

IAEA Safety Standards

for protecting people and the environment

Design Extension Conditions and the Concept of Practical Elimination in the Design of Nuclear Power Plants

Specific Safety Guide

No. SSG-88



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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**.

Information on the IAEA's safety standards programme is available on the IAEA Internet site

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The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 1400 Vienna, Austria.

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DESIGN EXTENSION CONDITIONS
AND THE CONCEPT OF
PRACTICAL ELIMINATION
IN THE DESIGN OF
NUCLEAR POWER PLANTS



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IAEA SAFETY STANDARDS SERIES No. SSG-88

DESIGN EXTENSION CONDITIONS
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IN THE DESIGN OF
NUCLEAR POWER PLANTS
SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2024

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FOREWORD

by Rafael Mariano Grossi
Director General

The IAEA's Statute authorizes it to "establish...standards of safety for protection of health and minimization of danger to life and property". These are standards that the IAEA must apply to its own operations, and that States can apply through their national regulations.

The IAEA started its safety standards programme in 1958 and there have been many developments since. As Director General, I am committed to ensuring that the IAEA maintains and improves upon this integrated, comprehensive and consistent set of up to date, user friendly and fit for purpose safety standards of high quality. Their proper application in the use of nuclear science and technology should offer a high level of protection for people and the environment across the world and provide the confidence necessary to allow for the ongoing use of nuclear technology for the benefit of all.

Safety is a national responsibility underpinned by a number of international conventions. The IAEA safety standards form a basis for these legal instruments and serve as a global reference to help parties meet their obligations. While safety standards are not legally binding on Member States, they are widely applied. They have become an indispensable reference point and a common denominator for the vast majority of Member States that have adopted these standards for use in national regulations to enhance safety in nuclear power generation, research reactors and fuel cycle facilities as well as in nuclear applications in medicine, industry, agriculture and research.

The IAEA safety standards are based on the practical experience of its Member States and produced through international consensus. The involvement of the members of the Safety Standards Committees, the Nuclear Security Guidance Committee and the Commission on Safety Standards is particularly important, and I am grateful to all those who contribute their knowledge and expertise to this endeavour.

The IAEA also uses these safety standards when it assists Member States through its review missions and advisory services. This helps Member States in the application of the standards and enables valuable experience and insight to be shared. Feedback from these missions and services, and lessons identified from events and experience in the use and application of the safety standards, are taken into account during their periodic revision.

I believe the IAEA safety standards and their application make an invaluable contribution to ensuring a high level of safety in the use of nuclear technology. I encourage all Member States to promote and apply these standards, and to work with the IAEA to uphold their quality now and in the future.

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.

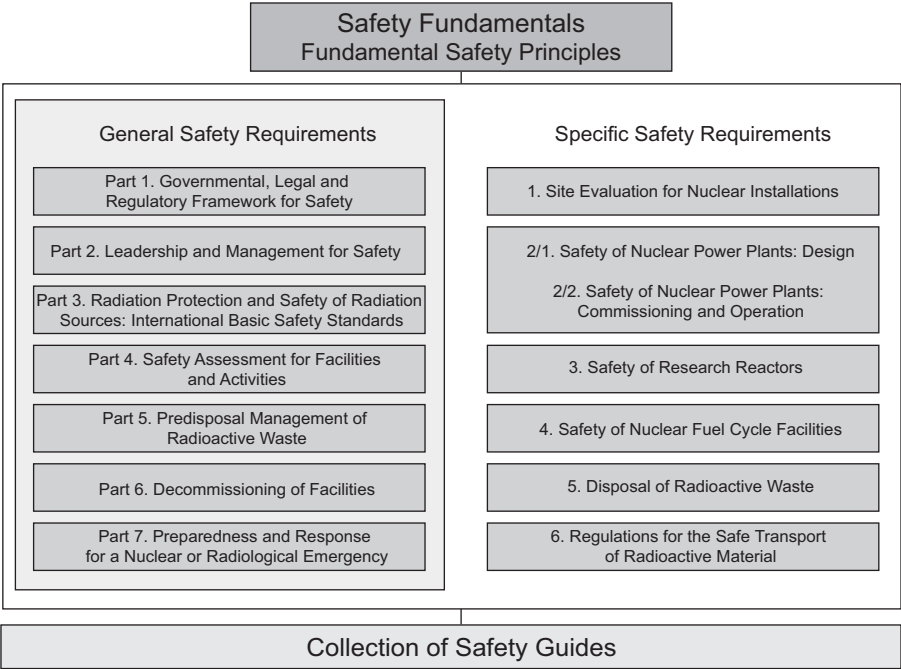


FIG. 1. The long term structure of the IAEA Safety Standards Series.

