INSAG-22

# Nuclear Safety Infrastructure for a National Nuclear Power Programme Supported by the IAEA Fundamental Safety Principles

## INSAG-22

A REPORT BY THE
INTERNATIONAL NUCLEAR SAFETY GROUP

INSAG

IAEA
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# NUCLEAR SAFETY INFRASTRUCTURE FOR A NATIONAL NUCLEAR POWER PROGRAMME SUPPORTED BY THE IAEA FUNDAMENTAL SAFETY PRINCIPLES

INSAG-22

A report by the International Nuclear Safety Group

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The International Nuclear Safety Group (INSAG) is a group of experts with high professional competence in the field of nuclear safety working in regulatory organizations, research and academic institutions, and the nuclear industry. INSAG is constituted under the auspices of the International Atomic Energy Agency with the objective of providing authoritative advice and guidance on nuclear safety approaches, policies and principles for nuclear installations (defined as nuclear power plants, fuel cycle facilities, research reactors and support facilities). In particular, INSAG provides recommendations and informed opinions on current and emerging nuclear safety issues, to the international nuclear community and public through the offices of the IAEA.

# FOREWORD

## by Richard A. Meserve
## Chairman of INSAG

This report is intended principally for use by IAEA Member States that are contemplating the introduction of nuclear power for the first time. States with an active nuclear programme that are considering expansion may also find this report of use to renew their knowledge and to correct any weaknesses in their nuclear safety infrastructure. For the purposes of this report, nuclear safety infrastructure is defined as *the set of institutional, organizational and technical elements and conditions established in a Member State to provide a sound foundation for ensuring a sustainable and high level of nuclear safety.*

The report seeks to provide insights drawn from the IAEA Fundamental Safety Principles — the foundation for nuclear installation safety within the IAEA Safety Standards Series. It is intended to complement the extensive guidance given in other important IAEA publications, such as Considerations to Launch a Nuclear Power Programme (2007) and Milestones in the Development of a National Infrastructure for Nuclear Power (2007). These publications reinforce the importance of the various infrastructure issues that bear on the obligation to ensure nuclear safety. It is hoped that this report will contribute to strengthening the Global Nuclear Safety Regime and will assist in achieving and maintaining worldwide a high level of safety at nuclear installations and in the conduct of related nuclear activities.

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# 1. INTRODUCTION

## 1.1. BACKGROUND

1. The safety infrastructure for nuclear installations and activities is intended to provide a framework for safety consistent with the IAEA Fundamental Safety Principles [1].[1] These principles constitute the safety foundation upon which nuclear facilities and activities must be built and operated. For the purposes of this report, nuclear safety infrastructure is defined as *the set of institutional, organizational and technical elements and conditions established in a Member State to provide a sound foundation for ensuring a sustainable high level of nuclear safety.* The IAEA has also published general guidance on infrastructure development in Considerations to Launch a Nuclear Power Programme [2] and Milestones in the Development of a National Infrastructure for Nuclear Power [3].

2. Many countries with limited or no nuclear power experience have recently expressed an interest in developing nuclear power. Some countries with current nuclear power programmes also have plans for expansion. Although many countries considering a nuclear power programme have managerial and engineering experience in constructing and operating large scale industrial and infrastructure projects, they may not be fully familiar with the unique requirements of nuclear power and thus may not fully recognize the major commitments and undertakings that they must assume.

3. The decision of a country to embark on a nuclear power programme entails a long term commitment (of more than a century[2]) to the peaceful, safe and secure use of nuclear technology based on a sustainable organizational, regulatory, social, technological and economic infrastructure. Experience has demonstrated that reliance on robust design and engineered safety systems alone is insufficient to ensure nuclear safety. A nuclear power plant is operated by people, and thus the achievement of safety requires qualified managerial and operating personnel with an appropriately embedded safety culture. Safe operation can only be ensured if there is a comprehensive infrastructure in

[1] The text of the Fundamental Safety Principles is set out in Annex III.

[2] The responsibility may extend for far longer than a century if the country takes long term responsibility for the disposition of spent fuel.

place that is properly maintained and improved throughout the duration of the nuclear power programme.

4. The need for a robust national nuclear safety infrastructure and commitment to the Global Nuclear Safety Regime has to be recognized early in the decision process concerning the start of a nuclear programme or the expansion of an existing one. The main features of such a regime and the ways to strengthen it are discussed in INSAG-21 [4]. In particular, all emerging nuclear countries should become Contracting Parties to the Convention on Nuclear Safety [5] and participate in the Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [6]. In light of the fact that a nuclear accident knows no boundaries, every country engaged in the nuclear enterprise should be connected to the international nuclear community.

### 1.2. SCOPE

5. This report is addressed to all those involved in the planning, regulating, decision making, designing, constructing, commissioning, operating and decommissioning of a new nuclear power project in countries with limited or no nuclear power experience and to those interested in expanding their nuclear power programmes. It is also addressed to reactor suppliers and relevant institutions in the vendor countries who may provide the technology, as well as scientific and technical institutions that may support these activities.

## 2. ELEMENTS OF NUCLEAR SAFETY INFRASTRUCTURE

### 2.1. SCOPE OF THE NECESSARY INFRASTRUCTURE FOR NUCLEAR SAFETY AND TIME FRAME FOR ITS DEVELOPMENT

6. Countries wishing to embark on a first nuclear power plant project will be at various levels of capability, ranging from no experience, to experience with laboratory scale nuclear facilities and industrial applications, operation of research reactors, or handling large amounts of radioactive material. In each

case, the existing safety infrastructure must be further developed or upgraded to meet the challenges associated with a nuclear power programme. The introduction of nuclear power requires the development of a legal and regulatory framework and training of nuclear experts whose combined knowledge adequately covers all areas of science and technology applied at a nuclear power plant. Furthermore, appropriate arrangements for stakeholder involvement are necessary for a sound decision on whether a national nuclear programme is justified.

