

IAEA Safety Standards

for protecting people and the environment

Core Management and Fuel Handling for Nuclear Power Plants

Specific Safety Guide

No. SSG-73



IAEA

International Atomic Energy Agency



Documents

Document Sharing Hub

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

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

<https://www.iaea.org/resources/safety-standards>

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.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Emergency Preparedness and Response** publications, **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** comprises informational publications to encourage and assist research on, and the development and practical application of, nuclear energy for peaceful purposes. It includes reports and guides on the status of and advances in technology, and on experience, good practices and practical examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

CORE MANAGEMENT AND FUEL HANDLING FOR NUCLEAR POWER PLANTS

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN	GERMANY	PALAU
ALBANIA	GHANA	PANAMA
ALGERIA	GREECE	PAPUA NEW GUINEA
ANGOLA	GRENADA	PARAGUAY
ANTIGUA AND BARBUDA	GUATEMALA	PERU
ARGENTINA	GUYANA	PHILIPPINES
ARMENIA	HAITI	POLAND
AUSTRALIA	HOLY SEE	PORTUGAL
AUSTRIA	HONDURAS	QATAR
AZERBAIJAN	HUNGARY	REPUBLIC OF MOLDOVA
BAHAMAS	ICELAND	ROMANIA
BAHRAIN	INDIA	RUSSIAN FEDERATION
BANGLADESH	INDONESIA	RWANDA
BARBADOS	IRAN, ISLAMIC REPUBLIC OF	SAINT KITTS AND NEVIS
BELARUS	IRAQ	SAINT LUCIA
BELGIUM	IRELAND	SAINT VINCENT AND THE GRENADINES
BELIZE	ISRAEL	SAMOA
BENIN	ITALY	SAN MARINO
BOLIVIA, PLURINATIONAL STATE OF	JAMAICA	SAUDI ARABIA
BOSNIA AND HERZEGOVINA	JAPAN	SENEGAL
BOTSWANA	JORDAN	SERBIA
BRAZIL	KAZAKHSTAN	SEYCHELLES
BRUNEI DARUSSALAM	KENYA	SIERRA LEONE
BULGARIA	KOREA, REPUBLIC OF	SINGAPORE
BURKINA FASO	KUWAIT	SLOVAKIA
BURUNDI	KYRGYZSTAN	SLOVENIA
CAMBODIA	LAO PEOPLE'S DEMOCRATIC REPUBLIC	SOUTH AFRICA
CAMEROON	LATVIA	SPAIN
CANADA	LEBANON	SRI LANKA
CENTRAL AFRICAN REPUBLIC	LESOTHO	SUDAN
CHAD	LIBERIA	SWEDEN
CHILE	LIBYA	SWITZERLAND
CHINA	LIECHTENSTEIN	SYRIAN ARAB REPUBLIC
COLOMBIA	LITHUANIA	TAJIKISTAN
COMOROS	LUXEMBOURG	THAILAND
CONGO	MADAGASCAR	TOGO
COSTA RICA	MALAWI	TONGA
CÔTE D'IVOIRE	MALAYSIA	TRINIDAD AND TOBAGO
CROATIA	MALI	TUNISIA
CUBA	MALTA	TÜRKİYE
CYPRUS	MARSHALL ISLANDS	TURKMENISTAN
CZECH REPUBLIC	MAURITANIA	UGANDA
DEMOCRATIC REPUBLIC OF THE CONGO	MAURITIUS	UKRAINE
DENMARK	MEXICO	UNITED ARAB EMIRATES
DJIBOUTI	MONACO	UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
DOMINICA	MONGOLIA	UNITED REPUBLIC OF TANZANIA
DOMINICAN REPUBLIC	MONTENEGRO	UNITED STATES OF AMERICA
ECUADOR	MOROCCO	URUGUAY
EGYPT	MOZAMBIQUE	UZBEKISTAN
EL SALVADOR	MYANMAR	VANUATU
ERITREA	NAMIBIA	VENEZUELA, BOLIVARIAN REPUBLIC OF
ESTONIA	NEPAL	VIET NAM
ESWATINI	NETHERLANDS	YEMEN
ETHIOPIA	NEW ZEALAND	ZAMBIA
FIJI	NICARAGUA	ZIMBABWE
FINLAND	NIGER	
FRANCE	NIGERIA	
GABON	NORTH MACEDONIA	
GEORGIA	NORWAY	
	OMAN	
	PAKISTAN	