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.

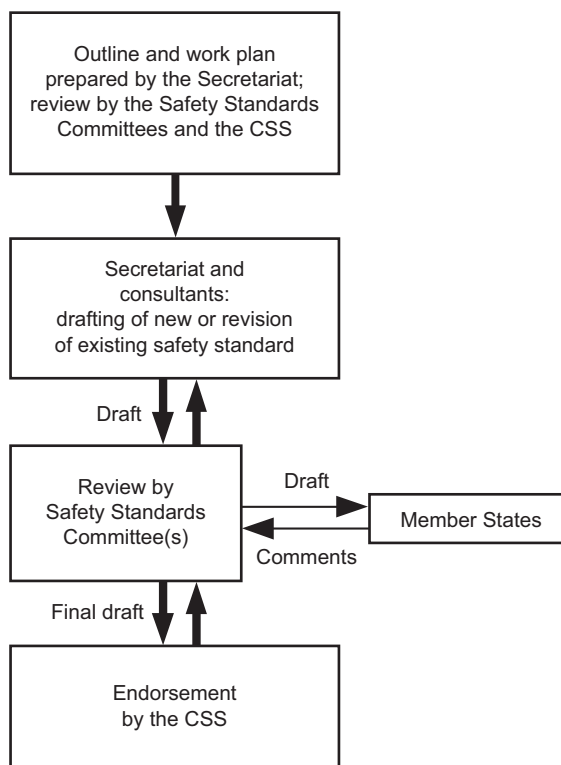


FIG. 2. The process for developing a new safety standard or revising an existing standard.

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 Nuclear Safety and Security Glossary (see <https://www.iaea.org/resources/publications/iaea-nuclear-safety-and-security-glossary>). 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.

CONTENTS

1.	INTRODUCTION	1
	Background (1.1, 1.2)	1
	Objective (1.3, 1.4)	1
	Scope (1.5–1.11)	2
	Structure (1.12, 1.13).....	3
2.	DESIGN APPROACH CONSIDERING THE RADIOLOGICAL CONSEQUENCES OF ACCIDENTS (2.1–2.9)	4
3.	IMPLEMENTATION AND ASSESSMENT OF DESIGN EXTENSION CONDITIONS WITHIN THE CONCEPT OF DEFENCE IN DEPTH	7
	Overall implementation of defence in depth (3.1–3.36)	7
	Assessment of the implementation of defence in depth (3.37–3.54)..	18
	Independence between levels of defence in depth (3.55–3.63).....	22
	Assessment of the independence of the levels of defence in depth (3.64–3.68)	24
4.	PRACTICAL ELIMINATION OF PLANT EVENT SEQUENCES THAT COULD LEAD TO AN EARLY RADIOACTIVE RELEASE OR A LARGE RADIOACTIVE RELEASE (4.1–4.9).....	26
	Identification of relevant plant event sequences (4.10–4.18)	28
	Identification and assessment of safety provisions for demonstrating practical elimination (4.19–4.26)	31
	Demonstration of practical elimination (4.27–4.42)	33
	Documentation of the approach to practical elimination (4.43)	37
5.	IMPLEMENTATION OF DESIGN PROVISIONS FOR ENABLING THE USE OF NON-PERMANENT EQUIPMENT FOR POWER SUPPLY AND COOLING (5.1–5.18)	37
	REFERENCES.....	41

ANNEX I: EXAMPLES OF CASES OF PRACTICAL
 ELIMINATION 45

ANNEX II: APPLICATION OF THE CONCEPTS OF DESIGN
 EXTENSION CONDITIONS AND PRACTICAL
 ELIMINATION TO NUCLEAR POWER PLANTS
 DESIGNED TO EARLIER STANDARDS 56