7. The time period from initial consideration of building a nuclear power plant to actually beginning commercial operation is anticipated to be about 10–15 years in a well managed project. This time period must be used to implement a systematic programme for developing or upgrading the nuclear safety infrastructure. This effort will require a major commitment to provide infrastructure and resources that are sustained over the duration of the nuclear programme.

8. Annex I sets out the main phases in the lifetime of a nuclear power plant. It identifies the corresponding time frames, the main safety related activities, and the necessary safety infrastructure that is required during each phase. New entrants must first consider the requirements for the early phases, but it is useful to consider the implementation, as early as possible, of the requirements of the subsequent phases. For countries with operating reactors wishing to expand their programmes and resume the construction of new units, it will be necessary to recover the knowledge and experience that may have been lost. They may also need to review their licensing and regulatory requirements to bring them up to date with regard to siting, design, construction, commissioning, operation and decommissioning.

9. The interfaces between nuclear safety and nuclear security should be adequately addressed in a harmonized and synergistic manner. Nuclear safety and nuclear security issues should be addressed in such a way that the impacts of each on the other are considered and an appropriate balance is achieved. The safety–security interface is being considered in a separate INSAG report [7].

## 2.2. STAKEHOLDER RESPONSIBILITIES

10. The government is responsible for the decision making process that leads to the implementation of a national nuclear programme. After the decision has

been taken to launch such a programme, the government should immediately start to train the personnel who will implement it. This entails ensuring basic academic education in all technologies that are relevant for construction and operation of a nuclear power plant and involvement in research programmes that develop in-depth knowledge of these technologies. The government must also prepare the nuclear legislation, establish the regulatory framework, and create an effective independent regulatory body. Furthermore, it is strongly recommended that the government organize and conduct an extensive national advisory and consultative process so as to ensure involvement by the general public and the stakeholders. INSAG-20 [8] advocates the establishment of such a societal involvement programme. The dialogue should be supported by the efforts of authorities and institutions to increase public knowledge of nuclear safety issues.

11. The regulatory body is responsible for developing national safety regulations and for verifying compliance with these regulations. It is also responsible for implementing an enforcement policy. The operator is responsible for providing organizational arrangements for safe nuclear power plant operation, training the plant personnel to operate the plant safely, and ensuring that the plant systems and equipment are maintained in good condition. The vendor has responsibility for ensuring that adequate safety standards, consistent with international safety standards, are integrated into the design of the plant, that the quality of the structures and components meets the specified requirements, and that knowledge is transferred to the prospective operator so as to enable sustainable safety performance during all phases of the plant's life. International organizations, such as the IAEA, can provide assistance to newcomers as well as countries with mature nuclear power programmes. Annex II identifies the major responsibilities of the different stakeholders, as discussed in INSAG-20.

## 2.3. PHASE 1: SAFETY INFRASTRUCTURE CONSIDERATIONS BEFORE A DECISION TO LAUNCH A NUCLEAR POWER PROGRAMME IS TAKEN

12. Phase 1 begins with an initiative by political or scientific actors or by private enterprises to explore the feasibility of the nuclear power option. A strong governmental project organization with adequate resources, staff and funding should be established to manage infrastructure development. The advantages and disadvantages of each energy source should be discussed and the risks and benefits derived from nuclear power should be compared with

those of alternative energy sources. The decision should be guided by a feasibility study that is accompanied by a parallel environmental impact assessment (EIA). A strong governmental project management organization with adequate resources, staff and funding should be established to track the progress of infrastructure development. During this phase, the government should emphasize the paramount obligation to ensure safety in all the activities involved in the development of a nuclear power programme.

13. This phase should reflect an understanding of the obligations expressed in Principles 2 and 4 of the IAEA Fundamental Safety Principles. Principle 2 addresses the role of government. Principle 4 addresses the justification for facilities and activities. Justification requires that the benefits prevail over the radiation risks and a full and fair evaluation be undertaken before deciding to introduce or expand nuclear power in the country. At this first stage, the assessment of the balance between risks and benefits may be of a general nature.

14. In launching a nuclear programme, the government should undertake the enactment or amendment of any nuclear legislation or law so as to encompass the new activity. The basic law should identify nuclear activities and facilities that require a specific license and it should establish the licensing process. It should also appoint a regulatory body with the responsibility to develop and promulgate detailed safety regulations and to arrange for the safety evaluation and oversight of the previously defined nuclear facilities and activities. The nuclear legislation should also allocate the safety responsibilities and cover the radiation protection principles, third party civil nuclear liability, fuel cycle activities, transport of nuclear substances and radioactive material, decommissioning, radioactive waste and spent fuel management. The government should also consider the possibilities and means for personnel development through education and training programmes, optimum institutional arrangements for nuclear safety research, and means for stakeholder involvement. A new entrant should commit that any application of nuclear technology will be used for peaceful purposes only and the government should sign all legally binding and non-binding international instruments in that regard. The IAEA has programmes to assist Member States in developing a solid legal foundation for their programmes and the new entrants are advised to take full advantage of these services.