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-73

CORE MANAGEMENT AND FUEL HANDLING FOR NUCLEAR POWER PLANTS

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2022

COPYRIGHT NOTICE

All IAEA scientific and technical publications are protected by the terms of the Universal Copyright Convention as adopted in 1952 (Berne) and as revised in 1972 (Paris). The copyright has since been extended by the World Intellectual Property Organization (Geneva) to include electronic and virtual intellectual property. Permission to use whole or parts of texts contained in IAEA publications in printed or electronic form must be obtained and is usually subject to royalty agreements. Proposals for non-commercial reproductions and translations are welcomed and considered on a case-by-case basis. Enquiries should be addressed to the IAEA Publishing Section at:

Marketing and Sales Unit, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 26007 22529
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
www.iaea.org/publications

© IAEA, 2022

Printed by the IAEA in Austria

September 2022

STI/PUB/2024

IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.

Title: Core management and fuel handling for nuclear power plants / International Atomic Energy Agency.

Description: Vienna : International Atomic Energy Agency, 2022. | Series: IAEA safety standards series, ISSN 1020-525X ; no. SSG-73 | Includes bibliographical references.

Identifiers: IAEAL 22-01524 | ISBN 978-92-0-131622-6 (paperback : alk. paper) | ISBN 978-92-0-131722-3 (pdf) | ISBN 978-92-0-131822-0 (epub)

Subjects: Nuclear power plants. | Nuclear power plants — Safety Measures. | Nuclear fuels. | Nuclear power plants — Management.

Classification: UDC 621.039.543 | STI/PUB/2024

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.

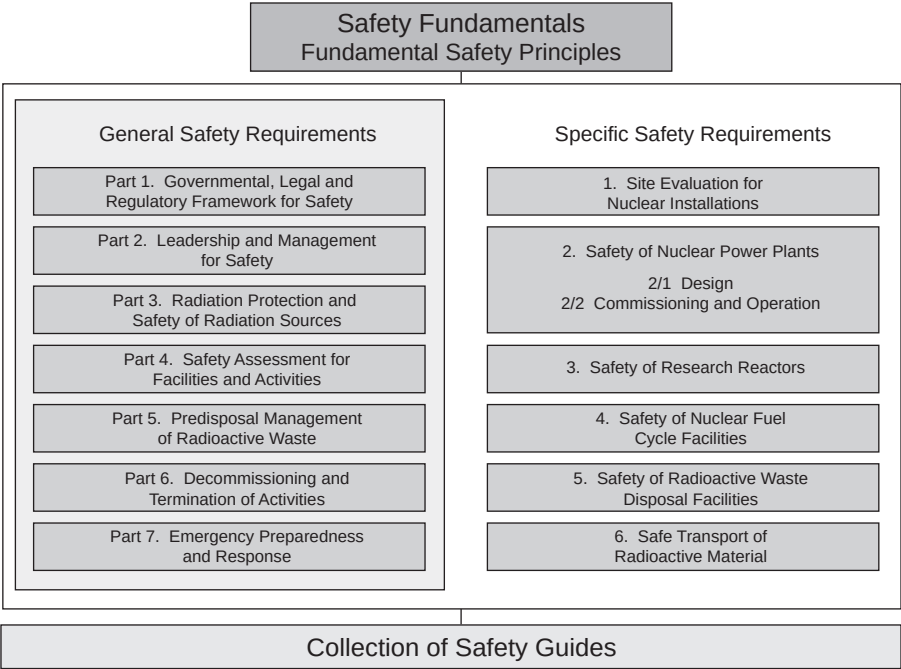


FIG. 1. The long term structure of the IAEA Safety Standards Series.

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.