DEFINITION 61

CONTRIBUTORS TO DRAFTING AND REVIEW 63

1. INTRODUCTION

BACKGROUND

1.1. The publication of IAEA Safety Standards Series No. SSR-2/1, Safety of Nuclear Power Plants: Design, in 2012¹ and its subsequent revision in 2016 as SSR-2/1 (Rev. 1) [1], introduced changes to the requirements for the design of nuclear power plants. These changes include measures for strengthening the application of the concept of defence in depth as follows:

- (a) Including design extension conditions among the plant states to be considered in the design;
- (b) Ensuring by design that plant event sequences that could lead to an early radioactive release or a large radioactive release² have been considered for ‘practical elimination’³;
- (c) Including design features that enable the use of non-permanent equipment for power supply and cooling.

1.2. The incorporation of these aspects into designs of new nuclear power plants will affect the necessary safety assessment. IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [3], establishes requirements for performing the safety assessment for all types of facility and activity, including assessment of defence in depth. Specific requirements for the safety assessment and the safety analysis of nuclear power plants are established in SSR-2/1 (Rev. 1) [1].

OBJECTIVE

1.3. The objective of this Safety Guide is to provide recommendations for the design of new nuclear power plants on the application of selected requirements

¹ INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012).

² An ‘early radioactive release’ in this context is a release of radioactive material for which off-site protective actions are necessary but are unlikely to be fully effective in due time. A ‘large radioactive release’ is a release of radioactive material for which off-site protective actions that are limited in terms of times and areas of application are insufficient for protecting people and the environment [1, 2].

³ For a definition of the term ‘practical elimination’, see the Definition section at the end of this publication.

in SSR-2/1 (Rev. 1) [1] related to defence in depth and the practical elimination of plant event sequences that could lead to an early radioactive release or a large radioactive release. This Safety Guide also provides recommendations in relation to design aspects of defence in depth, in particular on those aspects associated with design extension conditions.

1.4. This Safety Guide is intended for use by organizations involved in the verification, review and assessment of safety of nuclear power plants. It is also intended to be of use to organizations involved in the design, manufacture, construction, modification and operation of nuclear power plants and in the provision of technical support for nuclear power plants, as well as to regulatory bodies.

SCOPE

1.5. This Safety Guide applies primarily to new land based stationary nuclear power plants with water cooled reactors designed for electricity generation or for other heat production applications (such as district heating or desalination) (see para. 1.6 of SSR-2/1 (Rev. 1) [1]). It is recognized that for reactors cooled by other media or for reactors based on innovative design concepts, some of the recommendations in this Safety Guide might not be applicable or fully applicable, or judgement might be needed in their application.

1.6. For nuclear power plants designed in accordance with earlier standards (see para. 1.3 of SSR-2/1 (Rev. 1) [1]), this Safety Guide might be useful when evaluating potential safety enhancements of such designs, for example as part of the periodic safety review of the plant.

1.7. This Safety Guide focuses on the implementation and assessment of the design safety measures provided in para. 1.1. These measures play an important role in the application of the concept of defence in depth, which constitutes the primary means of both preventing and mitigating the consequences of accidents, in accordance with Principle 8 of IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [4].

1.8. As described in para. 2.13 of SSR-2/1 (Rev. 1) [1], defence in depth at nuclear power plants comprises five levels. Plant states considered in the design correspond to one or more levels of defence in depth. This Safety Guide is

structured in terms of the design of safety provisions⁴ necessary for each plant state, rather than for each level of defence in depth. In this way, the significance and the importance of design extension conditions for the safety approach are emphasized. The specific focus of this Safety Guide is on the nuclear fuel, as the main source of radioactivity, with special emphasis on design extension conditions.

1.9. This Safety Guide considers the assessment of the independence of structures, systems and components implemented at different defence in depth levels in a general manner. However, factors that could cause dependence between structures, systems and components, such as environmental factors, operational or human factors, and external or internal hazards, are not addressed in detail in this Safety Guide.