## 2.4. PHASE 2: SAFETY INFRASTRUCTURE PREPARATORY WORK FOR THE CONSTRUCTION OF A NUCLEAR POWER PLANT AFTER A POLICY DECISION HAS BEEN TAKEN

15. Once the country has decided to embark on the introduction or expansion of nuclear power, the basic legislation has been enacted, and the regulatory body created, focused actions are needed to build the national safety infrastructure. The prospective licensee will become the key actor in the development efforts. Principle 1 of the Fundamental Safety Principles, addressing the licensee's primary responsibility for safety, should be clearly understood by all parties. The licensee may be a public or private organization or consortia of both and perhaps might include foreign enterprises. The licensee must be fully aware of its primary responsibility for safety. In this connection, regulations need to be in place specifying the extent to which the licensee should bear liability in the event of an accident. Nuclear legislation should be in place to cover such liability, which in some cases might affect neighbouring countries. The new entrant country should become a Party to the Vienna or Paris Conventions and their amendments.[3]

16. The development of the work processes, human resources and competences of the independent regulatory body is a high priority task in phase 2 and should continue also through phase 3. The major responsibilities of the regulatory body are: (a) to propose and promulgate safety regulations and guides that properly cover all foreseen nuclear activities in the country; (b) to verify compliance with applicable legislation and regulations and to assess the safety of installations and activities through analysis, evaluations and inspections; and (c) to enforce the application of such regulations in case of unanticipated departures or deviations. The safety regulations promulgated by the regulatory body may be derived from the IAEA safety standards, similar regulations in other countries, or from the rules of the supplier country of the technology, if identified.

17. The regulatory body must be effective, which requires that it have adequate authority, effective independence, financial resources, and competent staff. The major attributes of a regulatory body are discussed in INSAG-17 [9]

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[3] The Vienna Convention on Civil Liability for Nuclear Damage of 21 May 1963 and the Paris Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960.

and developed in the IAEA Safety Standards Series.[4] An effective and efficient regulatory programme requires the establishment of procedures to ensure that issues are addressed in a thorough and timely fashion, with priority determined in accordance with the risks involved. The licensing and safety oversight processes should be open to stakeholder scrutiny, to the extent practicable, as discussed in INSAG-20. Even if the regulatory body is technically assisted by supporting technical organizations, either internally or externally, it needs to have sufficient capacity and capability to assess the advice it receives and to make the final safety decisions competently and in an objective manner. Stability in financial resources must be ensured. The government may provide funding, or fees may be collected from licensees. The determination of the process for decommissioning and radioactive waste disposition, as well as the means for funding these activities, should be undertaken during this phase.

18. The strategy adopted by the prospective plant owner should include particular attention to technology transfer and training requirements. A national educational system in nuclear science and technology, complemented by specialized training in foreign nuclear institutes and by industry, is an essential prerequisite to create and sustain a competent workforce. Parties to the Convention on Nuclear Safety are committed to take the appropriate steps to ensure that a sufficient number of qualified staff with appropriate education is available. International institutions, such as the IAEA and the OECD Nuclear Energy Energy (OECD/NEA), conduct training courses on general and specific issues related, inter alia, to licensing, nuclear legislation, safety evaluation, physical protection, inspection techniques, emergency planning and radiation protection. Regional and national courses are often organized jointly and sponsored by the IAEA. The World Nuclear University also conducts summer courses specially tailored to serve the needs of new entrants. National and private universities and educational institutions also provide valuable nuclear education. Maintaining the necessary supporting research infrastructure for nuclear safety is recommended in INSAG-16 [10]. The implementation of a national research programme, including the possible use of a research reactor in the early stage of the project, can provide a sound basis for developing specific nuclear technical competence.

19. Plans and activities related to the development of sustainable radiation protection programmes should be considered during this phase (if not

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[4] For further information on IAEA Safety Standards Series publications, see http://www-ns.iaea.org/standards/default.htm.

undertaken before) and should be fully developed in subsequent phases. The programmes should reflect: Principle 4, Justification of facilities and activities; Principle 5, Optimization of protection; Principle 6, Limitation of risks to individuals; and Principle 9, Emergency preparedness and response.

20. At the end of this phase, the prospective plant owner should recruit competent staff and hire consultants, as needed, for assistance in site selection, the tendering process, and the evaluation and choice of offers from reactor vendors. Vendors, architect-engineers, equipment suppliers, constructors and service companies will also have legal, professional and functional responsibilities for safety, which need to be clearly specified in the respective contracts. The regulatory body will be responsible for ensuring that the safety regulations and the licensing process are developed and well defined in order to provide a foundation for the tendering process. The regulator should also assess the development of the prospective plant owner's organization and capability for assuming full responsibility for safety. The underlying nuclear legislation should give the regulatory body adequate inspection rights during the implementation stage and the plant owner should provide in its call for tenders that such rights be incorporated in all contracts. In the process of evaluating bids from various vendors, it is important to clearly define vendor responsibilities, as well as those of the vendor country.

## 2.5. PHASE 3: SAFETY INFRASTRUCTURE ACTIVITIES TO IMPLEMENT A FIRST NUCLEAR POWER PLANT

21. Implementation includes site selection and characterization, the tendering process with clear definition of roles and responsibilities of each implementing organization, design, and plant construction. The plant owner must have the competence to develop an application based on the regulatory requirements defined in the earlier phases. The regulatory body must also have the competence to evaluate and rule on the application. The main initial concern will be to verify that the safety of the proposed plant is compatible with the site characteristics regarding population distribution, external natural hazards (extreme meteorological, seismological, and hydrological events), human induced events, and the suitability of a final heat sink. Detailed requirements and guides for site evaluation, design and construction are available in the IAEA Safety Standards Series.

