

IAEA Safety Standards

for protecting people and the environment

Design of Fuel Handling and Storage Systems for Nuclear Power Plants

Specific Safety Guide

No. SSG-63



IAEA

International Atomic Energy Agency



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IAEA SAFETY STANDARDS

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The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

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DESIGN OF
FUEL HANDLING AND
STORAGE SYSTEMS FOR
NUCLEAR POWER PLANTS



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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA SAFETY STANDARDS SERIES No. SSG-63

DESIGN OF FUEL HANDLING AND STORAGE SYSTEMS FOR NUCLEAR POWER PLANTS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2020

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FOREWORD

The IAEA's Statute authorizes the Agency to “establish or adopt... standards of safety for protection of health and minimization of danger to life and property” — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures¹ have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered ‘overarching’ requirements, are expressed as ‘shall’ statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it

¹ See also publications issued in the IAEA Nuclear Security Series.

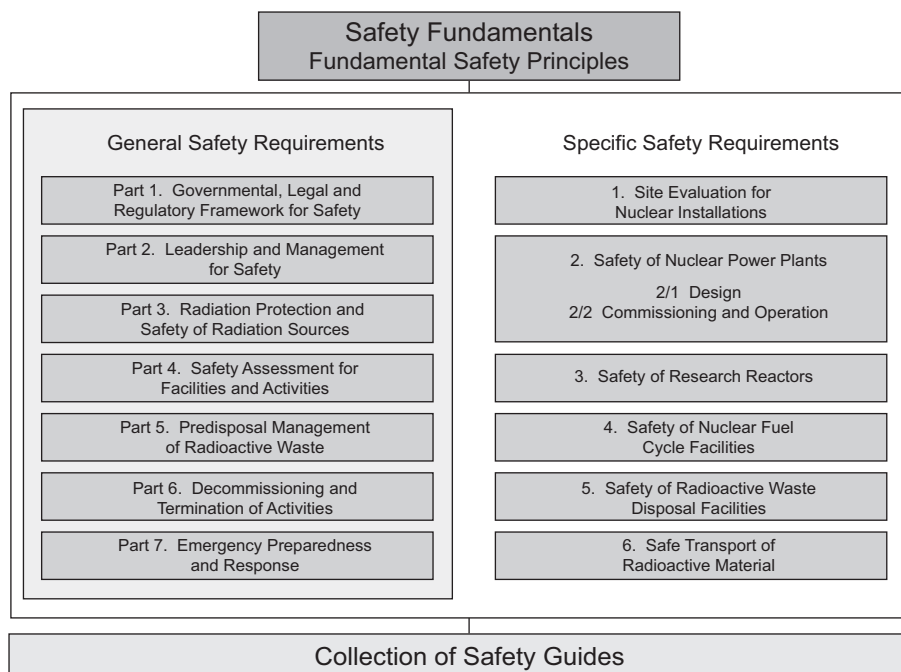


FIG. 1. The long term structure of the IAEA Safety Standards Series.

is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be

used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five safety standards committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards.

