

# IAEA Safety Standards

for protecting people and the environment

## Safety Assessment for Research Reactors and Preparation of the Safety Analysis Report

Specific Safety Guide

No. SSG-20



**IAEA**  
International Atomic Energy Agency

**AVA** 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 at the IAEA Internet site

<http://www-ns.iaea.org/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 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](mailto: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 and protection 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 **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.

SAFETY ASSESSMENT FOR  
RESEARCH REACTORS AND  
PREPARATION OF THE  
SAFETY ANALYSIS REPORT



**Documents**  
Document Sharing Hub

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

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

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-20

# SAFETY ASSESSMENT FOR RESEARCH REACTORS AND PREPARATION OF THE SAFETY ANALYSIS REPORT

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY  
VIENNA, 2012

## 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 2600 29302  
tel.: +43 1 2600 22417  
email: [sales.publications@iaea.org](mailto:sales.publications@iaea.org)  
<http://www.iaea.org/books>

© IAEA, 2012

Printed by the IAEA in Austria  
November 2012  
STI/PUB/1508

### IAEA Library Cataloguing in Publication Data

Safety assessment for research reactors and preparation of the safety analysis report : specific safety guide. — Vienna : International Atomic Energy Agency, 2012.

p. ; 24 cm. — (IAEA safety standards series, ISSN 1020-525X ; no. SSG-20)

STI/PUB/1508

ISBN 978-92-0-115410-1

Includes bibliographical references.

1. Nuclear power plants — Research. 2. Nuclear reactors — Safety measures. 3. Nuclear power plants — Licenses. I. International Atomic Energy Agency. II. Series.

IAEAL

12-00776

## FOREWORD

**by Yukiya Amano**  
**Director General**

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.

## **NOTE BY THE SECRETARIAT**

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. The process of developing, reviewing and establishing the IAEA standards involves the IAEA Secretariat and all Member States, many of which are represented on the four IAEA safety standards committees and the IAEA Commission on Safety Standards.

The IAEA standards, as a key element of the global safety regime, are kept under regular review by the Secretariat, the safety standards committees and the Commission on Safety Standards. The Secretariat gathers information on experience in the application of the IAEA standards and information gained from the follow-up of events for the purpose of ensuring that the standards continue to meet users' needs. The present publication reflects feedback and experience accumulated until 2010 and it has been subject to the rigorous review process for standards.

Lessons that may be learned from studying the accident at the Fukushima Daiichi nuclear power plant in Japan following the disastrous earthquake and tsunami of 11 March 2011 will be reflected in this IAEA safety standard as revised and issued in the future.



**Documents**

Document Sharing Hub

# 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 measures<sup>1</sup> 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 is necessary to take the measures recommended (or equivalent alternative measures). The Safety

---

<sup>1</sup> See also publications issued in the IAEA Nuclear Security Series.

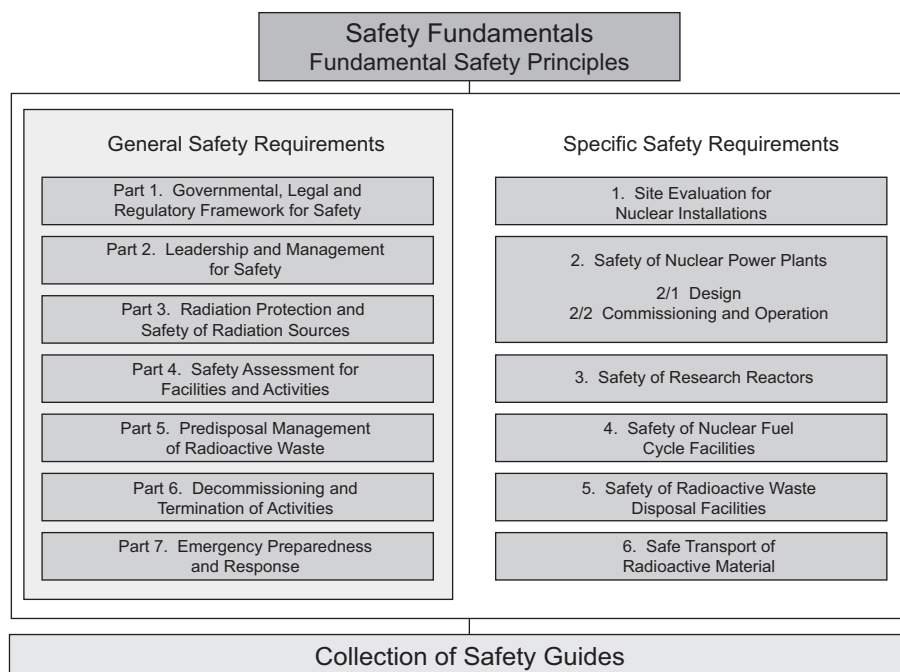


FIG. 1. The long term structure of the IAEA Safety Standards Series.

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 four safety standards committees, for 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. It articulates the mandate of the IAEA, the vision for the future application of the

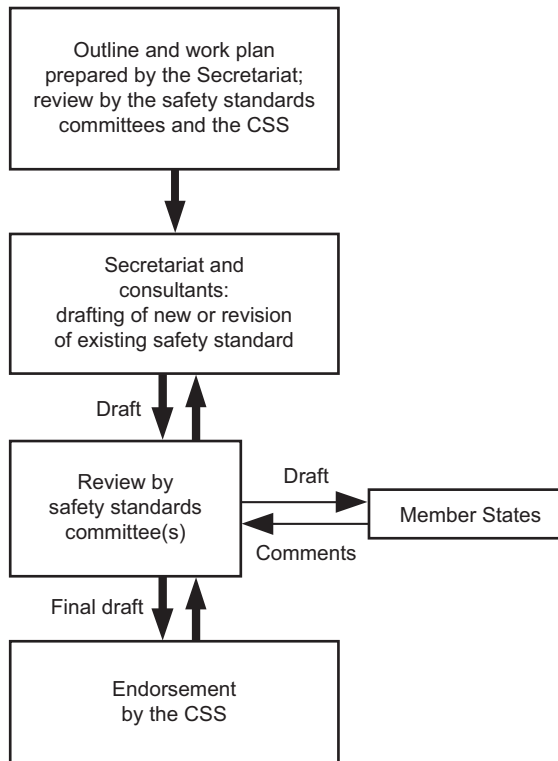


FIG. 2. The process for developing a new safety standard or revising an existing standard.

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.