22. The application of Principle 3 of the Fundamental Safety Principles on leadership and management for safety should be applied to site selection and

the construction of the nuclear power plant. Similarly, the application of Principle 8, on the prevention of accidents, must be clearly reflected in the design of the plant. In accordance with Principle 3, a project management team with a clear structure and responsibility for safety should be established by the nuclear power plant owner. Leadership in safety must start at the highest managerial levels of the owner and be infused throughout the entire management and workforce. Leadership, safety culture and an overall commitment to safety (see INSAG-4 [11] and INSAG-15 [12]) must continue throughout the lifetime of the plant. In all cases, safety should be integrated into the management structure so that safety requirements are not unduly compromised by financial or other demands. The regulatory body will be responsible for ensuring that the management system is competent, that the corresponding activities are conducted properly, that design, engineering and construction progresses in accordance with the regulatory limits and conditions, and that any deviations are either justified or corrected. The management system is considered in detail in the IAEA Safety Standards Series.

23. Prevention of accidents is best implemented through the defence in depth concept developed in INSAG-10 [13]. The concept entails a design that includes multiple independent and consecutive levels of protection configured in such a way that any isolated failure or a combination of failures at a given level of protection will not propagate and jeopardize safety at the subsequent levels. This concept has been used in the design of all operating nuclear power plants and it has been recently adapted to cope with severe accidents. Specific requirements for safe designs are described in the IAEA Safety Standards Series. It is anticipated that all vendors will offer designs complying with the defence in depth concept, but the plant owner and the regulatory body should confirm that the proposed system fully complies with such requirements.

24. Although there are a variety of ways to approach licensing, it is anticipated that in all cases the plant owner will have to request a construction authorization. Such a request should be supported by an application with the content specified by the regulator. It is generally accepted that a preliminary safety analysis report is one of the key documents. The plant owner should have the necessary expertise to prepare and understand the supporting documentation, while the regulatory body needs to have the capacity to verify the safety of the proposed plant and its appropriateness for the site. At this time, and throughout the construction phase, there should be a close working relationship between the applicant and the regulatory body in order to ensure the necessary flow of information, but without jeopardizing effective

regulatory independence. The plant vendor should support the plant owner in supplying the requested information. But it is recommended that the plant vendor should not have a direct relationship with the regulatory body that is separate from the owner; the owner's responsibility for safety should be reinforced by the licensing and regulatory process.

25. Many mature nuclear countries used a so-called "reference plant" concept for their first nuclear units. Under this approach, an imported plant has the same design and safety features as a plant already licensed by the regulatory body of the exporting country. However, care should be taken to ensure that the selected site and the reference plant site have similar characteristics or that any significant differences have been taken into account.

26. Also any construction by a new entrant will likely be based on the well proven technologies of an exporting country. It might be expected that the design has been licensed by the regulatory body in the exporting country, perhaps with the benefit of analysis by other regulatory bodies. Adherence to proven engineering practices that are demonstrated by analysis, testing and experience and reflected in approved codes and standards is recommended in INSAG-12 [14]. This implies a need for the regulatory body in the importing country to make use of international knowledge, including the experience of the regulatory body in the exporting country. It is highly recommended that the regulatory body in the importing country establish and maintain a knowledge transfer relationship with the regulatory body in the exporting country. For innovative or unproven technologies, any necessary specific regulations will have to be established early in the process.

27. During construction, quality assurance (QA) in the design and in the manufacture, testing and assembly of systems, structures and components is a basic responsibility of the plant license holder. This responsibility cannot be transferred, and a turnkey type of contract signed with the plant vendor should not reduce the licensee's responsibility for QA during plant construction. Because fulfilment of the QA obligations is critically important, it is recommended that a management structure for QA in the licensee organization be independent from the management structure otherwise responsible for construction. Leadership of the QA organization should be drawn from the highest rank of managers, with full authority to reject any design, material, component, system or structure that does not meet the standards for the project. The regulatory body has the responsibility for verifying that the management for QA satisfies the established conditions and that any departure is fully justified or corrected. Analysing international construction experience

is also recommended. The regulatory body must make it a priority to become familiar with the plant. This will allow for effective scrutiny of construction and better oversight during operation. Training of the licensee organization and the regulatory staff that will oversee operation should be implemented at this point to ensure well trained staff before entering the operation phase. Consideration should also be given to engaging operating personnel and regulatory body staff who have been trained in the reference plant or an operating plant of similar design.

## 2.6. PHASE 4: SAFETY INFRASTRUCTURE DURING THE OPERATION PHASE OF THE NUCLEAR POWER PLANT

28. The operation phase can be divided into two distinct periods: commissioning and commercial power operation. Commissioning is a short but very intense period, typically encompassing one–two years in the life of a nuclear power plant. The licensee's management of safety during design and construction has to adjust to accommodate the different obligations that arise in the commissioning and operations stage in the life of the plant. Radiation risks will arise for the first time during commissioning and radioactive waste will be generated. As a result, the emergency preparedness programme should be in place before commissioning begins. Experience shows that the commercial operation phase of present nuclear power plants could last 60 years or more. (The operating life of the new designs is likely to be an element defined by the reactor vendor in the bidding process, and will be adjusted based on economics, safety, and plant performance during operation.) During operation, it is of crucial importance that the safety infrastructure developed during the previous phases continue to be strengthened, safety culture fully implemented, and knowledge and experience maintained, improved and shared. Safety during operation is addressed in the IAEA Safety Standards Series.

29. During commissioning, the operating organization has to accept full responsibility for safety and the plant vendor has to transfer a safe plant to the operating organization. It is recommended that a nuclear safety office or senior advisory group be established to evaluate safety issues that is independent of the plant manager and that has direct access to the top management of the licensee organization.