1.10. This Safety Guide does not provide specific recommendations for the design of particular safety features for design extension conditions or for any other plant state considered in the design. Such recommendations are provided in Safety Guides for the design of various types of plant system, such as IAEA Safety Standards Series Nos SSG-56, Design of the Reactor Coolant System and Associated Systems for Nuclear Power Plants [5]; SSG-53, Design of the Reactor Containment and Associated Systems for Nuclear Power Plants [6]; SSG-34, Design of Electrical Power Systems for Nuclear Power Plants [7]; and SSG-39, Design of Instrumentation and Control Systems for Nuclear Power Plants [8].

1.11. This Safety Guide does not consider the specific safety analyses to be carried out for different plant states, as these are addressed in IAEA Safety Standards Series Nos SSG-2 (Rev. 1), Deterministic Safety Analysis for Nuclear Power Plants [9]; SSG-3 (Rev. 1), 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], as appropriate. However, this Safety Guide takes into account the recommendations provided in these publications.

STRUCTURE

1.12. Section 2 sets out the requirements in SSR-2/1 (Rev. 1) [1] that govern the approach to the design of nuclear power plants relating to the prevention of radiological consequences, on which the recommendations in this Safety

⁴ In this Safety Guide, ‘safety provisions’ are used to refer to design solutions applied to structures, systems and components and related operational strategies.

Guide are based. Section 3 provides recommendations on the implementation and assessment of design extension conditions within the concept of defence in depth, and on the independence of the safety provisions considered for the levels of defence in depth. Section 4 provides recommendations on the application of the concept of practical elimination of plant event sequences that could lead to an early radioactive release or a large radioactive release. Section 5 provides recommendations on the implementation of design provisions for enabling the use of non-permanent equipment for power supply and cooling.

1.13. Annex I provides examples of cases of practical elimination that may differ among Member States. Annex II provides some considerations for the application of recommendations included in this Safety Guide to nuclear power plants designed to earlier standards (see para. 1.3 of SSR-2/1 (Rev. 1) [1]).

2. DESIGN APPROACH CONSIDERING THE RADIOLOGICAL CONSEQUENCES OF ACCIDENTS

2.1. This Safety Guide focuses on the design features of a nuclear power plant that provide for the protection of the public and the environment in accident conditions and that should be assessed for compliance with a number of requirements in SSR-2/1 (Rev. 1) [1]. These requirements pertain to the general plant design and particularly to the capability of the plant to withstand, without unacceptable radiological consequences, accidents that are either more severe than design basis accidents or that involve additional failures.

2.2. Requirement 5 of SSR-2/1 (Rev. 1) [1] states:

“The design of a nuclear power plant shall be such as to ensure that radiation doses to workers at the plant and to members of the public do not exceed the dose limits, that they are kept as low as reasonably achievable in operational states for the entire lifetime of the plant, and that they remain below acceptable limits and as low as reasonably achievable in, and following, accident conditions.”

2.3. Paragraph 4.3 of SSR-2/1 (Rev. 1) [1] states (footnote omitted):

“The design shall be such as to ensure that plant states that could lead to high radiation doses or to a large radioactive release have been ‘practically eliminated’, and that there would be no, or only minor, potential radiological consequences for plant states with a significant likelihood of occurrence.”

2.4. Furthermore, para. 4.4 of SSR-2/1 (Rev. 1) [1] states that (footnote omitted) “Acceptable limits for purposes of radiation protection associated with the relevant categories of plant states shall be established, consistent with the regulatory requirements.”

2.5. Further requirements on criteria and objectives relating to radiological consequences of different plant states considered in the design, including accident conditions, are also established in SSR-2/1 (Rev. 1) [1] as follows:

- “Criteria shall be assigned to each plant state, such that frequently occurring plant states shall have no, or only minor, radiological consequences and plant states that could give rise to serious consequences shall have a very low frequency of occurrence” (para. 5.2 of SSR-2/1 (Rev. 1) [1]).
- “A primary objective shall be to manage all design basis accidents so that they have no, or only minor, radiological consequences, on or off the site, and do not necessitate any off-site protective actions” (para. 5.25 of SSR-2/1 (Rev. 1) [1] in relation to design basis accidents).
- “The design shall be such that the possibility of conditions arising that could lead to an early radioactive release or a large radioactive release is ‘practically eliminated’” (para. 5.31 of SSR-2/1 (Rev. 1) [1] in relation to design extension conditions).
- “The design shall be such that for design extension conditions, protective actions that are limited in terms of lengths of time and areas of application shall be sufficient for the protection of the public, and sufficient time shall be available to take such measures” (para. 5.31A of SSR-2/1 (Rev. 1) [1] in relation to design extension conditions).