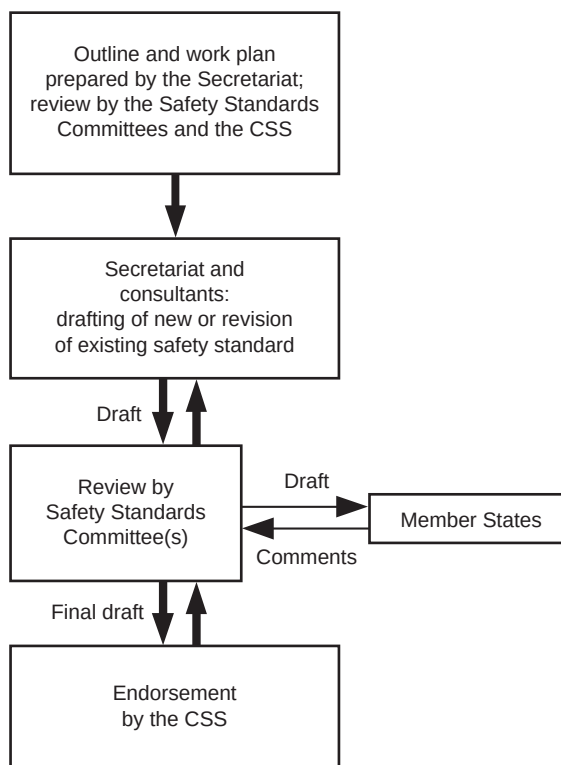


FIG. 2. The process for developing a new safety standard or revising an existing standard.

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 Safety Glossary (see <https://www.iaea.org/resources/safety-standards/safety-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 (1.1–1.5).....	1
	Objective (1.6, 1.7).....	2
	Scope (1.8–1.11).....	2
	Structure (1.12).....	3
2.	CORE MANAGEMENT	3
	Objective of core management (2.1–2.4)	3
	Analysis of conditions and characteristics of the reactor core (2.5–2.13).....	5
	Computational methods for core calculations (2.14–2.18).....	8
	Operation of the reactor core (2.19–2.26)	9
	Reactivity management programme (2.27–2.31).....	11
	Core monitoring programme (2.32–2.43).....	12
	Ensuring fuel integrity (2.44–2.61)	16
	Refuelling programme (2.62–2.72)	20
	Surveillance relating to core management and fuel handling (2.73, 2.74)	24
3.	HANDLING AND STORAGE OF FRESH FUEL	24
	Management of fresh fuel (3.1–3.15).....	24
	Receipt of fresh fuel (3.16–3.22)	27
	Storage of fresh fuel (3.23–3.31)	28
4.	IMPLEMENTATION OF THE REFUELLING PROGRAMME..	29
	Preparation for refuelling (4.1–4.3)	29
	Loading fuel and core components into the reactor (4.4–4.11)	30
	Unloading fuel and core components (4.12–4.18)	32
	Precautions for loading and unloading fuel and core components (4.19–4.24)	33
	Foreign material exclusion arrangements for fuel handling (4.25–4.27)	36

5.	HANDLING, STORAGE AND INSPECTION OF IRRADIATED FUEL	37
	General (5.1–5.3)	37
	Handling of irradiated fuel (5.4–5.10)	38
	Storage of irradiated fuel (5.11–5.20).....	39
	Inspection of irradiated fuel (5.21, 5.22)	42
6.	HANDLING AND STORAGE OF CORE COMPONENTS (6.1–6.9)	43
7.	PREPARATION OF FUEL FOR DISPATCH (7.1–7.7).....	45
8.	ADMINISTRATIVE AND ORGANIZATIONAL ASPECTS OF CORE MANAGEMENT AND FUEL HANDLING (8.1–8.11) ...	46
9.	DOCUMENTATION FOR CORE MANAGEMENT AND FUEL HANDLING ACTIVITIES (9.1–9.3).....	50
	REFERENCES.....	51
	CONTRIBUTORS TO DRAFTING AND REVIEW.....	55

1. INTRODUCTION

BACKGROUND

1.1. Requirements for the operation of nuclear power plants are established in IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [1], while requirements for the design of nuclear power plants are established in IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [2].