30. All of the activities in this phase are subject to surveillance by the regulatory body, which is also responsible for granting authorization for the

commissioning activities and operation. The licensee will have to request such an authorization. The request should be supported by a complete set of safety documents, typically including a final safety analysis report, the technical specifications for operation, the radiation protection manual, the emergency plan, and emergency and routine operating procedures, the quality assurance programme for operation and the surveillance test programme. Knowledge and expertise to prepare and to analyse such documents must be available to the plant licensee and to the regulatory body. For new entrants, the "reference plant" approach will likely be valuable in facilitating the preparation of such documents.

31. Operating personnel should have the benefit of an intense, focused training programme that is fully utilized during commissioning. This requires a concentrated and demanding interchange of knowledge and experience among the reactor vendor, other suppliers, the operating organization and other entities with similar operating nuclear power plants. At the time of operation, it is necessary to put into practice the radiation protection principles, emergency preparedness, radioactive waste management and new operational safety management. The regulatory body is also confronted for the first time with the safety oversight of an operating plant. It may issue individual licences/ authorizations to those persons directly involved in taking actions concerning safety during plant operation. A new entrant country should not underestimate the challenge that fulfilling these responsibilities will place on both the operator and the regulatory body and the importance of ensuring satisfactory fulfilment of these responsibilities.

32. Radiation protection should be fully implemented during this phase. It should be considered in site selection and in the characterization and design of the plant, but its significance is largest during operation. Three radiation protection principles are relevant (Principle 4 on justification of facilities and activities; Principle 5 on optimization of protection; and Principle 6 on limitation of risks to individuals). In this phase, when the details of the plant or plants to be built are better known, the regulatory body may require a careful definition and quantification of the risks through application of a probabilistic methodology.

33. Radiation protection is considered to be optimized when that protection provides the highest level of safety that can reasonably be achieved throughout the lifetime of the plant without unduly limiting its use. The concept of ALARA — as low as reasonably achievable — provides the means to implement the optimization principle. The implementation of ALARA should

start with commissioning and continue throughout operation and decommissioning. It is recommended that there be a person responsible for radiation protection who is independent of operations and who reports directly to the plant manager or to a higher level within the operating organization. The main responsibility of such management should be to make sure that the ALARA concept is properly applied, sustained and improved. The regulatory body will be responsible for overseeing ALARA activities in the plant.

34. Radiation risks to individuals are limited by legally established radiation dose limits. The International Commission on Radiation Protection (ICRP) is the most prominent international organization providing the scientific basis for such limits. Radiation limits advocated by the IAEA, other international organizations, and many national radiation programmes are based on ICRP recommendations. The dose limits represent an upper bound of acceptability, but they do not ensure the best achievable protection. It is the combination of optimization and the limitation principles that provides the means to achieve a high level of radiation safety.

35. Many advanced nuclear countries use probabilistic methods to evaluate the safety of their plants. This methodology can discover weaknesses in plant design and operation. The methodology is reviewed in INSAG-6 [15], where its merits and limitations are addressed. Level 1 PSA has proved to be an especially powerful tool to provide a quantitative indication of risk for overall safety evaluation. It can be used to assess whether the plant is maintained in a safe state during unusual equipment configurations in the course of maintenance. And it can provide the basis for so-called "risk-informed regulation" that will permit evaluation of designs, operating procedures, changes in plant configuration, and departures from prescribed limits and conditions. A re-evaluation of the probabilistic safety study is often a prerequisite for plant life extension. New entrants are encouraged to develop the sophistication to apply and effectively utilize probabilistic methodologies.

36. A robust emergency preparedness programme should be initiated in phase 1, but fully implemented during the commissioning phase and considerably improved and exercised periodically during operation (see Principle 9 on emergency preparedness and response). Such preparedness is the last level of defence in the defence in depth concept. Emergency preparedness involves local, regional, national and international authorities and, in particular, may be of significant importance to contiguous States. Thus, the basic responsibilities and procedures for emergency preparedness should be part of the basic

legislation of the country. Emergency preparedness and response are fully considered in the IAEA Safety Standards Series.

37. For each nuclear power station there will be a specific emergency plan that is established in accordance with the basic regulations. The licensee and the regulatory body will be assigned specific responsibilities. The licensee will be responsible for establishing accident management procedures for returning the reactor to a safe state during any accident situation and/or for mitigating any harmful consequences. Coordination with local, regional, national and international organizations is paramount in developing an effective emergency preparedness programme. The regulatory body will be responsible for overseeing such accident management procedures and for conducting and/or reviewing periodic emergency drills and exercises to evaluate the level of preparedness. In the case of a real emergency, the licensee should be prepared to provide the necessary assistance to the authorities, and the regulatory body must closely follow the event with the aim of limiting adverse consequences.

38. The infrastructure for emergency preparedness for nuclear incidents may have some connection to or be part of the national capability for responding to other types of events, but its central objective should be to mitigate adverse radiological consequences to the general public. Emergency preparedness should also cover potential long term post-emergency activities derived from soil and water contamination, as well as plant recovery or dismantling activities. Third-party liability and procedures to cover compensation for radiation damage to persons, property and the environment should be an essential part of the underlying legislation undertaken in phase 1 and should now be well developed.

39. Small and well controlled amounts of mainly short lived radioactive waste are typically released to the environment through gaseous and liquid effluents by nuclear power plants. Limited amounts of solid or solid-convertible radioactive waste are also produced, containing low and medium specific activity intermediate life radionuclides. Most importantly, highly radioactive spent fuel elements with short and long life isotopes are removed periodically from the reactor core. The immediate management of this spent fuel is the responsibility of the licensee, under the supervision of the regulatory body, but the long term disposal of the solid waste is generally the responsibility of the State.