# CONTENTS

|    |                                                                                                  |     |
|----|--------------------------------------------------------------------------------------------------|-----|
| 1. | INTRODUCTION .....                                                                               | 1   |
|    | Background (1.1–1.6) .....                                                                       | 1   |
|    | Objective (1.7–1.9) .....                                                                        | 3   |
|    | Scope (1.10–1.14) .....                                                                          | 4   |
|    | Structure (1.15–1.20) .....                                                                      | 5   |
| 2. | SAFETY ASSESSMENT IN THE LICENSING PROCESS .....                                                 | 7   |
|    | Responsibilities (2.1–2.13) .....                                                                | 7   |
|    | Acceptance criteria (2.14–2.18) .....                                                            | 11  |
|    | Information requirements during the various stages of<br>the licensing process (2.19–2.21) ..... | 13  |
|    | Submission of information to the regulatory body (2.22–2.45) .....                               | 13  |
| 3. | PREPARATION OF THE SAFETY ANALYSIS REPORT .....                                                  | 20  |
|    | Purpose and scope (3.1–3.6) .....                                                                | 20  |
|    | Specific guidance (3.7–3.16) .....                                                               | 21  |
|    | Selected postulated initiating events (3.17) .....                                               | 23  |
|    | Development of the safety analysis (3.18–3.31) .....                                             | 26  |
| 4. | INFORMATION TO BE SUBMITTED FOR<br>THE REVIEW AND ASSESSMENT PROCESS .....                       | 30  |
|    | Purpose and scope (4.1–4.2) .....                                                                | 30  |
|    | Programme for review and assessment (4.3–4.13) .....                                             | 31  |
|    | APPENDIX: CONTENT OF A SAFETY ANALYSIS REPORT .....                                              | 35  |
|    | REFERENCES .....                                                                                 | 99  |
|    | ANNEX I: APPROACH TO AND METHODS OF<br>SAFETY ANALYSIS .....                                     | 101 |
|    | ANNEX II: EXAMPLES OF INPUT PARAMETERS AND<br>INITIAL CONDITIONS .....                           | 108 |

ANNEX III: ITEMS TO BE CONSIDERED IN  
THE DESCRIPTION OF THE RESEARCH REACTOR... 109

ANNEX IV: TYPICAL RADIATION SOURCES AND  
RADIATION FIELDS IN A RESEARCH REACTOR. .... 112

CONTRIBUTORS TO DRAFTING AND REVIEW ..... 113

BODIES FOR THE ENDORSEMENT OF  
IAEA SAFETY STANDARDS ..... 115

# 1. INTRODUCTION

## BACKGROUND

1.1. This Safety Guide was developed under the IAEA programme for safety standards, which covers all the important areas of research reactor safety. The Fundamental Safety Principles publication [1] establishes principles for ensuring the protection of workers, the public and the environment from harmful effects of ionizing radiation. Requirements that apply seven of these principles<sup>1</sup> are directly addressed in this Safety Guide. Recommendations are provided on which analyses, acceptance criteria, verifications and evaluations should be performed and used to prove that the safety objectives will be met to fulfil the safety requirements for the operating organization that are established in paras 2.15, 2.17–2.20, 3.6–3.12 and 4.14 of Ref. [2].

1.2. This publication supersedes IAEA Safety Series No. 35-G1<sup>2</sup>. The main changes and adaptations relate to consistency with Ref. [2], the other recently published Safety Guides for research reactors and other relevant safety standards. Where applicable, references to the safety standards have been incorporated.

---

<sup>1</sup> These are Principles 1, 2, 3, 5, 6, 8 and 9 (see Ref. [1]):

- “Principle 1: Responsibility for safety: The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.”
- “Principle 2: Role of government: An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.”
- “Principle 3: Leadership and management for safety: Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.”
- “Principle 5: Optimization of protection: Protection must be optimized to provide the highest level of safety that can reasonably be achieved.”
- “Principle 6: Limitation of risks to individuals: Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.”
- “Principle 8: Prevention of accidents: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.”
- “Principle 9: Emergency preparedness and response: Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.”

<sup>2</sup> INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report, IAEA Safety Series No. 35-G1, IAEA, Vienna (1994).

1.3. Owing to the particular characteristics of research reactors, safety aspects relating to all stages in the lifetime of a research reactor have been given special emphasis and have been incorporated into Ref. [2]. These characteristics include: the large variety of designs; the wide range of maximum power levels; the different modes of operation and different purposes of utilization; the particularities of siting; and the differences between organizations operating research reactors, in particular concerning their available resources. These characteristics necessitate a graded approach (Ref. [2], paras 1.11–1.14; Ref. [3]) in the setting and the fulfilment of the requirements when dealing with certain specific topics. These circumstances have been taken into account in the present Safety Guide.

1.4. The organizations involved in ensuring the safety of research reactors and the protection of site personnel, the public and the environment have a number of responsibilities that are interrelated. Most important are the performance of the safety analysis by the operating organization and the review and assessment of the safety analysis report by the regulatory body. The preparation, submission and evaluation of other important safety related documents is also necessary during the licensing process or in other special circumstances, such as for a modification or utilization project. The present Safety Guide develops the general concepts in these areas and is to be used in conjunction with Ref. [2], in which the concepts are presented. Furthermore, this publication covers other aspects of reactor operation normally included in the safety analysis report, such as operational limits and conditions<sup>3</sup>, commissioning, operating procedures, and utilization and modification, which are also discussed in other publications.

1.5. The use of the terms ‘safety assessment’, ‘safety analysis’ and ‘review and assessment’ in this Safety Guide requires explanation. ‘Safety assessment’ is assessment of all aspects of a practice that are relevant to protection and safety; for an authorized facility, this includes siting, design and operation of the facility. The safety assessment of the reactor may cover many and varied activities during the licensing process, with iterations between the design and confirmatory analytical activities, such as analyses and the preparation and submission of documents for review, and may involve several organizations. The safety assessment should continue throughout all the stages of the reactor’s lifetime and

---

<sup>3</sup> The terms ‘safety specifications’, ‘technical specifications (tech. specs) for safe operation’ and ‘general operating rules’ are used by operating organizations and by regulatory bodies for nuclear reactors in some States instead of the term ‘operational limits and conditions’. These expressions usually cover safety limits, safety system settings, limiting conditions for safe operation, surveillance requirements and administrative requirements.

in accordance with the potential magnitude and nature of the hazard associated with the particular research reactor or activity. In general, in the safety standards for research reactors the term ‘safety assessment’ is used instead of the term ‘safety analysis’, which has a more specific meaning. Safety analysis is the evaluation of the potential hazards associated with the conduct of an activity. In this regard, the safety analysis is performed by the designer and/or by the operating organization. The safety analysis is one of the most important parts of the reactor licensing process, and it is required to be included in the safety analysis report and submitted to the regulatory body for review and assessment [2]. The term ‘review and assessment’ is used in this Safety Guide specifically in the frame of the licence application with regard to the information to be submitted to the regulatory body, which has responsibility for assessing safety documentation (see Requirements 25 and 26 of Ref. [4]).