1.2. This Safety Guide provides specific recommendations on core management¹ and fuel handling² for nuclear power plants to ensure the safe and reliable use of the nuclear fuel in the reactor.

1.3. This Safety Guide was developed in parallel with six other Safety Guides on the operation of nuclear power plants, as follows:

- IAEA Safety Standards Series No. SSG-70, Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants [3];
- IAEA Safety Standards Series No. SSG-71, Modifications to Nuclear Power Plants [4];
- IAEA Safety Standards Series No. SSG-72, The Operating Organization for Nuclear Power Plants [5];
- IAEA Safety Standards Series No. SSG-74, Maintenance, Testing, Surveillance and Inspection in Nuclear Power Plants [6];
- IAEA Safety Standards Series No. SSG-75, Recruitment, Qualification and Training of Personnel for Nuclear Power Plants [7];
- IAEA Safety Standards Series No. SSG-76, Conduct of Operations at Nuclear Power Plants [8].

A collective aim of this set of Safety Guides is to support the fostering of a strong safety culture in nuclear power plants.

¹ In this publication, ‘core management’ refers to the activities associated with fuel management in the core and with reactivity control.

² In this publication, ‘fuel handling’ refers to the receipt of fresh fuel; the movement, storage and control of fresh and irradiated fuel; and the handling of fuel packages in the spent fuel pool.

1.4. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Safety Glossary [9].

1.5. This Safety Guide supersedes IAEA Safety Standards Series No. NS-G-2.5, Core Management and Fuel Handling for Nuclear Power Plants³.

OBJECTIVE

1.6. The purpose of this Safety Guide is to provide recommendations on core management and fuel handling activities at nuclear power plants to meet the relevant requirements established in SSR-2/1 (Rev. 1) [2] and Requirement 30 of SSR-2/2 (Rev. 1) [1]. These activities are necessary in order to allow optimum reactor core operation without compromising the limits imposed by the design safety considerations relating to the nuclear fuel and to the plant as a whole.

1.7. The recommendations provided in this Safety Guide are aimed primarily at operating organizations of nuclear power plants and regulatory bodies.

SCOPE

1.8. It is expected that this Safety Guide will be used primarily for land based stationary nuclear power plants with water cooled reactors designed for electricity generation or for other production applications (such as district heating or desalination).

1.9. This Safety Guide covers the safety objective of core management and the basic tasks of the core management programme. The receipt of fresh fuel, the storage and handling of fuel assemblies and core components⁴, the loading and unloading of fuel assemblies and core components, and the insertion and removal of other reactor materials are also within the scope of this Safety Guide.

³ INTERNATIONAL ATOMIC ENERGY AGENCY, Core Management and Fuel Handling for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.5, IAEA, Vienna (2002).

⁴ A 'fuel assembly' is a set of fuel elements and associated components that are loaded into and subsequently removed from a reactor core as a single unit [9]. 'Core components' are the elements of a reactor core, other than fuel assemblies, that are used to provide structural support of the core construction, or the tools, devices or other items that are inserted into the reactor core for core monitoring, flow control or other technological purposes and are treated as core elements [9].

1.10. This Safety Guide covers the preparations for the dispatch of irradiated fuel from the site. Transport, off-site storage and disposal of irradiated fuel and core components are outside the scope of this publication.

1.11. Aspects of fuel accounting not directly relating to nuclear safety are not considered in this publication; thus, the State system for accounting for and control of nuclear material is outside the scope of this Safety Guide.

STRUCTURE

1.12. Recommendations on the core management and monitoring programme for the safe use of the nuclear fuel are provided in Section 2. Section 3 provides recommendations on managing the handling and storage of fresh fuel. Section 4 provides recommendations on the implementation of the refuelling programme to preserve fuel integrity. Recommendations on the handling, storage and inspection of irradiated fuel are provided in Section 5. Section 6 provides recommendations on the handling and storage of core components. Section 7 provides general recommendations on the preparatory arrangements for dispatch of fuel from the site. Sections 8 and 9 describe the responsibilities of the operating organization for administrative and organizational aspects and documentation in relation to core management and fuel handling.