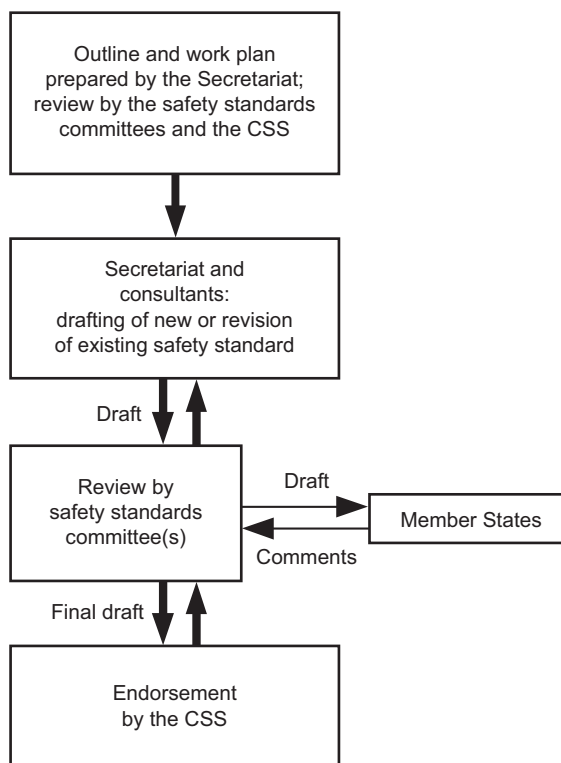


FIG. 2. The process for developing a new safety standard or revising an existing standard.

It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see <http://www-ns.iaea.org/standards/safety-glossary.htm>). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide provides recommendations on how to meet the requirements established in IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1], in relation to the design of fuel handling and storage systems for nuclear power plants.

1.2. This Safety Guide is a revision of IAEA Safety Standards Series No. NS-G-1.4, Design of Fuel Handling and Storage Systems for Nuclear Power Plants¹, which it supersedes.

1.3. This Safety Guide takes into account lessons from the accident at the Fukushima Daiichi nuclear power plant in 2011, in particular in respect of the application of strengthened defence in depth to the design of fuel handling and storage systems in nuclear power plants.

OBJECTIVE

1.4. The objective of this Safety Guide is to provide recommendations for the design of fuel handling and storage systems in nuclear power plants, in order to meet the requirements established in SSR-2/1 (Rev. 1) [1] for these systems.

SCOPE

1.5. This Safety Guide applies primarily to land based stationary nuclear power plants with water cooled reactors. All statements are applicable to light water reactors (i.e. pressurized water reactors, boiling water reactors) and are generally applicable to pressurized heavy water reactors unless otherwise specified. The concepts in this Safety Guide can be applied, with judgement, to other reactor types (e.g. gas cooled reactors, small and modular reactors, innovative reactors).

¹ INTERNATIONAL ATOMIC ENERGY AGENCY, Design of Fuel Handling and Storage Systems for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-1.4, IAEA, Vienna (2003).

1.6. This Safety Guide addresses the design aspects of handling and storage systems for fuel that remains part of the operational activities of a nuclear reactor. From this perspective, this Safety Guide covers the following stages of fuel handling and storage in a nuclear power plant:

- (a) Receipt of fresh fuel;
- (b) Storage and inspection of fresh fuel before use;
- (c) Transfer of fresh fuel into the reactor;
- (d) Removal of irradiated fuel from the reactor and transfer of irradiated fuel to the spent fuel pool;
- (e) Reinsertion of irradiated fuel from the spent fuel pool into the reactor, as necessary;
- (f) Storage, inspection and repair of irradiated or spent fuel in the spent fuel pool, and the preparation for the removal of this fuel from the spent fuel pool;
- (g) Handling of fuel casks in the spent fuel pool;
- (h) Transfer of spent fuel casks.

Handling and storage systems for spent fuel that does not remain part of the operational activities of a nuclear reactor (e.g. as needed for interim wet or dry storage) are addressed in IAEA Safety Standards Series No. SSG-15 (Rev. 1), Storage of Spent Nuclear Fuel [2].

1.7. Limited consideration is given in this Safety Guide to the handling and storage of certain irradiated core components, such as reactivity control devices.

1.8. This Safety Guide is intended for application to uranium dioxide fuels (natural, enriched or reprocessed uranium) and plutonium blended uranium dioxide fuel (mixed oxide fuel) with metal cladding.

1.9. This Safety Guide is primarily intended for application to fuel handling and storage systems for new nuclear power plants. For nuclear power plants designed to earlier standards, it is expected that in the safety assessments of such designs, a comparison will be made with the current standards (e.g. as part of the safety reassessment of the plant) to determine whether the safe operation of the plant could be further enhanced by means of reasonably practicable safety improvements (see para. 1.3 of SSR-2/1 (Rev. 1) [1]).