1.6. This Safety Guide provides guidance to operating organizations on carrying out independent verification of the safety assessment for a new research reactor with a new design or an existing design, or of a revised and updated safety assessment for an existing research reactor. Although this Safety Guide provides guidance to operating organizations, it is also suitable for designers performing a safety assessment for a new or an existing research reactor.

## OBJECTIVE

1.7. The objective of this Safety Guide is to provide recommendations on meeting the requirements for safety assessment for research reactors in the licensing process, such as the responsibilities and functions of the organizations involved in the licensing process (Ref. [2], paras 3.2 and 3.3, and 4.1–4.4) and the steps towards the issuing of the licence (Ref. [2], paras 3.4 and 3.5), as well as on meeting the requirements for conducting the safety assessment of facilities and activities [5]. This Safety Guide also provides recommendations on the performance of the safety analysis (Ref. [2], paras 6.72–6.78) and the preparation of the safety analysis report (Ref. [2], paras 3.6–3.10). Guidance is also given on which analyses, verifications and evaluations should be performed to demonstrate that the safety objectives will be met and to fulfil the safety requirements on the operating organization. Finally, recommendations are provided on what information has to be submitted for the review and assessment of the safety analysis report by the regulatory body.

1.8. This Safety Guide provides recommendations on carrying out a safety assessment during the initial design process and for design modifications, as well

as for independent verification of the safety assessment of new research reactors of a new or existing design. The guidelines are also applicable for a revised and updated safety assessment of an existing reactor.

1.9. This Safety Guide provides recommendations with respect to utilization<sup>4</sup> (for experiments and experimental facilities) only in direct relation to safety analyses for the safety analysis report for the reactor. Recommendations on safety analyses for experiments at research reactors and experimental facilities are provided in Ref. [6].

## SCOPE

1.10. The recommendations provided in this Safety Guide are applicable to any type of research reactor<sup>5</sup>. However, the particular characteristics of research reactors, as set out in para. 1.3, necessitate that a graded approach (see Ref. [2], paras 1.11–1.14; Ref. [3]) be adopted in implementing the recommendations in this Safety Guide. It is therefore necessary that users of this Safety Guide make a conscious and justified selection of the recommendations provided. In addition, the extent of detail in the application of the requirements will depend on the potential hazard and on discussions and agreements between the operating organization and the regulatory body, with the final decision to be made by the regulatory body.

1.11. This Safety Guide focuses mainly on research reactors of a capacity of up to a few tens of megawatts. The amount of detail required in the safety analysis report for small research reactors (i.e. those with a capacity of less than a few tens of kilowatts) and critical assemblies may be substantially less. Nevertheless, when using the graded approach, all items included in this Safety Guide should be assessed. Additional recommendations on the safety analysis, on preparation of the safety analysis report and on the licensing process for high powered or otherwise advanced or complex research reactors are provided in IAEA Safety

---

<sup>4</sup> Utilization (or reactor utilization) is the use of the research reactor, including for isotope production, or the conduct of experiments or the use of experimental facilities during operation of the reactor.

<sup>5</sup> In this Safety Guide, the term ‘research reactor’ includes associated experimental facilities and subcritical and critical assemblies. An experimental facility includes any device installed in or around a reactor to utilize the neutron flux and ionizing radiation from the reactor for research, development, isotope production or any other purpose.

Guides for power reactors.<sup>6</sup> Use of the Safety Guides for power reactors also necessitates that a graded approach (see Ref. [2], paras 1.11–1.14; Ref. [3]) be applied in implementing the recommendations on the basis of the potential hazard associated with the research reactor.

1.12. Although this Safety Guide mainly concerns newly designed and constructed research reactors, its content is applicable to any relicensing process or reassessment of a research reactor requested by the regulatory body or decided on by the operating organization. In any case, the justification for the approach selected on the basis of this Safety Guide should be provided to the regulatory body. Licensing of decommissioning activities<sup>7</sup> is not discussed in this Safety Guide.

1.13. Most research reactors have a small potential for hazard to the public compared with power reactors, but they may pose a greater potential hazard to operating personnel. The scope, extent and detail of the safety assessment should be based on the potential hazard associated with the research reactor and its utilization. The requirement for a graded approach should be adopted (see Ref. [2], paras 1.11–1.14; Ref. [3]) in applying the recommendations and guidance in this Safety Guide.

1.14. The interfaces between nuclear safety and nuclear security should be considered in such a way that the impacts of safety on security and the impacts of security on safety are taken into account from the design stage and an appropriate compatibility is achieved. However, security aspects are subject to confidentiality requirements, and they are not discussed in this Safety Guide (see paras A.13.12 and A.13.13).

## STRUCTURE

1.15. This Safety Guide addresses two interrelated issues: the safety assessment of the research reactor and the preparation of the safety analysis report. It also provides general recommendations on the conduct of the steps in the licensing of a research reactor. The main reason for presenting these two topics together in a

---

<sup>6</sup> Further recommendations on preparation of the safety analysis report for a research reactor with greater potential hazard are provided in Refs [7, 8].

<sup>7</sup> Recommendations on decommissioning activities are provided in Ref. [9].

single Safety Guide is their interrelationship and their joint importance in the licensing process.

1.16. Section 2 describes the licensing process by which the safety of the research reactor and the issuing of licences are controlled and determined.

1.17. Section 3 presents general recommendations on the preparation of the safety analysis report, in particular the preparation of the safety analysis by the operating organization.

1.18. Section 4 provides general recommendations on the information to be provided to the regulatory body to facilitate the process of review and assessment of the safety of the research reactor by the regulatory body.

1.19. The Appendix provides comprehensive guidance on the preparation of the safety analysis report for a research reactor having the characteristics discussed in paras 1.3 and 1.10–1.13. It provides recommendations on the standard content of the safety analysis report.

1.20. Annexes I and II outline, and provide information on, the application of a basic approach to performing the safety analysis for a research reactor using mainly deterministic methods<sup>8</sup> to analyse accidents, including their radiological consequences. Annex III deals with specific aspects of the reactor to be described in the safety analysis report. Finally, Annex IV provides a list of typical sources of radiation in a research reactor to be considered and described in the safety analysis report.

---

<sup>8</sup> Annex I deals mainly with deterministic methods which are normally used for safety evaluations for research reactors. Probabilistic techniques could be used to supplement deterministic methods; see paras 3.28 and 3.29.

