuclear industry, such as deregulation, competitiveness, plant ageing and potential loss of experience. The upgrade of the standards is already reflected in IAEA guidelines, seminars, workshops, training courses and projects developed in line with the Agency's work plan.

Designing for Safety

Safety concepts

In the design phase of a nuclear facility, safety analysis is conducted on the whole range of plant situations — normal operation, anticipated operational occurrences and possible accidents. By examining all these situations in detail, the robustness of the plant design and the effectiveness of the safety systems is demonstrated.

A safely designed nuclear power plant is one that ensures the following basic functions at all times, even in an accident situation:

- control of the nuclear chain reaction in the reactor core,
- removal of heat from the core, and
- containment of the radioactive materials.

All possible accident scenarios have to be taken into account at a very early stage in the design process.

Design principles

IAEA Safety Series No. 110, entitled the Safety of Nuclear Installations, specifies the following design principles:

- The design shall ensure that the nuclear installation is suited for reliable, stable and easily manageable operation. The prime goal shall be the prevention of accidents.
- The design shall include the appropriate application of the defence-in-depth principle so that there are several levels of protection and multiple barriers to prevent releases of radioactive materials, and to ensure that failures or combinations of failures that might lead to

significant radiological consequences are of very low probability.

- Technologies incorporated in a design shall be proven or qualified by experience or testing or both.
- The systematic consideration of the man-machine interface and human factors shall be included in all stages of design and in the associated development of operational requirements.
- The exposure to radiation of site personnel and releases of radioactive materials to the environment shall be made by design as low as reasonably achievable.
- A comprehensive safety assessment and independent verification shall be carried out to confirm that the design will fulfill the safety objectives and requirements before the operating organization completes its submission to the regulatory body.

Human factors

There is a high potential for error when working with complex systems that have inter-related sub-systems, generating large amounts of data. A safe design is 'operator friendly' and aimed at accommodating human error. Physical or administrative barriers are used to prevent human error or to limit its effects. At the user interface (where there is a relatively high potential for error), the operator should be presented with information in a way that is manageable, allowing sufficient time for decision-making and action.

A safe design is also aimed at promoting the appropriate operator actions with proper regard to the time available, the psychological demands of the situation and the physical environment. The need for operator intervention in the short term should be minimized. When prompt action is necessary, it should be initiated automatically. If manual operation of the plant is required, equipment must be in an accessible position, taking into account all anticipated environmental conditions.

Operating Safely

Good design, manufacture and construction are pre-requisites for high levels of safety. But the ultimate responsibility for safe operation lies with the operating organization. During the operational phase of a plant's life, the personnel who operate the plant share this responsibility. Operational safety largely depends on:

- the capability and competence of the personnel responsible for all aspects of plant operation, together with their attitude and approach to meeting their responsibilities.
- the activities and the operator support features at the human-system interface, and local management

systems that help operators to do their work, such as policies and procedures, the working environment, training, communication methods, supervision, work practices and management methods.

Safety culture

A plant is considered to have a strong safety culture when the characteristics of the organization and the attitudes of individuals are geared towards protection and safety. Safety management and safety culture are inter-related and inseparable. Safety emerges from everything that management does or does not do. To manage safety effectively, a systematic approach has to be adopted. At the same time, there is still the human element and the potential for human error, so both have to be taken into account. Managers must be aware of how their approach affects individual and collective behaviour.

Advances in operational safety

Two factors — excellence in nuclear operation and an uncompromising attitude to safety — lead on to strong economic performance in nuclear power generation. In recent years, significant improvements have been made in terms of safety performance and increased production.

This progress is confirmed by international organizations that assess plant performance. Statistics known as ‘performance indicators’, compiled by the World Association of Nuclear Operators (WANO), have shown continuous improvement. Experience gained from use of the International Nuclear Event Scale (INES), which measures the severity of plant problems, clearly indicates a decrease in the number of events that are of higher significance.