40. The production of radioactive waste and the accumulation of spent fuel elements mean that Principle 7 on protection of present and future generations

has an impact on operations. The principle considers that "subsequent generations have to be adequately protected without any need for them to take significant protective actions". This includes consideration of populations remote from the facility. This requirement is implemented by a radioactive waste management plan aimed at producing the minimum possible amount of waste and by disposing of such waste in a safe and secure manner. It is important that a comprehensive waste management plan that includes a funding arrangement be considered in phase 1 and further developed in phase 2. Requirements for waste management, decommissioning and remediation have been addressed in the IAEA Safety Standards Series.

41. An appropriate effluent control and monitoring system has to be implemented by the licensee to measure and check for compliance with the limits on radioactive releases to the affected population and the environment. A pre-operational background radiation survey is necessary to enable an assessment of the impact should there be normal or unplanned releases of radiation during operations. The regulatory body must exercise the necessary control and vigilance over such activities and the results should be available to the public.

42. The low and intermediate level solid radioactive wastes generated by operational activities are normally stored on-site and eventually disposed of in near surface repositories. The storage and disposal facilities must be ready to receive waste soon after plant operations commence. The management of spent fuel can include reprocessing and reuse, intermediate storage on-site and off-site, and geological disposal of high level radioactive waste. Requirements for geological disposal have been considered in the IAEA Safety Standards Series.

43. Because the operating life of a plant can cover several generations of workers, knowledge management and configuration control are of great importance. Knowledge management requires that the knowledge and the experience gained in each one of the phases in the life of the nuclear power plant are properly documented using the most advanced techniques and managed to ensure its subsequent availability. That knowledge and experience should be used for training reactor personnel and regulatory staff, as well as for the staff of technical support organizations. Useful knowledge and experience can also be gained by participating in regional and international training and international nuclear safety research and safety related computer code development and validation activities. INSAG-16 stresses the importance of

maintaining knowledge, training and infrastructure for research and development in nuclear safety.

44. The obligation to maintain the design integrity of the nuclear power plant throughout its operating life is explained in INSAG-19 [16]. Safety during operation also requires the regular assessment of safety performance and the application of lessons learned from operating experience. These activities, together with a close follow-up of ageing in materials, components and structures, constitute the basis for plant life extension. Defence in depth in operation requires the existence of comprehensive operating procedures, maintenance activities and accident management procedures.

45. Plant operating personnel, as well as those in engineering support, should devote a significant portion of their working time to systematic training. The plant owner should maintain an accredited training programme established in phase 2 and provide for certified trainers and advanced training facilities, including full scale simulators, thermodynamic loops, and electric and electronic circuits. Training that includes extensive utilization of appropriate simulators is strongly encouraged. Regulatory bodies should also continue training programmes for their own staff and those experts in technical support organizations to cover new developments in regulation, safety evaluation methodologies, and inspection techniques.

46. One of the safety principles in INSAG-12 refers to the conduct of independent peer reviews by experts with technical competence and experience in safety. These reviews are "aimed at increasing the effectiveness of practices and procedures of the organization being reviewed" . These peer reviews may be conducted at the national, bilateral, multinational and international level. Upon the request of the government, the IAEA can provide a wide range of services covering general topics and also centred on specific areas. IAEA peer reviews are based on its IAEA Safety Standards Series and Member States are encouraged to use them in the development and maintenance of their programmes. The World Association of Nuclear Operators (WANO) also conducts services of this type at the request of the interested member utilities. Most operating utilities also conduct self-assessments to verify compliance with safety regulations and operating procedures.

47. Specific international instruments for global peer review of nuclear programmes and individual power plant safety are established through the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent

Fuel Management and Safety of Radioactive Waste Management [17]. The conventions are incentive instruments requiring the Contracting Parties to meet various obligations covering siting, design, construction, commissioning, operation and decommissioning. They also cover, inter alia, the availability of adequate financial and human resources, the assessment and verification of safety and safety culture, radiation protection procedures, quality assurance and emergency preparedness. The conventions require the Contracting Parties to submit reports on the implementation of their obligations for peer review at regular review meetings. During implementation of a new project, several such reviews may be held, thus providing ample opportunities to benchmark national efforts against the level of safety achieved internationally.

48. The analysis of operating experience is considered a major source of knowledge that can enable continued improvement in safety. INSAG-23 [18] discusses the importance of applying such knowledge. The IAEA/NEA Incident Reporting System (IRS) is a relevant international means to obtain access to the operating experience of other countries. The regulatory body must also establish requirements for a licensee to report events, accident precursors, near misses, accidents and unauthorized acts, both to guide regulatory action and to ensure that lessons may be learned, shared and acted upon. It is also important to provide feedback on actions that have been taken by both operators and regulatory bodies in response to reported events. The reporting of lessons learned is perhaps the most useful aspect of an effective operating experience feedback programme because the widespread application of those lessons can enhance safety by preventing the recurrence of events.

## 2.7. PHASE 5: SAFETY INFRASTRUCTURE DURING THE DECOMMISSIONING AND WASTE MANAGEMENT PHASES OF THE NUCLEAR POWER PLANT

49. The operation of a nuclear power plant may end because the facility has reached the end of its licence, an accident has occurred there or elsewhere, the operation is no longer economical, or perhaps for other reasons. After the final decision is taken to end the operation of the plant, there will be sufficient time (of the order of a few years) before actual decommissioning work will start. It is necessary to take the eventual future decommissioning into account from the very beginning of the project so that responsibilities are clearly identified. As long as nuclear fuel is on the premises, safety requirements must be followed and the necessary operating personnel must be kept in place to avoid criticality accidents and to ensure cooling of the spent fuel and retention of radioactivity.