2. CORE MANAGEMENT

OBJECTIVE OF CORE MANAGEMENT

2.1. The objective of core management is to ensure the safe and reliable use of the nuclear fuel in the reactor on the basis of the safety analysis, with due consideration of the limits imposed by the design of the fuel and of the plant. Recommendations on design are provided in IAEA Safety Standards Series No. SSG-52, Design of the Reactor Core for Nuclear Power Plants [10], and recommendations on the safety analysis are provided in IAEA Safety Standards Series No. SSG-2 (Rev. 1), Deterministic Safety Analysis for Nuclear Power Plants [11]. For maximum efficiency, heat flux and coolant temperatures need to be as high as possible, while at the same time the key parameters need to be kept within operational limits. Because of this, high levels of expertise and meticulous control of the associated operations are essential.

2.2. The concept of defence in depth is required to be applied to core management (see para. 2.12 of SSR-2/1 (Rev. 1) [2]). The application of this concept should cover a number of operational precautions within the levels of defence (e.g. thorough planning of core management activities, equipment and procedures, core analysis and monitoring, fuel integrity monitoring, contingency measures) aimed at ensuring fuel integrity, preventing accidents and ensuring appropriate protection if an accident were to occur.

2.3. Although the specific details of core management are dependent on the reactor type and plant organization, in all cases the core management programme should meet the following objectives:

- (a) To provide the means to perform core management functions effectively throughout the lifetime of the fuel in order to ensure that core parameters remain within the approved operational limits. Core management functions include the following:
 - (i) Core performance monitoring (including provision of redundancy for key instruments and procedures for dealing with loss of functions);
 - (ii) Thermomechanical evaluation;
 - (iii) Making fuel depletion calculations, reactivity calculations, neutronic calculations and thermohydraulic state calculations.
- (b) To provide support for core operating strategies in order to obtain maximum operating flexibility and optimum fuel utilization, while remaining within the established safety limits.
- (c) To ensure that only fuel assemblies of an approved design are handled.

2.4. The basic core management tasks to be undertaken to ensure the safe use of fuel in the core include the following:

- (a) Procuring fresh fuel in accordance with paras 7.18 and 7.19 of SSR-2/2 (Rev. 1) [1] (see also the recommendations provided in appendix III to IAEA Safety Standards Series No. GS-G-3.1, Application of the Management System for Facilities and Activities [12]);
- (b) Ensuring the integrity of the fuel by maintaining relevant core operating parameters in accordance with operational limits and conditions (see paras 7.20–7.25 of SSR-2/2 (Rev. 1) [1]);
- (c) Securing the ability to shut down the reactor from any operational state (including transient conditions);
- (d) Unloading fuel when its specified burnup or dwell time limit has been reached, or if operating experience (e.g. of corrosion, leakage, bowing) necessitates earlier unloading;

- (e) Avoiding loading fuel and other core components that might potentially degrade to a level where an additional radiological risk could be created before the scheduled unloading;
- (f) Providing safety justification before allowing any fuel assembly to exceed its limiting conditions;
- (g) Detecting failed fuel, and unloading such fuel if necessary;
- (h) Updating plant operating strategies on the basis of fuel performance and operating experience from the plant and from other plants, as well as further progress in science and technology;
- (i) Assessing the safety implications, including seismic and dynamic responses, of any component or material proposed for insertion into the core or the reactor vessel;
- (j) Assessing the effects of irradiation on core components, adjacent reactor internals and the reactor pressure vessel.

ANALYSIS OF CONDITIONS AND CHARACTERISTICS OF THE REACTOR CORE

2.5. Core analysis should be performed in accordance with the recommendations provided in SSG-52 [10].

2.6. Reactor core analysis should be carried out at appropriate times throughout the operating lifetime of the reactor to ensure that the operational strategy and the limitations on operation do not violate any design limits appropriate to each plant state.