Managing Risks

Risk assessment and management

Possible accident sequence scenarios in a nuclear power plant are identified and analyzed in a process called a Probabilistic Safety Assessment (PSA). Most plants around the world have had PSAs carried out on them. In these assessments, reliability models are developed in a comprehensive and structured manner to produce probabilistic estimates of risk. A PSA is therefore a powerful tool for assessing the risks associated with a particular plant.

There is general agreement in the nuclear energy field that a plant’s PSA should be a living assessment of safety. In other words, it should be updated as and when necessary to reflect current design and operational features, and should be used by designers, utilities and regulators alike. An increasing number of plants are using PSAs to monitor safety/risk factors, prioritize safety improvements and optimize operational safety.

Safety goals

The International Nuclear Safety Advisory Group (INSAG), an advisory body to the IAEA Director General, has recommended probabilistic targets representing an acceptable level of risk for different hypothetical accident situations. These recommended targets consist of numerical values and are known as Probabilistic Safety Criteria (PSC). National regulators may insist on the risks being even lower than the levels recommended internationally. The targets cover the hypothetical frequency of damage to the reactor core; a large release of radioactive material; and health effects on members of the public.

For **core damage frequency** — the most common measure of risk for most nuclear power plants — INSAG has proposed a one in 10 000 chance per year for existing plants and a one in 100 000 chance per year for future plants.

A **large release of radioactive material** would have severe implications for the public and would require the implementation of off-site emergency arrangements. For this, the INSAG targets are a one in 100 000 chance per year for existing plants and a one in 1 000 000 chance per year for future plants.

For **health effects on members of the public**, INSAG has given no guidance on targets. However, in some countries, the target for the individual risk of death is set at a one in 1 000 000 chance per year.

Regulatory Oversight and Effectiveness

Essential Infrastructures

The regulation of nuclear safety is built on basic governmental and legal infrastructures. These have to cover not only reactor operations but also radiation safety, radioactive waste management and the transport of nuclear materials. Guidance provided in this area is directed towards developing the legal framework for establishing a nuclear regulatory body. The guidance also identifies the level of authority that the regulatory body must be given to function properly and carry out its responsibilities.

A primary function of the regulatory body is to authorize the activities of those who make use of nuclear energy. The regulatory body first needs to have in place the safety principles and criteria that it will use as the basis for its decision-making. Only then will it be in a sound position to grant permission for different activities to take place.

Another primary function for the regulator is inspection work to determine whether plant licensees or licence applicants are in compliance with the conditions that have been set. If non-compliance is identified, the regulatory body has the power to enforce the conditions of the authorization. For instance, a regulator might refuse to renew a plant operating licence until certain important conditions have been met.

The Role of the IAEA

The IAEA performs two safety-related functions, which are laid down in its Statute (Article III.A.6). These are:

- establishing standards of safety for the protection of health against the effects of radiation, and
- providing for the application of those standards at the request of a Member State.

The IAEA is devoting considerable efforts to nuclear safety activities world-wide by:

- facilitating the development of international legal agreements;
- developing safety standards which represent international consensus;
- offering international expert review and safety services and training; and
- fostering scientific research, technical co-operation and information exchange.

The IAEA has developed a comprehensive array of safety standards in the fields of nuclear energy, radiation protection, radioactive waste management and the transport of radioactive materials. At times, this has been done jointly with other international organizations. The standards are updated from time to time to ensure they can provide guidance on up-to-date methods for achieving a high level of safety.

In providing for the application of its safety standards the IAEA makes safety review and advisory services available upon request to nuclear power plants and research reactors. A central element of these services are peer review missions conducted by international experts, who provide independent advice, based on IAEA safety standards and best international practices in the areas of Legislation and Governmental Infrastructure, NPP and Research Reactor Design and Operation, and various Safety Assessments. Some 50 safety review missions are conducted by the IAEA every year dealing with the various areas of nuclear installations safety.



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