## 2. SAFETY ASSESSMENT IN THE LICENSING PROCESS

### RESPONSIBILITIES

2.1. In accordance with the Fundamental Safety Principles (Ref. [1], para. 2.1), it should be ensured that for a research reactor to be built (or to undergo a major modification), the highest safety standards that can reasonably be achieved should be met, to protect people and the environment in the vicinity of the site where it is operated. This assurance is provided by the governmental, legal and regulatory framework, which ensures that an adequate legal and regulatory basis for assessing the safety implications of the project is available (Ref. [4], Requirements 1 and 2). The establishment of an independent regulatory body is an important requirement for an adequate legal and regulatory framework. The IAEA Safety Requirements publication on the Safety of Research Reactors [2] establishes general requirements for the framework of the system for ensuring safety, including the licensing process. Further requirements on the establishment of a regulatory body are established in Ref. [4]. These requirements also apply, as appropriate, for research reactors.

2.2. Compliance with the requirements imposed by the regulatory body does not relieve the operating organization of its prime responsibility for safety throughout the lifetime of the research reactor. The operating organization retains the responsibility for demonstrating to the satisfaction of the regulatory body that this prime responsibility has been, and will continue to be, adequately discharged. The prime responsibility for safety cannot be delegated. One of the ways the operating organization demonstrates that it has achieved adequate safety is through the information normally incorporated into a safety analysis report. This information also constitutes the prime basis for the regulatory body's decision on licensing the research reactor. A close liaison should be maintained between the regulatory body and the operating organization throughout the entire process of regulatory control over the operation of the research reactor.

2.3. The content of the application for a licence should be based on the legal and regulatory framework of the State. Relevant requirements for the licensing process are established in Ref. [4]. The information provided in support of a licence application should be commensurate with the magnitude of the potential hazard associated with the research reactor and its utilization, and should be consistent with the particular stage of the licensing process.

2.4. Licensing is an ongoing process, starting at the stages of siting and site evaluation and continuing up to and including decommissioning and the release of the research reactor from regulatory control. The licensing process should be understandable by interested parties and should be predictable (i.e. well defined, clear, transparent and traceable). The different stages of the licensing process should be established in a coherent yet flexible way in order to achieve the most efficiency. These stages should be discrete and should follow in a logical order (Ref. [10], para. 2.5).

2.5. In all cases, the major stages of the licensing process for research reactors should encompass the regulation of:

- (1) Siting and site evaluation;
- (2) Design and construction;
- (3) Commissioning;
- (4) Operation, including utilization and modification<sup>9</sup>;
- (5) Decommissioning and release from regulatory control.

2.6. In some licensing regimes, consideration has been given to the adaptation of a ‘prelicensing’ process, such as steps that provide for early approval of siting, approval of the safety concept and design, and issuing of a construction licence. Such a licensing regime may help to minimize the duplication of effort through different stages of the licensing process. It may also allow for some stages to be conducted in parallel. It provides for the clear division of responsibilities for different stages between regulatory bodies, vendors and operating organizations; gives the public opportunities for early participation; and ensures that the most important safety issues are dealt with early in such a ‘prelicensing’ phase. A detailed demonstration of nuclear safety, including an adequate safety analysis, should be submitted by the operating organization, and should be reviewed and assessed by the regulatory body before the next stage is authorized. Detailed guidance on the licensing process is presented in Ref. [10].

2.7. At all stages, the operating organization should be able to demonstrate that it has control over the research reactor and that it has an adequate organizational

---

<sup>9</sup> Although utilization and modification of research reactors are processes comprising activities normally included in operation (Ref. [2], paras 7.85–7.92), they may be considered separate stages in the licensing process, because their safety implications lead to a large number of review and assessment activities that are repeated many times over the reactor’s lifetime (see paras 2.40–2.43).

structure, a management system<sup>10</sup>, and adequate resources to discharge its obligations and, as appropriate, its liabilities. The totality of the documentation that the operating organization uses in making this demonstration, some of which may not be included in the initial formal submission, should cover all appropriate topics, depending on the stage of the licensing process.

2.8. On the basis of the requirements for the governmental, legal and regulatory framework for safety with regard to the review and assessment of safety related documentation [4], the operating organization should submit to the regulatory body, in a timely manner, any information that the regulatory body has requested. It is the responsibility of the operating organization to make arrangements with the vendors to ensure the availability of information that has been requested by the regulatory body. It should also be the responsibility of the operating organization to keep the regulatory body informed of relevant new information and of any alterations to information submitted previously.

2.9. The format and content of documents submitted by the operating organization in support of a licence application should be based on the information presented in this Safety Guide. However, the regulatory body may require or may use additional information in the licensing process.

2.10. The review and assessment of information by the regulatory body is a continuous process. Sections of the safety analysis report or other documents should be submitted to the regulatory body at an early stage. A schedule for the review and assessment by the regulatory body should be discussed between the operating organization and the regulatory body.

2.11. The operating organization should revise all documentation associated with any modification or activity that may affect the safety of a research reactor (and all documentation having an indirect but significant influence on safety related aspects of a research reactor), as appropriate. The revised documentation should be submitted to the regulatory body to allow for its review and assessment (Ref. [4], para. 4.45), with the potential magnitude and nature of the associated hazards being taken into account (Ref. [4], Requirement 26).

---

<sup>10</sup> The term ‘management system’ reflects and includes the concepts of quality control, quality assurance and quality management. The management system is a set of interrelated or interacting elements that establishes policies and objectives, and enables those objectives to be achieved in a safe, efficient and effective manner. Further requirements and guidance are provided in Refs [11, 12].

2.12. The operating organization should submit information to the regulatory body on the basis of which the regulatory body can determine whether the proposed research reactor can be sited, designed, constructed, commissioned, operated, utilized, modified and decommissioned without undue radiation risks to site personnel, the public or the environment. On the basis of the documentation submitted, the regulatory body should be able to do the following:

- (a) To acquire an understanding of the reactor design, the safety concepts on which it is based, the management system and the operating principles proposed by the operating organization.
- (b) To perform a review and assessment of the operating organization's technical submissions. This review and assessment should proceed from an overall survey of the reactor to an in-depth review and assessment of the design of individual structures, systems and components, and their behaviour in normal operation, anticipated operational occurrences and accident conditions.

When necessary, modifications to the matters stated in (a) and (b) also have to be submitted at the request of the regulatory body.

2.13. The primary basis of the review and assessment of the safety aspects of the proposed research reactor is the information contained in the safety analysis report submitted by the operating organization to the regulatory body. The safety analysis report should be sufficient for the regulatory body to decide on the following points:

- Whether the operating organization has provided the necessary and adequate information for the purpose and scope of the review and assessment (see para. 4.2).
- Whether this information is in compliance with the requirements of all applicable rules and regulations.
- Whether this information is accurate; this might be determined by means of independent checks of the design, including calculations, and by inspections of the programmes and facilities (e.g. design and review programmes or management system requirements and their implementation).