2.7. Reactor core analysis should be performed to cover the entire operating cycle for a variety of operational states and core conditions, such as the following:

- (a) Full power, including representative power distributions;
- (b) Load following (as applicable);
- (c) Stretch-out⁵;
- (d) Approach to criticality and power operation;
- (e) Power cycling;
- (f) Startup;
- (g) Refuelling;

⁵ Stretch-out is used in some reactors to allow power operation beyond the natural end of the burnup cycle, where the decrease in reactivity associated with burnup is compensated by gradually reducing power and temperature levels.

- (h) Shutdown;
- (i) Anticipated operational occurrences;
- (j) Operation at and beyond the thermohydraulic stability boundary (for boiling water reactors).

2.8. Whenever the management of fuel in the core is changed, or any characteristics of core loading patterns or the fuel elements (such as the fuel enrichment, fuel element dimensions, fuel element configuration or fuel cladding material) are changed, a new safety analysis should be performed and documented to demonstrate compliance with the acceptance criteria for the fuel.

2.9. The reactor core analysis should include an analysis of fuel element performance (based on average and local power levels, and axial temperature or void distributions) to demonstrate that the respective thermal and mechanical fuel design limits are met for normal operation, anticipated operational occurrences and design basis accidents without core melt. Fuel element performance analysis should take into account the power and burnup distributions along the radius of fuel pellets. For light water reactors, the reactor core analysis should include peak channel power and peak linear power rates at each assembly location and axially along each fuel assembly, for normal full power operation and for steady state power distributions. The effects of changes in the geometry of a fuel assembly on neutronic and thermohydraulic performance (e.g. changes due to bowing of the assembly) should be taken into account. The reactor core analysis should also include the radial power distribution within a fuel assembly and the axial power distortion due to spacers, grids and other components, in order to identify localized higher values and to evaluate the local power levels.

2.10. The types of fuel in use should be taken into account in the analysis of core conditions. Neutronic, thermohydraulic, chemical and mechanical analyses should be performed as part of a detailed core analysis, which should include the following core parameters for both steady state and transient conditions:

- (a) Variations in reactivity with burnup of the fuel and the actions needed to maintain core reactivity (e.g. changes in control rod positions, neutron absorbers, coolant temperature and void content, or refuelling rate);
- (b) Location and reactivity worth of all control rods or rod groups;
- (c) The rate of change of the concentration of soluble absorber in the moderator and the coolant;
- (d) Impact on reactivity of temperature (of the fuel, moderator and coolant), power, boron concentration (in pressurized water reactors), pressure

and void, for all modes of normal operation and for anticipated transient conditions and design basis accidents;

- (e) The neutron flux and distribution of power in the core and within the fuel assemblies, and the control of these parameters by appropriate movement of control rods or zonal absorbers;
- (f) Fuel and moderator temperatures, coolant flow rates, coolant chemical conditions, pressure drop, and temperature, density and thermal margins of the coolant;
- (g) Stability of the power distribution;
- (h) Changes in xenon concentration due to transients;
- (i) Minimum boron concentration ensuring the subcriticality margin in shutdown states (for pressurized water reactors);
- (j) Growth of oxidation and hydriding of the cladding over the lifetime of the fuel;
- (k) Changes in the delayed neutron fraction and prompt neutron lifetime.

2.11. Changes in the parameters listed in para. 2.10 and the effects of these changes should be predicted for both steady state and transient conditions. The results of such predictions should be compared with measured parameters, as far as practicable, and should be used to confirm that there is sufficient capability for control at all times to ensure that the reactor can be shut down safely and remain shut down following any normal operation, anticipated operational occurrence or design basis accident, with predefined failures taken into account.

2.12. During reactor operation, the following items should be considered, as appropriate:

- (a) Variations in the reactivity worth of control rods due to irradiation effects, temperature effects and boron concentration changes (in pressurized water reactors);
- (b) The effects of irradiation and control rod shadow effects on neutron flux detectors, particularly the variation in sensitivity;
- (c) The adequacy of the neutron source strength and the sensitivity and location of neutron detectors for startup, especially following a long shutdown (the irradiated fuel and photoneutrons might not constitute a source of sufficient strength).