In some countries, when the spent fuel and the radioactive waste have been removed from the plant site, there is a transfer of responsibility from the plant owner to the national or private dismantling and radioactive waste management organization.

50. During dismantling the three radiation protection principles (4, 5 and 6), and the waste management principle (7) grow in relative importance. Large amounts of low specific activity solid radioactive waste are produced during dismantling, which should be recycled or disposed of safely. In any case, during the waiting period and during dismantling, safety oversight by the regulatory body must continue. Specific requirements for decommissioning have been developed in the IAEA Safety Standards Series.

51. Principle 7, on the protection of present and future generations, should continue to be applied during the dismantling stage to ensure that the radioactive waste and the spent fuel elements are properly managed by present as well as future generations. The site will have to be restored for other applications as well. Principle 10, on the protective actions to reduce existing radiation risks, should be implemented. This means that site recovery must be justified and the protective measures should yield more benefits than detriments from radiation risks.

# 3. CONCLUSIONS AND RECOMMENDATIONS

52. The introduction of nuclear power in any country requires the early establishment of a long term nuclear safety infrastructure. This is to ensure that the siting, design, construction, commissioning, operation and dismantling of any nuclear power plant and any other related installation, as well as the long term management of radioactive waste and spent fuel, are conducted in a safe and secure manner. The IAEA Fundamental Safety Principles provide a sound basis for a sustainable high level of nuclear safety within the Global Nuclear Safety Regime. INSAG publications could also be of help in this endeavour.

53. The continued operation or expansion of existing nuclear power programmes needs attention to ensure that nuclear safety infrastructure elements are established, reviewed, maintained and upgraded in accordance

with the IAEA Fundamental Safety Principles and the Global Nuclear Safety Regime.

54. The development and implementation of a nuclear safety infrastructure should progress through the five phases in the lifetime of a nuclear power plant described in this report. At the end of the pre-decision and decision making phases, nuclear legislation should have been conceived, developed or enacted, the licensing and regulatory system should be in development or established, a competent regulatory body should be formed and be functioning, and the electric utilities and the regulatory body should have begun to develop technical competence for siting, design, procurement and construction.

55. At the end of the commissioning phase, the nuclear safety infrastructure for operation should be fully operative. During operation, training of operation and maintenance personnel should be carried out fully, as well as training for safety oversight within the regulatory body. Expertise on nuclear safety should be enhanced through the analysis of operating experience and by participating in international confirmatory safety related research.

56. Implementation of emergency preparedness, radiation protection and radioactive waste management principles should be functional as soon as radiation risks emerge during the commissioning phase and be perfected during the entire life of the plant. Plant decommissioning, site restoration and long term radioactive waste management should be taken into account and should not produce unaceptable radiation risks to present and future generations.

57. Countries can take advantage of the experience already gained by other countries by becoming members of the various international instruments and conventions, such as the Convention on Nuclear Safety. In addition, countries are strongly encouraged to use the IAEA Safety Standards for the various activities related to the introduction or expansion of a nuclear power programme in the country and take full advantage of the benefits and associated responsibilities of the Global Nuclear Safety Regime. These actions will help in ensuring a high level of safety in accordance with the Fundamental Safety Principles.

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## Annex I

## MAIN PHASES IN THE LIFETIME OF A NUCLEAR POWER PLANT

| Phase | Duration (years) | Major safety activities | Necessary safety structure |
|---|---|---|---|
| 1. Safety infrastructure before deciding to launch a nuclear power programme | 1–3 | Develop and justify a nuclear power plan. Conduct a public consultation. Develop basic legislation. Create a scientific, technical and educational nuclear programme. | A formal public consultation procedure. A State organization for nuclear plan management, development and oversight. |
| 2. Safety infrastructure preparatory work for construction of a nuclear power plant after a policy decision has been taken | 3–7 | Define responsibilities of the plant licensee. Establish licensing methodology and define basic requirements for siting, design and construction. | Nuclear legislation based on the fundamental safety principles and defining the regulatory infrastructure and the licensing procedure. Independent regulatory body. National system for education and development in nuclear science and technology. An organization responsible for security. |
| 3. Safety infrastructure during implementation of the first nuclear power plant | | | |
| 3(a) Site selection and characterization | 2–3 | Select and characterize the site. Evaluate the site specific conditions to be incorporated into the design basis. | Safety requirements for siting. National institutions with knowledge of extreme natural phenomena and human-made hazards. |

| Phase | Duration (years) | Major safety activities | Necessary safety structure |
| --- | --- | --- | --- |
| 3(b) Design and construction | 5–7 | Select the technology and the plant supplier. Specify and satisfy responsibilities for site preparation, design, construction and equipment procurement. Apply for the construction permit. Initiate site preparation, equipment procurement and detail design. Construct the plant in accordance with the safety requirements. Verify quality. Establish a strong safety culture. Integrate security and safety. | Safety requirements and safety guides for design, construction and quality assurance. Competent regulatory body for safety evaluation and for inspecting equipment fabrication, plant construction and quality assurance process. Expert organizations that can provide independent technical support to the regulatory body. Security requirements that are integrated with safety. |
| 4. Safety infrastructure during the operation phase of a nuclear power plant | | | |
| 4(a) Testing and commissioning | 1–2 | Verify that the plant complies with safety requirements. Apply for operation permit. Perform established nuclear tests. Transfer knowledge and responsibility to operator. | Safety requirements and safety guides for commissioning. Regulatory competence for the review and approval of test results and licensing reactor operators. |
| 4(b) Commercial operation | 40–60 | Operate the plant within the safety requirements. Perform periodic testing and inspection of safety related components, systems and structures. Evaluate operating experience and apply the lessons learned for enhancing safety. Conduct emergency drills. | Safety requirements and safety guides for operation. Competent regulatory body for oversight of plant operation and of radioactive waste and spent fuel management. Party to the international global safety regime and networks for safe operation and sharing operating experience. |