## ACCEPTANCE CRITERIA<sup>11</sup>

2.14. In addition to the acceptance criteria established within the regulatory framework, the operating organization should develop additional acceptance criteria to demonstrate the adequate application of the principles and objectives of safe design and operation established in the IAEA safety standards. These principles include the Fundamental Safety Principles [1] and the radiation protection objectives stated in para. 2.2 of Ref. [2].<sup>12</sup>

2.15. Acceptance criteria should be applied to judge the acceptability of the results of the safety analysis for both the operational states of the research reactor and the accident conditions considered in its design. They may be:

- A set of numerical limits on the values of predicted parameters;
- A set of conditions for plant states during and after an accident;
- A set of performance requirements on systems;
- A set of requirements on the need for, and the ability to credit, actions by the operating organization.

2.16. The acceptance criteria should include additional margins beyond the basic acceptance criteria as established within the regulatory framework, to allow for uncertainties. These specific acceptance criteria may be defined by the designer or by the operating organization. The set of acceptance criteria should be satisfactory to the regulatory body.

2.17. In the development of the acceptance criteria, consideration should be given to the criteria listed below:

- (a) Radiological criteria such as:
- Maximum allowable doses to the public;
  - Dose limits (or design target doses<sup>13</sup>) for staff of the operating organization, including experimenters and workers at the reactor site;
  - Dose limits for intervention in accident conditions to perform life saving actions and mitigatory actions;

---

<sup>11</sup> Practical examples of acceptance criteria are provided in Ref. [13].

<sup>12</sup> Requirements on radiation protection are established in Ref. [14], and additional recommendations and guidance are given in Ref. [15].

<sup>13</sup> Guidance on design target doses is provided in Ref. [15], paras 2.8 and 2.9.

- Authorized limits on releases to the environment during normal operation and acceptable limits on releases to the environment in accident conditions;
- Risk criteria (where applicable).
- (b) Nuclear fuel performance criteria:
  - Maximum cladding temperature below blistering temperature;
  - Maximum heat flux not exceeding the critical heat flux during a transient;
  - Maximum heat flux not exceeding the onset of significant voiding during a transient;
  - Flow conditions not exceeding the onset of flow instability;
  - Frequency limits for significant damage to fuel cladding.
- (c) Performance criteria, including:
  - Limits on parameters to prevent damage of the primary coolant system boundary;
  - Limits on parameters to prevent damage to safety relevant systems caused by in-core or out of core experimental facilities<sup>14</sup>;
  - Limits on parameters to prevent damage to the containment systems;
  - Maintenance of core cooling;
  - Frequency limits for certain anticipated operational occurrences and for particular accident conditions.

2.18. The detailed acceptance criteria should include the following:

- An event should not generate a more serious condition of the research reactor without the occurrence of a further independent failure. Thus an anticipated operational occurrence by itself should not generate a design basis accident, and a design basis accident by itself should not generate a beyond design basis accident.
- There should be no consequential loss of function of the safety systems necessary to mitigate the consequences of an accident.
- Systems used for mitigation of the consequences of accidents should be designed and constructed to withstand the maximum loads and stresses and the most extreme environmental conditions for the accident analysed.

---

<sup>14</sup> An isotope production facility is regarded as an experimental facility.

## INFORMATION REQUIREMENTS IN THE VARIOUS STAGES OF THE LICENSING PROCESS

2.19. The operating organization should provide the regulatory body with all relevant information on the safety of the research reactor. This information is normally presented in a safety analysis report, which is described comprehensively in the Appendix to this Safety Guide. Guidance on the preparation and presentation of the safety analysis report is provided in Section 3, and guidance on its review and assessment is provided in Section 4. The following paragraphs provide a summary of the information that is normally required for each stage of the licensing process. The sequential request for information may lead to successive updating, with each version of the safety analysis report corresponding to a particular stage of the licensing process, as outlined in para. 2.5.

2.20. The preparation of the safety analysis report should start as early as possible in the project, to allow the designers to derive the maximum benefit from the safety analysis, as well as to allow the regulatory body to become familiar with the design and the safety features of the reactor. The amount of information provided in the safety analysis report, at each stage, should be sufficient to allow both the operating organization and the regulatory body to make a decision on the acceptability of the reactor for that stage.

2.21. At various stages in the course of the design process (for example, before the start of construction or operation), the status of the design should be described in the safety analysis report, and the description should include the design and safety assessment that has been carried out up to that point.

## SUBMISSION OF INFORMATION TO THE REGULATORY BODY

### **Schedule for the submission of information**

2.22. A schedule should be drawn up that indicates the timescale for the preparation of the different chapters of the safety analysis report. Since the approval of one stage is normally required before commencement of the next stage, the safety analysis report should be made available for review and assessment on a timescale that has been agreed upon by the regulatory body. An estimate of the size and scope of the analyses should be conveyed to the assessor. In this timescale, reasonable periods of time should be allotted for each

assessment phase such that they can be completed before commencement of the next phase (see paras 4.3 and 4.4).

### **Siting and site evaluation**

2.23. The operating organization should provide sufficient information to demonstrate to the regulatory body that the proposed site is suitable for the type and design of the proposed research reactor. Difficulties to be resolved during the subsequent stages of the licensing process should be identified. Information on the site itself, and preliminary information on the reactor and its interaction with the site and the surrounding environment, should be provided. In addition, a preliminary statement on the potential radiological impacts on site personnel, on the population in the surrounding area and on the environment should be provided. If required in the State, an environmental impact study should be performed as a part of the licensing process.

2.24. The characteristics of the site, which may affect safety related aspects of the research reactor, should be investigated and assessed by the operating organization. The objective of the assessment should be to assess how the site characteristics would influence the design and operation of the research reactor and to demonstrate the adequacy of the characteristics of the site from the point of view of safety. The requirements for the initial site evaluation and site selection, the general criteria for site evaluation and the external events that have to be considered for site evaluation are provided in section 5 of Ref. [2]. Additional guidance on siting and site evaluation is provided in the Appendix (see Chapter 3: Site characteristics) and in Ref. [10] and requirements on site evaluation are established in Ref. [16]. The details on siting that have to be addressed in the safety analysis report are presented under Chapter 3 of the Appendix.

### **Design and construction**

2.25. Before authorization of the construction of the research reactor, features such as the physical layout and the type of construction of the reactor as well as the key elements of the process should be carefully considered, and their effects on the safety of the research reactor throughout its lifetime should be assessed. At this stage, due consideration should be given to the ageing mechanisms for materials and structures, systems and components, and to the effects of these ageing mechanisms on safety.<sup>15</sup> The operating organization should describe the

---

<sup>15</sup> Additional guidance on ageing management for research reactors is given in Ref. [17].

arrangements for the control of activities in construction, manufacture and installation. In addition, an outline plan for decommissioning, covering issues such as strategies to be applied, radiation doses to be expected and amounts of waste expected to be generated, should be prepared at the design stage. Information on the matters discussed in this paragraph should be submitted to the regulatory body for review and assessment.