1.10. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Safety Glossary [3].

STRUCTURE

1.11. Section 2 provides general recommendations for the design of fuel handling and storage systems for nuclear power plants to meet the requirements mainly established in sections 3 and 4 of SSR-2/1 (Rev. 1) [1]. Sections 3–6 provide specific recommendations to fulfil the fundamental safety functions in terms of the general design approach and to meet the requirements mainly established in sections 5 and 6 of SSR-2/1 (Rev. 1) [1]. Sections 3 and 4 provide specific recommendations for the safe design of fuel storage systems and fuel handling systems, respectively. Section 5 provides specific recommendations for the safe design of equipment used for inspection and repair of irradiated fuel, and for handling damaged fuel. Section 5 also provides specific recommendations for the safe design of handling and storage systems for irradiated core components. Section 6 provides guidance on the design of handling equipment for spent fuel casks in the spent fuel pool.

1.12. The Annex describes some operating aspects of the handling of spent fuel casks.

2. DESIGN OBJECTIVES AND DESIGN APPROACH

MANAGEMENT SYSTEM

2.1. The design of fuel handling and storage systems is required to be conducted in accordance with Requirements 1–3 of SSR-2/1 (Rev. 1) [1] and the requirements established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [4]. The recommendations provided in IAEA Safety Standards Series Nos GS-G-3.1, Application of the Management System for Facilities and Activities [5], and GS-G-3.5, The Management System for Nuclear Installations [6], should also be taken into account.

FUNDAMENTAL SAFETY FUNCTIONS

2.2. In accordance with Requirement 4 of SSR-2/1 (Rev. 1) [1], the design should identify the fuel handling and storage structures, systems and components that are necessary to fulfil the following fundamental safety functions for all plant states:

- (a) Maintaining subcriticality of the fuel;
- (b) Removal of the decay heat from irradiated fuel;
- (c) Confinement of radioactive material, shielding against radiation as well as limitation of accidental radioactive releases.

DESIGN APPROACH

Maintaining subcriticality of the fuel

2.3. Paragraphs 2.4–2.6 address the requirements in para. 6.66(a) of SSR-2/1 (Rev. 1) [1].

2.4. Fuel handling and storage systems are required to be designed to prevent criticality by maintaining specified subcriticality margins in all operational states and accident conditions.

2.5. The storage systems for authorized fuel² should be designed to prevent criticality preferably by the use of geometrically safe configurations.

2.6. The design of fuel storage systems should consider the use of physical means or physical processes to increase subcriticality margins in normal operation to avoid reaching criticality during postulated initiating events, including those postulated initiating events arising from the effects of internal hazards and external hazards.

Removal of the decay heat from irradiated fuel

2.7. In accordance with para. 6.67(a) of SSR-2/1 (Rev. 1) [1], fuel handling and storage systems are required to be designed to maintain adequate fuel cooling capabilities for irradiated fuel. As such, these systems should be designed to

² Authorized fuel refers to specific fuel type(s) licensed for use in fuel handling and storage systems.

ensure that the fuel cladding temperature limits and/or the coolant temperature limits, as defined for operational states and accident conditions, are not exceeded.

Confinement of radioactive material and limitation of radioactive releases

2.8. Paragraphs 2.9–2.11 provide recommendations on meeting Requirements 5 and 80 of SSR-2/1 (Rev. 1) [1].

2.9. Design provisions are required to prevent damage to the fuel (rods and assemblies) during handling (see para. 6.66(d) of SSR-2/1 (Rev. 1) [1]). There should also be design provisions to collect and filter radioactive material from the spent fuel storage in order to keep radioactive releases as low as reasonably achievable in operational states.

2.10. Ventilation systems are required to be implemented, as necessary, to reduce the concentrations of airborne radioactive material, and to prevent or reduce direct exposure and contamination in areas with radiation hazards (see Requirement 73 of SSR-2/1 (Rev. 1) [1]).