2.6. Paragraph 2.10 of SSR-2/1 (Rev. 1) [1] states:

“Measures are required to be taken to ensure that the radiological consequences of an accident would be mitigated. Such measures include the provision of safety features and safety systems, the establishment of accident management procedures by the operating organization and, possibly, the establishment of off-site protective actions by the appropriate authorities,

supported as necessary by the operating organization, to mitigate exposures if an accident occurs.”⁵

2.7. As stated in para. 2.13 of SSR-2/1 (Rev. 1) [1], “The safety objective in the case of a severe accident is that only protective actions that are limited in terms of lengths of time and areas of application would be necessary and that off-site contamination would be avoided or minimized.”

2.8. Harmful radiological consequences to the public can arise only from the occurrence of uncontrolled accidents. Therefore, the recommendations in this Safety Guide are focused on the implementation and assessment of the concept of defence in depth and the complementary need to demonstrate the practical elimination of plant event sequences that could lead to an early radioactive release or a large radioactive release.

2.9. Recommendations on radiation protection in the design of nuclear power plants are provided in IAEA Safety Standards Series No. SSG-90, Radiation Protection Aspects of Design for Nuclear Power Plants [13]. Recommendations on the protection of the public and the environment are provided in IAEA Safety Standards Series No. GSG-8, Radiation Protection of the Public and the Environment [14].

⁵ The establishment of off-site protective actions belongs to the fifth level of defence in depth and is outside the scope of this Safety Guide. Requirements regarding such arrangements are established in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [12].

3. IMPLEMENTATION AND ASSESSMENT OF DESIGN EXTENSION CONDITIONS WITHIN THE CONCEPT OF DEFENCE IN DEPTH

OVERALL IMPLEMENTATION OF DEFENCE IN DEPTH

3.1. The concept of defence in depth for the design of nuclear power plants is described in paras 2.12–2.14 of SSR-2/1 (Rev. 1) [1]. As stated in para. 2.14 of SSR-2/1(Rev. 1) [1]:

“A relevant aspect of the implementation of defence in depth for a nuclear power plant is the provision in the design of a series of physical barriers, as well as a combination of active, passive and inherent safety features that contribute to the effectiveness of the physical barriers in confining radioactive material at specified locations. The number of barriers that will be necessary will depend upon the initial source term in terms of the amount and isotopic composition of radionuclides, the effectiveness of the individual barriers, the possible internal and external hazards, and the potential consequences of failures.”

3.2. Requirement 7 of SSR-2/1 (Rev. 1) [1] on the application of defence in depth in the design of nuclear power plants states that **“The design of a nuclear power plant shall incorporate defence in depth. The levels of defence in depth shall be independent as far as is practicable.”** Paragraphs 4.9–4.13A of SSR-2/1 (Rev. 1) [1] develop this overarching requirement.

3.3. For the safety provisions at each level of defence in depth, the following should be demonstrated:

- (a) The performance of the safety provisions implemented at that level to maintain the integrity of the barriers;
- (b) The adequate reliability of the safety provisions at that level so that it can be assured, with a sufficient level of confidence, that a certain plant condition can be brought under control without the need to implement safety provisions associated with the next level of defence in depth;

- (c) The independence, as far as practicable, of the safety provisions at that level, including their physical separation⁶, from the safety provisions associated with the previous levels of defence in depth.

3.4. Frequently, for purposes of design safety and operational safety, the various levels of defence in depth are associated with the various plant states considered in the design. The introduction of design extension conditions among the plant states has resulted in different approaches in different States regarding interpretation of the correspondence between the plant states considered in the design and the levels of defence in depth. Two of these approaches are presented in Table 1.