2.26. To obtain a construction licence or an approval for the start of construction, the operating organization should submit to the regulatory body information that demonstrates that the design will result in a safe research reactor and that construction will achieve the design intent. The information should contain a description of the design of the reactor and the associated safety systems and process systems. It should also present the results of the safety analysis to demonstrate the adequacy of the design of safety related structures, systems and components. This information should be submitted in the safety analysis report, which may be preliminary and subject to updating as the project proceeds.

2.27. Those aspects of the design that should be submitted to the regulatory body for review and assessment before the design is finalized should be identified so that activities can proceed while the reactor is under construction. The information should be updated and resubmitted to the regulatory body as the detailed design and the construction of the reactor proceed. In some cases, revised versions of documents will be sufficient; in other cases, technical supplements may be appropriate. Additional guidance on the licensing process for this stage is given in Ref. [10].

2.28. The safety analysis report is the main document provided at this stage for review and assessment by the regulatory body for the authorization of the detailed design and construction.

## **Commissioning**

2.29. When construction is at a sufficiently advanced stage, the information contained in the safety analysis report should be reviewed and updated, where necessary. The updated safety analysis report should be resubmitted to the regulatory body for review and assessment in order to obtain the required authorization for commissioning.

2.30. Reference [2] (para 7.46) requires that commissioning tests be arranged in functional groups and in a logical sequence. This sequence includes pre-operational tests, initial criticality tests, low power tests, tests to verify the

shutdown capabilities, power ascension tests and full power tests. Every test sequence should be completed successfully, and the results should be submitted to the regulatory body for review and assessment. The test results should be approved at the appropriate level of management before the subsequent test sequence is started. The commissioning programme should therefore be divided into stages, which are usually arranged according to the following sequence:

- Stage A: tests prior to fuel loading;
- Stage B: fuel loading tests, initial criticality tests, low power tests and tests to prove the shutdown capabilities;
- Stage C: power ascension tests and full power tests.

Commissioning should be carried out in accordance with the commissioning programme that has been reviewed and assessed by the regulatory body. Detailed guidance on the commissioning of research reactors is given in Refs [10, 18].

2.31. The updated safety analysis report should include the commissioning programme and should demonstrate its adequacy (Ref. [2], paras 7.42–7.44). The ‘as-built’ reactor, the analyses of postulated accidents and the capability of safety systems to limit the consequences of postulated accidents should also be fully documented in the updated safety analysis report.

2.32. The commissioning procedures for a commissioning stage should be reviewed before the start of the next stage and should be updated, where necessary. The ‘as-built’ design of the research reactor and the results of the previous commissioning stages should be taken into account. The updated commissioning procedures should be submitted to the regulatory body for review and assessment to obtain the required authorizations for commissioning.

2.33. Stage A (tests prior to fuel loading) should ensure that the reactor has been constructed, manufactured and installed correctly and in accordance with the design documentation. If deviations from the design documentation have occurred, they should be recorded, and it should be shown that the safety analysis has not been compromised. The results of this stage should also confirm the operational features of the research reactor and should lead to the development of detailed instructions for operating personnel, which should be confirmed during Stages B and C.

2.34. Stage B (fuel loading tests, initial criticality tests, low power tests and tests to prove the shutdown capabilities with the introduction of fissile material) is a major step in the authorization process. The commissioning programme of the

previous stage, the organizational structure, the qualifications of operating personnel, the radiation protection programme, emergency preparedness and response, the operational limits and conditions for commissioning, and the preliminary operating procedures<sup>16</sup> should be taken into account at this commissioning stage. Whenever there are deviations from the design parameters, these should be analysed by the operating organization and reported to the regulatory body for review and assessment.

2.35. As power ascension test and full power test processes in Stage C move closer to completion, this commissioning stage should focus on how the research reactor will be operated, utilized and maintained, and on procedures for controlling and monitoring operation and for responding to deviations and other occurrences. Before authorization for routine operation is requested, the test results, any corrections of non-conformances, modifications to the design or modifications to the operational procedures, and any proposed changes to the operational limits and conditions should be submitted to the regulatory body for review and assessment.

2.36. The information referred to in paras 2.30–2.35 should be updated after each stage, and submission to the regulatory body should form the basis of the start of the next commissioning stage as a part of the licensing process.

## **Operation**

2.37. In its application for an operating licence, the operating organization should submit all of the information referred to in the preceding sections. Additional information to prove the capability for safe operation should be submitted to the regulatory body. Some of this information is required in the licensing steps, and some information should be submitted after the formal licence has been obtained. Additional guidance on the licensing steps is given in Ref. [10], and detailed guidance on ensuring safe operation is given in Ref. [2] and the related Safety Guides [15, 19, 20].

2.38. The final version of the safety analysis report should be prepared for the stage of application for an operating licence. The results from the commissioning programme should be included and assessed to demonstrate that the design intentions have been achieved.

---

<sup>16</sup> Guidance on operating procedures is provided in Ref. [19].

2.39. A review of the safety measures for the operation of the research reactor should be undertaken periodically. While the need for reassessment may arise in a number of ways, systematic safety reassessments (i.e. periodic safety reviews) should be carried out by the operating organization at intervals to review important issues such as the cumulative effects of ageing of the research reactor. The nature of this review and the interval between reviews should reflect the risks that the research reactor presents. For this review, a comparison of the existing safety analysis report with information on operating experience should be made, including lessons from accidents and information on radiological aspects, modifications, experiments and other aspects of operation. If required as a result of the review of the safety measures for operation, the operating organization should submit to the regulatory body a request for an amendment of the licence. This request may include a revised safety analysis report.

### **Utilization and modification**

2.40. The operating organization should submit to the regulatory body for review and assessment information on experiments and modifications that might affect the safety of the research reactor. The specific submission requirements will depend on the safety significance of the experiments and modifications. These requirements are set out in paras 7.86 and 7.88 of Ref. [2]. Specific guidance on the development of appropriate procedures for the control of experiments and modifications is provided in Refs [6, 19].