| Phase | Duration (years) | Major safety activities | Necessary safety structure |
|---|---|---|---|
| 5. Safety infrastructure during decommissioning and waste management phases of a nuclear power plant | | | |
| 5(a) Decommissioning | 5–10 | Develop and implement a plan for decommissioning, dismantling and radioactive waste management. Enhance workers internal and external dosimetry. | Safety requirements and safety guides for decommissioning. Competent regulatory body to verify safety, radiation protection and waste management during dismantling. |
| 5(b) Long term management of spent fuel | 15–100+ | Establish and maintain a long term radiological control of spent fuel and high level waste. | Safety requirements and safety guides for the long term storage of spent fuel and high level waste. Regulatory competence to verify compliance with regulations on waste management. |

## Annex II

## MAJOR RESPONSIBILITIES OF STAKEHOLDERS FOR NUCLEAR SAFETY INFRASTRUCTURE

| STAKEHOLDER | | RESPONSIBILITIES |
|---|---|---|
| Government | (a) | Create a State organization to perform a prospective analysis of the need for nuclear power and to manage political and public consultation on a potential nuclear power programme. |
| | (b) | Establish the national policy and strategy for ensuring long term safety of the nuclear power programme. |
| | (c) | Make a decision on launching the nuclear power programme. |
| | (d) | Establish an educational programme and scientific institutions to develop and sustain national knowledge in all areas of nuclear safety. Create a State organization for programme management and oversight. |
| | (e) | Consult or submit the nuclear power programme for approval. |
| | (f) | Create or enhance and maintain a basic nuclear legal system that provides licensing and regulatory framework. |
| | (g) | Establish an independent regulatory body that is dedicated to safety evaluation and oversight and is effectively separated from bodies involved in promotion of nuclear power or in energy policy decisions or their implementation. |
| | (h) | Establish a national strategy for radioactive waste final disposition. |
| | (i) | Become a party in the major international conventions |
| Electrical utilities | (a) | Develop specific projects within the framework of the national nuclear programme. |
| | (b) | Ensure the technical capabilities and economical capacities for the development and execution of the specific projects. |
| | (c) | Enter into negotiations with reactor suppliers and architect engineers. |
| | (d) | Arrange maintenance of the knowledge of the plant safety design basis. |
| | (e) | Ensure the competence and skills for operation and maintenance of all plant systems and equipment for the entire lifetime of the plant. |

| | |
|---|---|
| Electrical utilities | (f) Become a member of international nuclear associations of nuclear operating organizations.<br>(g) Participate in safety related peer reviews to maintain safety.<br>(h) Establish a strong commitment to safety by developing an advanced safety culture.<br>(i) Share construction and operating experiences. |
| Regulatory body | (a) Establish an efficient methodoly for overseeing safety during design, construction, commissioning and operation.<br>(b) Build up sustainable competence in all areas of nuclear safety.<br>(c) Ensure availability of independent expert knowledge as needed to support safety evaluations and inspections.<br>(d) Develop and adopt a complete and satisfactory set of nuclear safety regulations and guides.<br>(e) Maintain close cooperation with regulatory bodies that have licensed similar nuclear power plants and with international safety organizations.<br>(f) Request assistance from international organizations when needed. |
| Suppliers | (a) Offer proposals based on proven technologies and complying within internationally accepted safety criteria.<br>(b) Design, contruct and commission the plant in accordance with internationally accepted safety criteria and with the safety requirements arising from the specific local conditions.<br>(c) Support the plant owner in the long term by planning or verifying safe implementation of the plant modifications and by sharing the operating experience and information on equipment ageing. |
| Public | (a) Participate in the decision making concerning plant licensing and the application of safety principles in national safety regulation. |
| IAEA | (a) Continue the development of capabilities for assisting countries requesting assistance.<br>(b) Develop, maintain and promulgate safety standards.<br>(c) Oversee application of the safety standards through peer review and other means.<br>(d) Maintain an effective system of operating experience feedback. |

## Annex III

## THE IAEA FUNDAMENTAL SAFETY PRINCIPLES

*Principle 1: Responsibility for safety*
The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.

*Principle 2: Role of government*
An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.

*Principle 3: Leadership and management for safety*
Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.

*Principle 4: Justification of facilities and activities*
Facilities and activities that give rise to radiation risks must yield an overall benefit.

*Principle 5: Optimization of protection*
Protection must be optimized to provide the highest level of safety that can reasonably be achieved.

*Principle 6: Limitation of risks to individuals*
Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.

*Principle 7: Protection of present and future generations*
People and the environment, present and future, must be protected against radiation risks.

*Principle 8: Prevention of accidents*
All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.

*Principle 9: Emergency preparedness and response*
Arrangements must be made for emergency preparedness for and response to nuclear or radiation incidents.

*Principle 10: Protective actions to reduce existing or unregulated radiation risks*
Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

## MEMBERS OF THE INTERNATIONAL NUCLEAR SAFETY GROUP

Asmolov, V.

Alonso, A.

Birkhofer, A.

Chang, N.

Couto, A.

Drábová, D.

Echávarri, L. E.

Kang, C.S.

Laaksonen, J. *(Vice-Chairman)*

Lauvergeon, A. (Decobert, V., *delegated*)

Meserve, R.A. *(Chairman)*

Sharma, S.K.

Rising, A.

Slabber, J.

Suzuki, A.

Torgerson, D.F.

Weightman, M.

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