2.11. Design provisions should be provided to collect and filter radioactive material released and to prevent uncovering of irradiated fuel assemblies in the spent fuel storage in accident conditions.

Shielding against radiation

2.12. Paragraphs 2.13 and 2.14 provide recommendations on meeting Requirements 5 and 81 of SSR-2/1 (Rev. 1) [1].

2.13. Fuel handling equipment and fuel storage systems should include shielding as necessary to keep occupational doses as low as reasonably achievable in operational states.

2.14. Design provisions should be implemented as necessary to prevent a loss of shielding from irradiated fuel resulting in high radiation doses for workers in operational states and accident conditions (see also para. 2.11 of SSR-2/1 (Rev. 1) [1]).

Interfaces of safety with security and safeguards

2.15. To meet Requirement 8 of SSR-2/1 (Rev. 1) [1], items important to safety in relation to fuel handling and storage should be designed taking into account

safety and nuclear security in an integrated manner in such a way that safety measures do not compromise nuclear security and nuclear security measures do not compromise safety. Nuclear security measures should be consistent with the objective and essential elements established in IAEA Nuclear Security Series No. 20, Objective and Essential Elements of a State's Nuclear Security Regime [7], and the recommendations provided in IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5) [8].

2.16. The design of fuel handling and storage systems should also facilitate the application and maintenance of IAEA safeguards, and the State system of accounting for, and control of, nuclear material.

Proven engineering practices

2.17. To meet Requirement 9 of SSR-2/1 (Rev. 1) [1], items important to safety in relation to fuel handling and storage should be of a design that has been proven either in equivalent applications based on operating experience or by the results of a relevant research programme. Alternatively, such items should conform to the design and design verification and validation processes stated in applicable codes and standards.

Safety assessment in design process

2.18. To meet Requirement 10 and para. 4.17 of SSR-2/1 (Rev. 1) [1], the safety assessment of fuel handling and storage systems is required to be performed as part of the design process, with iterations between design stages and safety analyses, and with increasing scope and level of detail as the design progresses. Recommendations on deterministic safety assessment are provided in IAEA Safety Standards Series No. SSG-2 (Rev. 1), Deterministic Safety Analysis for Nuclear Power Plants [9], and recommendations on probabilistic safety assessment are provided in IAEA Safety Standards Series Nos SSG-3, Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants [10], and SSG-4, Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants [11].

Other considerations

2.19. In addition to ensuring that fuel is stored safely, fuel handling and storage systems are also required to facilitate the following activities (see paras 6.66 and 6.67 of SSR-2/1 (Rev. 1) [1]):

- (a) Inspection of the fuel (rods and assemblies);
- (b) Maintenance, periodic inspection, calibration and testing of items important to safety;
- (c) Identification of individual fuel assemblies;
- (d) Arrangements to permit accounting for, and control of, nuclear fuel;
- (e) Decontamination of areas, maintenance and future decommissioning.

2.20. To meet Requirement 12 of SSR-2/1 (Rev. 1) [1], design provisions should be introduced to minimize the potential for generating radioactive effluents and waste during normal operation.

2.21. The effects of irradiation should be considered in the design of structures, systems and components of fuel handling and storage systems.

3. DESIGN BASIS FOR STRUCTURES, SYSTEMS AND COMPONENTS OF FUEL STORAGE

GENERAL

3.1. In the context of this Safety Guide, items important to safety include the pool structure, pool liner, pool cooling systems, pool purification systems, make-up systems, gates and fuel storage racks.

3.2. Items important to safety are required to be designed in compliance with Requirement 80 of SSR-2/1 (Rev. 1) [1], with account taken of Requirements 14–28 of SSR-2/1 (Rev. 1) [1] relevant to:

- (a) The protection of workers, the public and the environment from harmful effects of ionizing radiation in operational states and in accident conditions;
- (b) Adequate reliability of the various systems;