2.41. Experiments and modifications having major safety significance should be subjected to procedures for design, construction, commissioning and safety analysis that are equivalent to those for the research reactor itself. This safety analysis may need to be performed in stages. These stages could be: (1) design and procurement; (2) disassembly; (3) installation or implementation of the modification; (4) reassembly; (5) testing; (6) commissioning; and (7) validation of the design. The safety aspects of each phase of the project should be analysed and presented in a dedicated safety analysis report, or a revision of the appropriate chapters of the existing safety analysis report for the reactor should be prepared. The dedicated safety analysis report or the revised chapters should be submitted to the regulatory body for review and assessment. In addition, the safety analysis report provides boundaries for operational limits and conditions that have been demonstrated to be safe, and any experiments and modifications should fall within these boundaries.

2.42. If applicable, the operating organization should revise the relevant acceptance criteria and should submit them to the regulatory body for review and

assessment, and for approval for use in the safety analysis of the proposed experiment or modification.

2.43. Commissioning of the experiment or the modified research reactor should be conducted to demonstrate compliance with the design intention in the safety analysis report. In addition, if changes to the safety analysis report or to some analyses are made, it should be ensured that the other safety analyses are still valid.

### **Decommissioning and release from regulatory control**

2.44. The decommissioning process, such that regulatory control may be removed, which includes decontamination and the dismantling and/or removal of radioactive material, radioactive waste, components and structures, should require approval by the regulatory body. Detailed requirements on the subject are established in Ref. [2], paras 8.1–8.8. The operating organization should provide documentation that describes the intended decommissioning process<sup>17</sup> to demonstrate that remaining radiological hazards, if any, at the former site will be minimal, that any radioactive waste generated will be properly dealt with, and that any particular hazards associated with the decommissioning process have been adequately analysed and assessed. Further guidance is provided in IAEA safety standards on the management of radioactive waste.

2.45. At some point in the decommissioning process (e.g. after the removal of all fuel from the site), the safety analysis report ceases to be a major working document and a detailed report on the decommissioning process should be prepared. Further guidance on decommissioning is provided in Ref. [9].

---

<sup>17</sup> This documentation describing the intended decommissioning process is required when initiating this decommissioning process.

### 3. PREPARATION OF THE SAFETY ANALYSIS REPORT

#### PURPOSE AND SCOPE

3.1. The operating organization should make arrangements for preparing a safety analysis report to demonstrate the safety of the design of the research reactor. The safety analysis report should also provide the basis for the safe operation of the research reactor, and should be the basis for the interaction between the operating organization and the regulatory body in the licensing process.

3.2. In addition, the preparation of a safety analysis report should also serve the following purposes:

- To aid the designer in confirming that individual systems are integrated correctly, since the design of the reactor and the development of the safety analysis report are complementary and interactive processes;
- To ensure that the safety analysis has properly identified the safety issues relevant to the design and that the safety analysis and the design are consistent;
- To aid in the appreciation of the relevant design criteria, limitations and requirements, and in the evaluation of the hazards posed by the research reactor;
- To aid in the training of operating personnel and in their familiarization with the research reactor;
- To aid in the establishment of operational limits and conditions on certain parameters that have to be met at all stages of the lifetime of the reactor in order to ensure adequate margins of safety for the reactor;
- To identify ageing mechanisms and their effects on safety for the development of an ageing management programme.

3.3. Over the lifetime of the research reactor, the safety analysis report should be continuously updated to describe:

- The evolution of the design, operation and utilization of the research reactor and the related experimental facilities, and any modifications to and upgrades of the research reactor;
- The consequences of events that may have occurred during the lifetime of the research reactor and that may influence the actions that will need to be taken during the eventual decommissioning of the research reactor.

3.4. The safety analysis report should give a detailed description of the reactor site, the reactor itself, the experimental facilities and all other facilities with significance for safety. It should provide a detailed description of the general safety concepts and criteria, as well as of the codes and standards applied to the design for the purposes of protection of the reactor, the operating personnel, the public and the environment. The potential hazards associated with the operation of the reactor should also be addressed in the safety analysis report. The safety analysis report should contain or should refer to the safety analysis of accident sequences and of the safety features incorporated into the design to prevent accidents or to mitigate their consequences through the design and operating procedures.

3.5. The safety analysis report should provide a set of operational limits and conditions to be incorporated into the licence for operation, or should describe the content of the operational limits and conditions if they will be described in a separate document. It should also provide details of the conduct of operations intended by the operating organization, including its organization and the management system procedures established for the design and operation of the research reactor. The safety analysis report should also provide details of the emergency plan.

3.6. While the topics listed in paras 3.4 and 3.5 have been deliberately stressed, all topics treated in the Appendix to this Safety Guide should be adequately covered in the safety analysis report. All of these topics should be prepared in accordance with the corresponding recommendations in the Appendix. However, some of the topics may be discussed in separate documents (e.g. in the operational limits and conditions, operational procedures, physical protection plans or emergency plans). In this case, these topics are treated briefly in the safety analysis report and reference is made to the appropriate separate document.

## SPECIFIC GUIDANCE

3.7. The operating organization should ensure that an independent verification of the safety assessment is performed by individuals or groups separate from those carrying out the design, before the design is submitted to the regulatory body (Ref. [2], para. 2.19).

3.8. The independent verification should be carried out under the responsibility of the operating organization by a team of experts who should be independent of the designers and of those performing the safety assessment. Personnel are

considered independent if they have not participated in any part of the design or the safety assessment. This independent verification is in addition to the reviews carried out within the design organization.

3.9. Whereas the safety assessment is a comprehensive study carried out by the designers throughout the design process to address all relevant safety requirements, the independent verification should be carried out by or on behalf of the operating organization.

3.10. In some States the proposal and the licence application for a research reactor may be subject to an open public debate.<sup>18</sup> For these purposes, the operating organization may have to develop a non-technical version of the safety analysis report that can be understood by the public.

3.11. The safety analysis report should present adequate references that may be necessary for the review and assessment process. This reference material should be freely available to the regulatory body and should not be subject to any classification or limitation that would prevent its adequate review and assessment. Such references need not be submitted together with the safety analysis report, but they should be retained by the operating organization or the designers so that they can be provided upon request.

3.12. Some regulatory bodies request the assistance of a technical support organization or an independent peer review group in reviewing the safety analysis report. In this case, the results of the review may be reported directly to the regulatory body.

3.13. Certain information provided by the operating organization or its contractors should be considered confidential, because of its proprietary nature, for security reasons or because of the right of individuals to privacy, in accordance with national laws and regulations. Such confidential information should be made available, as necessary, without restriction to the regulatory body; that is, it should be made available to its staff, technical support organizations, consultants and advisory committees as well as to any governmental bodies involved in the review and assessment process. The regulatory body should formally inform the operating organization which consultants and advisers will be involved on behalf of the regulatory body. Those persons to whom such information is to be entrusted should be advised of its confidential nature and

---

<sup>18</sup> Guidance on public participation is given in paras 2.42–2.45 of Ref. [10].

should be obliged, consistent with national laws and regulations, to protect its confidentiality. If consultants, technical support organizations and external advisory committees need to have confidential documents at their disposal, a process to ensure confidentiality should be put in place.