3.5. In Approach 1, depicted on the left side of Table 1, design extension conditions without significant fuel degradation are associated with the third level of defence in depth. With this approach, each level has a clear objective that reflects the progression of an accident and the protection of the barriers (i.e. the third level is implemented to prevent fuel damage and the fourth level is implemented to mitigate severe accidents and prevent off-site contamination). As stated in para. 3.39 of SSG-2 (Rev. 1) [9]:

“The initial selection of sequences for design extension conditions without significant fuel degradation should be based on the consideration of single initiating events of very low frequency or multiple failures to meet the acceptance criteria with regard to the prevention of core damage.”

TABLE 1. LEVELS OF DEFENCE IN DEPTH

Level of defence	Objective	Essential design means	Essential operational means	Level of defence
Approach 1			Approach 2	
Level 1	Prevention of abnormal operation and failures	Robust design and high quality in construction of normal operation systems, including monitoring and control systems	Operational limits and conditions and normal operating procedures	Level 1

⁶ Physical separation is separation by geometry (distance, orientation, etc.), by appropriate barriers, or by a combination thereof [2].

TABLE 1. LEVELS OF DEFENCE IN DEPTH (cont.)

Level of defence	Objective	Essential design means	Essential operational means	Level of defence
Approach 1			Approach 2	
Level 2	Control of abnormal operation and detection of failures	Limitation and protection systems and other surveillance features	Abnormal operating procedures and/or emergency operating procedures	Level 2
3a	Control of design basis accidents	Safety systems	Emergency operating procedures	Level 3
Level 3	3b Control of design extension conditions to prevent core melting	Safety features for design extension conditions without significant fuel degradation ^a	Emergency operating procedures	
Level 4	Control of design extension conditions to mitigate the consequences of severe accidents	Safety features for design extension conditions with core melting ^b Technical support centre	Severe accident management guidelines	Level 4
Level 5	Mitigation of the radiological consequences of significant releases of radioactive substances	On-site and off-site emergency response facilities	On-site and off-site emergency plans and procedures	Level 5

^a Such safety features are understood as additional safety features for design extension conditions, or as safety systems with an extended capability to prevent the consequences of severe accidents (see para. 5.27 of SSR-2/1 (Rev. 1) [1]).

^b Such safety features are understood as additional safety features for design extension conditions, or as safety systems with an extended capability to mitigate the consequences of severe accidents or to maintain the integrity of the containment (see para. 5.27 of SSR-2/1 (Rev. 1) [1]).

Therefore, in Approach 1, acceptable limits on predicted radiological consequences for design extension conditions without significant fuel degradation may be the same as, or similar to, acceptable limits for design basis accidents. Furthermore, the physical phenomena associated with design basis accidents and design extension conditions without significant fuel degradation are similar, although there might be differences in the analysis. In contrast, the physical phenomena associated with design extension conditions with core melt are completely different.

3.6. In Approach 2, depicted on the right side of Table 1, design extension conditions without significant fuel degradation and design extension conditions with core melt are considered together in the fourth level of defence in depth. This approach emphasizes the distinction between the set of rules to be applied for design extension conditions and the set of rules to be applied for design basis accidents, both in the design and in the safety assessment.

3.7. Despite their differences, both approaches are in compliance with para. 5.29(a) of SSR-2/1 (Rev. 1) [1] and support the implementation, to the extent practicable, of independence between safety systems and those safety features for design extension conditions.

Normal operation and anticipated operational occurrences

3.8. Operational states comprise two sets of plant states: normal operation and anticipated operational occurrences. Modes of normal operation include, for example, startup, power operation, shutting down, shutdown and refuelling and are defined in the documentation governing the operation of the plant (e.g. the operational limits and conditions⁷). Anticipated operational occurrences⁸ could happen from a postulated initiating event⁹ involving a failure to prevent an abnormal operation or an equipment failure expected to happen during the operating lifetime of the plant.

⁷ In some States, the term ‘technical specifications’ is used instead of the term ‘operational limits and conditions’.

⁸ An anticipated operational occurrence is a deviation of an operational process from normal operation that is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions [2].

⁹ Examples of relevant postulated initiating events are provided in para. 3.28 of SSG-2 (Rev. 1) [9].