3.14. Owing to the volume of documentation required to support a safety analysis report, a document control system should be established to manage the indexing and to control the issue of the separate documents that make up the safety analysis report. The document control system should be used to control the updating, revision, issue or removal of reports in accordance with the management system procedures, so that information is always kept up to date.

3.15. The type of reactor, its site and its characteristics (design, power and utilization) may influence the extent of the information to be presented in the safety analysis report. Accident scenarios for reactors with higher power levels or with a significant inventory of radioactive material will usually require more details to be provided about the site and about the safety features to protect against any significant release of radioactive material to the environment.

3.16. For small, low risk facilities (such as critical assemblies or reactors with low power levels), these requirements are much less stringent. However, as the safety analysis report is often the only comprehensive document produced, every topic discussed in the Appendix to this Safety Guide should be considered. Although the extent of information on each topic would be limited, the scope of some topics (e.g. the protection of operating personnel against overexposure in critical assembly facilities) may be much larger for small, low power facilities.

## SELECTED POSTULATED INITIATING EVENTS

3.17. The following list of selected postulated initiating events is based on the appendix to Ref. [2]:

- (1) Loss of electrical power supplies:
  - Loss of normal electrical power.<sup>19</sup>

---

<sup>19</sup> Although it is not considered an initiating event, consideration should be given to the loss of normal power followed by the loss of emergency power, to ensure that the consequences would be acceptable under emergency conditions.

- (2) Insertion of excess reactivity:
- Criticality during fuel handling and loading (due to an error in fuel insertion);
  - Startup accident;
  - Control drive failure or system failure;
  - Failure of other reactivity control devices (such as a moderator or reflector);
  - Unbalanced rod positions;
  - Failure or collapse of structural components;
  - Insertion of cold water;
  - Changes in the moderator (e.g. voids or leakage of heavy water (deuterium oxide, D<sub>2</sub>O) into water (H<sub>2</sub>O) systems);
  - Influence by experiments and experimental devices (e.g. flooding or voiding, temperature effects, insertion of fissile material or removal of absorber material);
  - Insufficient shutdown margin;
  - Inadvertent ejection of control rods;
  - Maintenance errors with reactivity devices;
  - Spurious control system signals.
- (3) Loss of flow:
- Failure of primary pump;
  - Reduction of flow of primary coolant (e.g. due to the failure of a valve or a blockage in piping or a heat exchanger);
  - Influence of the failure or mishandling of an experiment;
  - Rupture of the primary coolant boundary leading to a loss of flow;
  - Fuel channel blockage;
  - Improper power distribution due to, for example, unbalanced rod positions, in-core experiments or fuel loading;
  - Reduction of coolant flow due to bypassing of the core;
  - Deviation of system pressure from specified limits;
  - Loss of heat sink (e.g. due to the failure of a valve or a pump, or damage to a system).
- (4) Loss of coolant:
- Rupture of the primary coolant boundary;
  - Damage to the pool;
  - Pump-down of the pool;
  - Failure of beam tubes or other penetrations.
- (5) Erroneous handling or malfunctioning of equipment or components:
- Failure of the cladding of a fuel element;
  - Mechanical damage to core or fuel (e.g. mishandling of fuel or dropping of a transfer flask onto the fuel);

- Failure of an emergency cooling system;
  - Malfunctioning of the reactor power control;
  - Criticality in fuel in storage;
  - Failure of means of confinement, including the ventilation system;
  - Loss of coolant during transfer or storage of fuel;
  - Loss or reduction of proper shielding;
  - Failure of experimental facilities or materials (e.g. due to loop rupture);
  - Exceeding of fuel ratings.
- (6) Special internal events:
- Internal fires or explosions, including internally generated missiles;
  - Internal flooding;
  - Loss of support systems;
  - Dropping of heavy loads;
  - Loss of integrity of pressurized vessels;
  - Malfunction during a reactor experiment;
  - Improper access by persons to restricted areas;
  - Fluid jets and pipe whip;
  - Exothermic chemical reactions;
  - Electromagnetic compatibility;
  - Security related incidents (see paras A.13.12 and A.13.13 in the Appendix).
- (7) External events<sup>20</sup>:
- Earthquakes (including seismically induced faulting and landslides);
  - Flooding (including failure of an upstream dam and blockage of a river);
  - Tornadoes and tornado missiles;
  - Sandstorms;
  - Hurricanes, storms and lightning strikes;
  - Tropical cyclones;
  - Explosions;
  - Aircraft crashes;
  - Fires;
  - Toxic spills;
  - Accidents on transport routes;
  - Effects from adjacent facilities (e.g. nuclear facilities, chemical facilities or waste management facilities);
  - Biological hazards such as microbiological fouling, structural damage or damage caused to equipment by rodents or insects;

---

<sup>20</sup> The possibility of extreme weather conditions associated with climate change needs to be taken into account for the determination of the external events.

- Extreme meteorological phenomena;
- Power surges or voltage surges on the external supply line;
- Security related external events (see paras A.13.12 and A.13.13 in the Appendix).

(8) Human errors.

## DEVELOPMENT OF THE SAFETY ANALYSIS

3.18. The safety analysis, as part of the safety assessment used in the licensing of a research reactor, should proceed in parallel with the design process, with iteration between the two activities. The scope and level of detail of the safety analysis should increase as the design process progresses, so that the final safety analysis reflects the final design of the reactor as constructed.

3.19. The safety analysis should be used mainly to enable the operating personnel to understand the basis for the safe operation of the reactor, and to demonstrate to the regulatory body the way in which the design of the research reactor and the related operational procedures will contribute to the prevention of accidents or mitigation of the consequences of accidents. The safety analysis should include analyses of the response of the reactor to a range of postulated initiating events (such as disturbances in process parameters, malfunctions and failures of equipment, internal and external events, postulated design basis accidents and human errors). The safety analysis should also serve as a basis for the determination of the operational limits and conditions, as well as for designing specifications for systems and components.

3.20. The consideration of fault conditions should determine the design of the research reactor and the design limits for the safety systems and for most structures, systems and components necessary for the operation of the research reactor. The consideration of fault conditions should also inform the operating instructions and procedures for operating personnel. In addition, the potential radiological consequences of fault conditions for workers, the public and the environment may be more severe than the radiological consequences in routine operation. For this reason, an important part of the effort in the peer review and verification by the operating organization should be directed to the safety analysis of fault conditions. This analysis should be performed in accordance with the magnitude and nature of the risks associated with the particular research reactor. Safety analysis may be considered to consist of the following major steps: