IAEA Safety Standards

for protecting people and the environment

The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors

Specific Safety Guide

No. SSG-84

IAEA

International Atomic Energy Agency

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.

THE OPERATING ORGANIZATION AND THE RECRUITMENT, TRAINING AND QUALIFICATION OF PERSONNEL FOR RESEARCH REACTORS

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

IAEA SAFETY STANDARDS SERIES No. SSG-84

THE OPERATING ORGANIZATION AND THE RECRUITMENT, TRAINING AND QUALIFICATION OF PERSONNEL FOR RESEARCH REACTORS

SPECIFIC SAFETY GUIDE

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FOREWORD

by Rafael Mariano Grossi
Director General

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

BACKGROUND

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

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

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

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

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

Safety Fundamentals

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

Safety Requirements

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

Safety Guides

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

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

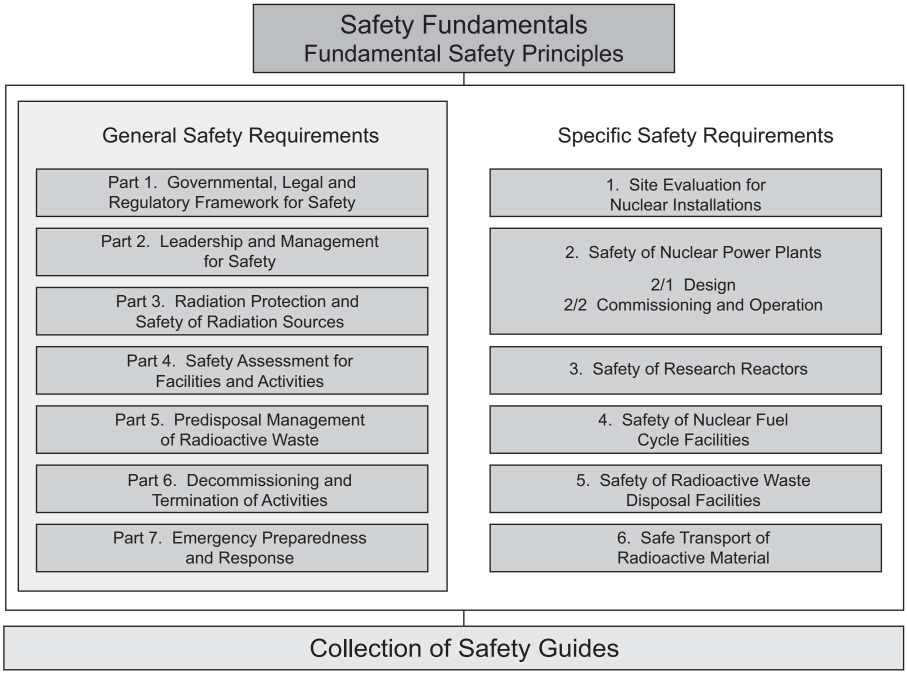

FIG. 1. The long term structure of the IAEA Safety Standards Series.

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

APPLICATION OF THE IAEA SAFETY STANDARDS

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

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

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

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

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

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

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

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

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

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

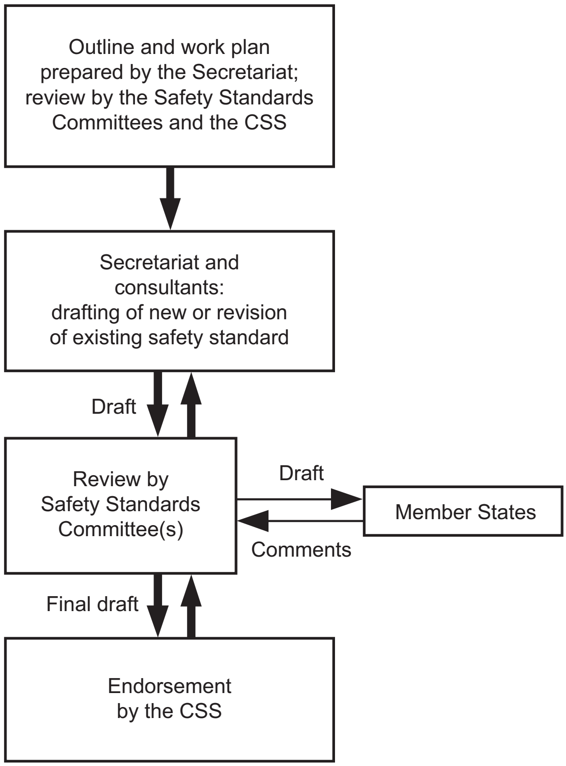

FIG. 2. The process for developing a new safety standard or revising an existing standard.

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

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

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

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Nuclear Safety and Security Glossary (see https://www.iaea.org/resources/publications/iaea-nuclear-safety-and-security-glossary). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

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

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

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

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Requirements for the safety of research reactors, with particular emphasis on their design and operation, are established in IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors [1].

1.2. This Safety Guide provides recommendations on the operating organization and the recruitment, training and qualification of personnel for research reactors.

1.3. This Safety Guide was developed in parallel with seven other Safety Guides on the safety of research reactors, as follows:

(a) IAEA Safety Standards Series No. SSG-80, Commissioning of Research Reactors [2];
(b) IAEA Safety Standards Series No. SSG-81, Maintenance, Periodic Testing and Inspection of Research Reactors [3];
(c) IAEA Safety Standards Series No. SSG-82, Core Management and Fuel Handling for Research Reactors [4];
(d) IAEA Safety Standards Series No. SSG-83, Operational Limits and Conditions and Operating Procedures for Research Reactors [5];
(e) IAEA Safety Standards Series No. SSG-85, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors [6];
(f) IAEA Safety Standards Series No. SSG-10 (Rev. 1), Ageing Management for Research Reactors [7];
(g) IAEA Safety Standards Series No. SSG-37 (Rev. 1), Instrumentation and Control Systems and Software Important to Safety for Research Reactors [8].

1.4. Additional recommendations on the safety of research reactors are provided in IAEA Safety Standards Series Nos SSG-20 (Rev. 1), Safety Assessment for Research Reactors and Preparation of the Safety Analysis Report [9], and SSG-24 (Rev. 1), Safety in the Utilization and Modification of Research Reactors [10].

1.5. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Nuclear Safety and Security Glossary [11].

1.6. This Safety Guide supersedes IAEA Safety Standards Series No. NS-G-4.5, The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors[1].

OBJECTIVE

1.7. The objective of this Safety Guide is to provide recommendations on the operating organization of a research reactor, and on the recruitment, training and qualification of personnel, to meet the relevant requirements of SSR-3 [1], in particular Requirements 2 and 67–70.

1.8. The recommendations provided in this Safety Guide are aimed at operating organizations of research reactors, regulatory bodies, other organizations involved in a research reactor project and organizations involved in educational programmes on nuclear science and technology.

SCOPE

1.9. This Safety Guide is primarily intended for use for heterogeneous, thermal spectrum research reactors that have a power rating of up to several tens of megawatts. For research reactors of higher power, specialized reactors (e.g. fast spectrum reactors) and reactors that have specialized facilities (e.g. hot or cold neutron sources, high pressure and high temperature loops), additional guidance may be needed. For such research reactors, the recommendations provided in IAEA Safety Standards Series Nos SSG-72, The Operating Organization for Nuclear Power Plants [12], and SSG-75, Recruitment, Qualification and Training of Personnel for Nuclear Power Plants [13], might be more suitable. Homogeneous reactors and accelerator driven systems are outside the scope of this publication.

1.10. Some research reactors, critical assemblies and subcritical assemblies with a low hazard potential might need less comprehensive arrangements than are recommended in this Safety Guide. While all recommendations in this Safety Guide are to be considered, some might not be applicable to such research reactors, critical assemblies and subcritical assemblies (see Requirement 12 and paras 2.15–2.17 of SSR-3 [1], as well as IAEA Safety Standards Series

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors, IAEA Safety Standards Series No. NS-G-4.5, IAEA, Vienna (2008).

No. SSG-22 (Rev. 1), Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors [14]).

1.11. In this Safety Guide, subcritical assemblies will be mentioned separately only if a specific recommendation is not relevant for, or is applicable only to, subcritical assemblies.

STRUCTURE

1.12. Section 2 provides recommendations on the organizational structure and staffing of a research reactor and the duties and responsibilities of the personnel. These recommendations form the basis for the specification of personnel qualifications and of the prerequisites for the recruitment of individuals. Section 3 provides recommendations on the factors to be taken into account in the recruitment and selection process. Section 4 provides recommendations on the knowledge and experience that operating personnel[2] in various positions need to have, as well as on training systems and training programmes, including continuing training and requalification. Recommendations on the training and qualification of support personnel[3] are also provided. Section 5 provides recommendations on the authorization and reauthorization of operating personnel by the operating organization and the regulatory body. Section 6 provides recommendations on recruitment, training and qualification records.

1.13. Annex I contains a description of the systematic approach to training. Annex II presents an example of a training curriculum that covers the main topics for the initial training and continuing training of reactor operators and senior reactor operators at a large research reactor.

[2] The operating personnel comprise the reactor manager, the reactor supervisor, the shift supervisors, the reactor operators, the maintenance personnel and the radiation protection personnel.

[3] Support personnel are personnel other than the operating personnel and include technical personnel such as training officers, safety officers and reactor chemists (see paras 7.24 and 7.25 of SSR-3 [1]).

2. THE OPERATING ORGANIZATION OF A RESEARCH REACTOR

SAFETY REQUIREMENTS FOR THE OPERATING ORGANIZATION OF A RESEARCH REACTOR

2.1. Requirement 2 of SSR-3 [1] states:

> "**The operating organization for a research reactor facility shall have the prime responsibility for the safety of the research reactor over its lifetime, from the beginning of the project for site evaluation, design, construction, commissioning, operation, including utilization and modification, and decommissioning, until its release from regulatory control.**"

2.2. Paragraph 4.1 of SSR-3 [1] states (footnote omitted):

> "In order to ensure rigour and thoroughness at all levels of the staff in the achievement and maintenance of safety, the operating organization:
>
> (a) Shall establish and implement safety policies and shall ensure that safety matters are given the highest priority;
> (b) Shall clearly define responsibilities and accountabilities with corresponding lines of authority and communication;
> (c) Shall ensure that it has sufficient staff with appropriate qualifications and training at all levels;
> (d) Shall develop and strictly adhere to sound procedures for all activities that might affect safety, ensuring that managers and supervisors promote and support good safety practices, while correcting poor safety practices;
> (e) Shall review, monitor and audit all safety related matters on a regular basis, and shall take appropriate corrective actions where necessary;
> (f) Shall develop and sustain a strong safety culture, and shall prepare a statement of safety policy and safety objectives, which is disseminated to and understood by all staff."

2.3. Requirement 67 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall have the prime responsibility for safety in the operation of the facility.**"

2.4. Paragraph 7.2 of SSR-3 [1] (footnotes omitted) states:

> "The operating organization shall establish an appropriate management structure for the research reactor and shall provide for all necessary infrastructure for the conduct of reactor operations. The…reactor management…shall include the reactor manager and the operating personnel. The operating organization shall ensure that adequate provision is made for all functions relating to the safe operation and utilization of the research reactor facility, such as maintenance, periodic testing and inspection, radiation protection, quality assurance and relevant support services."

The reactor management comprises the members of the operating organization to whom the responsibility and authority for directing the operation of the research reactor facility has been assigned. The reactor manager is the member of the reactor management to whom the direct responsibility and authority for the safe operation of the research reactor are assigned by the operating organization and whose duties constitute the discharge of this responsibility.

2.5. Paragraph 7.3 of SSR-3 [1] states that "The responsibility of the operating organization for the safety of the research reactor shall not be delegated."

2.6. Requirement 69 of SSR-3 [1] states:

> "**The operating organization for a research reactor facility shall assign direct responsibility and authority for the safe operation of the reactor to the reactor manager. The reactor manager shall have overall responsibility for all aspects of operation, training, maintenance, periodic testing, inspection, utilization and modification of the reactor. Discharge of this responsibility shall be the primary duty of the reactor manager.**"

2.7. With regard to a research reactor, the term 'operating organization' includes an academic institution, corporation, institute, centre, national laboratory or other entity authorized by the regulatory body to operate a research reactor and to be responsible for its safety. In the majority of States, an operating organization is the legal entity responsible for fulfilling the financial, commercial and safety obligations and other obligations that might arise in connection with the operation of the research reactor. The reactor manager may also be a head of department or the centre director, or may hold other titles.

2.8. The senior management of the operating organization should demonstrate leadership on safety matters and take an active interest and participate in supervising safety throughout the entire lifetime of the research reactor. The reactor manager is responsible for the safety of the facility and for the management of its personnel and should therefore maintain close oversight of operations.

2.9. The operating organization is required to apply for an authorization from the regulatory body (see paras 3.4 and 3.5 of SSR-3 [1]) to operate a research reactor in accordance with national regulations. General requirements on the authorization of facilities and activities are established in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [15], and recommendations on this topic are provided in IAEA Safety Standards Series No. GSG-13, Functions and Processes of the Regulatory Body for Safety [16].

2.10. Compliance with the requirements of the regulatory body does not relieve the operating organization of its prime responsibility for safety. The discharge of this prime responsibility for safety should be regularly reviewed by the operating organization.

2.11. The function of the operating organization of a research reactor is to support an effective utilization programme in accordance with Requirement 83 of SSR-3 [1]. Experimenters and other users of the research reactor are often external to the operating organization or outside the normal line of control of the reactor management. Special arrangements should therefore be established for proper lines of authority and communication (see para. 7.4 of SSR-3 [1]) and for training of experimenters and other users (see para. 7.16 of SSR-3 [1]) in the safe design, construction, installation, operation, utilization and modification of experimental facilities.

ORGANIZATIONAL PLAN FOR A RESEARCH REACTOR

2.12. The operating organization should examine the various functions necessary for safe operation of the research reactor and should either assign authority and responsibility to the appropriate persons within the organization or make arrangements for external support personnel to perform designated tasks or programmes.

2.13. Paragraph 7.11 of SSR-3 [1] states:

> "The organizational structure and the arrangements for discharging responsibilities shall be documented in the safety analysis report and made available to the staff and, if required, to the regulatory body. The structure of the operating organization shall be specified so that all roles that are critical for safe operation are specified and described. Proposed organizational changes to the structure and associated arrangements, which might be of importance to safety, shall be analysed in advance by the operating organization and submitted to the regulatory body for approval."

2.14. The organizational plan should specify the general policies of the operating organization, the lines of responsibility and authority, the lines of communication, and the duties and numbers of operating personnel and their associated qualifications necessary for safe operation of the research reactor. In preparing the organizational plan, the operating organization should take into account all operational states and accident conditions.

2.15. The organizational plan should indicate the staffing arrangements in the categories of operating personnel and support personnel. The extent to which support functions are self-sufficient or are dependent on services from outside the operating organization should be specified. The organizational plan should specify human resource allocations and the duties and responsibilities of key personnel.

2.16. The organizational structure and the functions to be performed, as well as the lines of responsibility, authority and communication, should be clearly and unambiguously stated in the organizational plan. This description is required to be included in the safety analysis report (see para. 2.13) and in the documentation of the management system for the research reactor. This description is also often included in the operational limits and conditions (OLCs) that establish administrative requirements. Activities undertaken by the reactor management should be subject to approval by the regulatory body in accordance with national practices.

2.17. The organizational plan should be established well in advance of the commencement of operation of the research reactor so that the recruitment, selection, training and qualification of personnel can be completed, as necessary, for the commissioning stage and, in all cases, before the commencement of operation. The organizational plan should form the basis for the initial recruitment and training programme and for all subsequent recruitment and training programmes at the research reactor.

2.18. The organizational plan should be regularly reassessed by the operating organization and, if necessary, updated to reflect developments in technology and advances in knowledge regarding the safe operation of the research reactor. The reactor safety committee (see paras 7.26 and 7.27 of SSR-3 [1]) should review the initial organizational plan and any significant changes to the plan.

2.19. Paragraph 7.12 of SSR-3 [1] states:

> "The operating organization shall be responsible for ensuring that the necessary knowledge, skills, attitudes and safety expertise are sustained at the research reactor, and that long term objectives for human resources are met and knowledge preservation policies are developed."

The organizational plan should provide for succession planning to cover attrition and promotion within the organization to ensure a smooth transition for each key position without a detrimental loss of institutional knowledge.

FACTORS TO BE CONSIDERED IN DETERMINING THE STRUCTURE OF THE OPERATING ORGANIZATION OF A RESEARCH REACTOR

2.20. The factors that should be considered in determining the organizational structure and staffing of the operating organization of a research reactor include the following:

(a) The need to ensure that all levels of defence in depth (see paras 2.10–2.14 of SSR-3 [1]) are properly implemented. The influence of human and organizational factors on one or more levels of defence in depth should be specifically considered, to avoid negative impacts on the reliability of these levels and the independence between the levels.
(b) The need to ensure that structures, systems and components important to safety remain in accordance with their design assumptions and intent.
(c) The need for a radiation protection programme, including workers' health surveillance.
(d) The need to ensure the control of reactivity and to prevent inadvertent criticality.
(e) The need to ensure that systems and components are available to cool the fuel, other reactor components and experimental devices, and to confine the radioactive material in all operational states and in accident conditions.
(f) The need for the design, construction, operation and modifications to be thoroughly analysed and reviewed for the purpose of ensuring safety.

(g) The need to be prepared for emergencies and to coordinate the emergency plan for the research reactor with the emergency plans of the regulatory body, public authorities and other organizations that may take actions in response to an emergency.
(h) The need to minimize and control radioactive discharges and to provide for environmental monitoring.
(i) The need to control access to the reactor and to certain areas on the site to ensure safety and to protect individuals and the research reactor against actions that could jeopardize safety.
(j) The need to conduct activities affecting items important to safety in accordance with the management system, including the need to verify whether activities have been performed as specified.
(k) The need for training and retraining of personnel to achieve and maintain adequate levels of competence and to promote a strong safety culture in the organization.
(l) The need to consider all organizational factors that could affect human performance, so that work can be performed safely and satisfactorily without imposing unnecessary physical and psychological stress on personnel.
(m) The need to ensure that a positive attitude towards safety is one of the criteria for recruiting and selecting personnel, appraising performance and promoting personnel.
(n) The need for personnel to know and understand regulatory requirements, to be in a position to make proposals for meeting those requirements and to implement the proposals in a timely manner.
(o) The need for an effective system of communication with the regulatory body.
(p) The need for additional services and facilities for conducting activities such as fuel management, reactor chemistry control, in-service inspection, and monitoring and improvement of the performance of the research reactor, and for modifying and procuring special items.
(q) The need for an effective system through which operating experience from elsewhere can be systematically reviewed and information fed back so that appropriate actions can be taken.
(r) The need to ensure an open exchange of information upward, downward and horizontally within the operating organization.
(s) The need to accommodate experimenters and other reactor users and to meet their needs for new or modified facilities to accomplish their utilization objectives.

2.21. In addition to the needs listed in para. 2.20, the organizational structure should be such as to ensure the following:

(a) That technical services and expertise, including those needed for emergency response, are provided. The extent to which these are provided from within or from outside the organization is a matter of management policy.
(b) That the review of safety related activities is independent of considerations of cost, schedules and reactor utilization.

2.22. The response time for obtaining services from off-site providers should be taken into account when determining the structure of the organization, in particular for a research reactor in a remote location. In such cases, the on-site organization should be capable of rendering all services that may be necessary before off-site support is available.

2.23. Descriptions of individual positions within the operating organization should be used to supplement the organizational plan (see paras 2.12–2.19). These descriptions should clearly define the authorities and responsibilities of and the competences necessary for each position within the operating organization. The descriptions of key positions (e.g. reactor manager, reactor supervisor, shift supervisor, senior reactor operator, reactor operator, radiation protection officer, maintenance personnel) may include provisions for delegating authority for periods when the incumbent is not available. In some States, a brief description of the key positions and provisions for delegation of authority is included in the OLCs that establish administrative requirements.

2.24. The description of the responsibilities of and the competences necessary for each position should form the basis for defining the qualifications and other prerequisites for recruitment, training and continuing training of individuals.

2.25. Proposed changes to staffing levels, ways of working or the organizational structure should be subject to analysis and independent review prior to their implementation. Changes should be monitored during and after their implementation to ensure that they are not detrimental to safety. Minimum staffing levels are often included in the OLCs that establish administrative requirements.

2.26. Before any changes are made to the organizational structure or staffing levels, the possible effects should be reviewed so that any safety implications can be properly considered. For such changes, independent internal review and review by the reactor safety committee may also be appropriate. If required by national regulations, the regulatory body should be informed about proposed changes to the organizational structure or staffing levels that might conflict with the OLCs before their implementation. The regulatory body may then assess the proposed changes and either approve them or withhold approval and intervene if it concludes that the proposed changes would compromise safety.

2.27. The operating organization is required to provide adequate training and retraining of those operating personnel whose positions may need an authorization in accordance with regulatory requirements (see para. 7.5 of SSR-3 [1]). In particular, the reactor manager and designated operating personnel are required to hold authorizations issued by an appropriate authority. Further recommendations on the authorization of operating personnel are provided in Section 5 of this Safety Guide.

2.28. The operating organization should review the functions and responsibilities of the research reactor management (see paras 2.61–2.85) and should ensure that the organizational arrangements and staffing for these management functions and responsibilities are adequately addressed. Special consideration should be given to ensuring that the reactor manager has the necessary authority over operating personnel, external support personnel and experimenters performing safety related activities.

2.29. An operating organization such as an academic institution or a research centre may have centralized services designated to serve the entire institution or centre. In other cases, governmental units or private contractors may provide support services. Examples of functions that might be provided by support services to a research reactor include the following:

(a) Training of personnel;
(b) Development of the management system;
(c) Measures for radiation protection and arrangements for emergency preparedness;
(d) Maintenance, surveillance and in-service inspection;
(e) Waste management and environmental monitoring;
(f) Safety review and assessment, including reviews of safety management;
(g) Core management and fuel handling, including arrangements for procurement;
(h) Design, construction and commissioning of major modifications;
(i) Firefighting service.

A research reactor is required to have its own radiation protection programme and emergency plan (see Requirements 84 and 81 of SSR-3 [1], respectively).

These may be part of the programme and plan for the entire institute or centre and may make use of services provided by the institute or centre.

2.30. The operating organization should ensure that the separate programmes for the operation of the research reactor described in paras 2.86–2.149 are integrated with one another to ensure the safe operation and utilization of the research reactor. This integration should be undertaken throughout the organization, under the direction of persons in designated positions of authority (e.g. reactor manager, reactor supervisor). The reactor safety committee (see para. 2.31) is required to review all proposed programmes for the operation of the research reactor (see para. 4.27 of SSR-3 [1]).

2.31. A reactor safety committee for reviewing the safety of operations (including modifications to the research reactor, to operating procedures and to the experimental programme (see para. 4.27 of SSR-3 [1])) should be included in the organizational plan described in paras 2.12–2.19 and should be consulted on the preparation of this plan. The operating organization should also define and document (e.g. in a written charter) the functions, composition, competence and communication channels of the reactor safety committee.

2.32. The reactor safety committee is required to be independent of the reactor manager and is required to provide advice to the operating organization (see Requirement 6 of SSR-3 [1]). The chairperson of the reactor safety committee should report to the operating organization, and the results of the committee's deliberations should be provided to the reactor manager. To ensure independence, the majority of individuals on the reactor safety committee should be from outside the line of control of the reactor manager. The administrative requirements for the reactor safety committee are often included in the OLCs.

COMMUNICATIONS AT A RESEARCH REACTOR

2.33. Paragraph 7.10 of SSR-3 [1] states that "lines of internal and external communication for the safe operation of the research reactor in all operational states and in accident conditions shall be clearly specified in writing."

2.34. The reactor management should encourage and foster effective communication between all levels of the operating organization. Downward communication should clearly explain the objectives and expectations of the management, upward communication should facilitate the identification and communication of problems to management, and horizontal communication should support effective coordination of work and collaboration.

2.35. Effective means of communication should be established at the research reactor to assist in the understanding of the safety policy (see Requirement 3 of SSR-3 [1]) and the implementation of an effective management system (see Requirement 4 of SSR-3 [1]). Through these means of communication, personnel should be able to understand and accept why particular standards of safety are required. Communication may be formal or informal, depending on the importance of the information provided. Communication should be such as to reinforce teamwork. In particular, there should be communication between shifts, in all operational states and in accident conditions. Horizontal communication should be fostered to establish open lines of communication between groups that work together in performing specific functions.

2.36. Arrangements should be established at the research reactor to facilitate feedback from individuals on any safety concerns. Such arrangements should include both formal mechanisms, such as safety meetings, and informal mechanisms, such as the provision of feedback to managers of the units within the operating organization. The management should be open and responsive to constructive criticism and to feedback received from individuals, especially operating personnel, and should avoid inhibiting effective communication.

2.37. External communications may involve the regulatory body, external maintenance organizations, the reactor vendor, emergency response organizations and technical support organizations. In particular, well defined and open means of communication with the regulatory body should be established. External communication should take into account the broader social framework within which the research reactor operates, and the requirement for the operating organization to communicate with interested parties (see para. 4.7(c) of IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [17]).

RESPONSIBILITIES AT A RESEARCH REACTOR

Responsibilities of the operating organization

2.38. The operating organization should be structured so as to facilitate the discharge of the following responsibilities:

(a) Ensuring the safe operation and utilization of the research reactor by means of implementing an appropriate organizational structure, allocating responsibilities and delegating authority within the organization.
(b) Ensuring that there is an established decision making process that gives adequate consideration to safety in the selection of priorities and the organization of activities.
(c) Establishing a safety policy, implementing operational policies, developing and applying safety performance standards and effectively implementing a management system for the research reactor (see paras 2.61–2.85).
(d) Supporting a safe and productive utilization programme for the reactor.
(e) Providing resources, services and facilities for the safe operation of the research reactor.
(f) Establishing and implementing an appropriate policy on individual fitness for duty that addresses physical and mental fitness, fatigue, and aspects such as the use of drugs, tobacco and alcohol, in accordance with national regulations. This policy should apply to all employees, contractors, experimenters and other users. Similar provisions should be incorporated into the policy for access of visitors to the research reactor.
(g) Liaising with design, construction, commissioning, manufacturing and other organizations involved with the research reactor to ensure proper knowledge transfer and understanding of the reactor design intent and assumptions, information and experience.
(h) Liaising with the regulatory body and other relevant authorities for the purposes of understanding and ensuring compliance with regulatory requirements.
(i) Providing adequate information for communications with the public.
(j) Ensuring the collection, evaluation, implementation and dissemination of operating experience.

The organizational plan (see paras 2.12–2.19) should include a statement of these responsibilities.

2.39. The operating organization is required to ensure that the design, construction, commissioning, operation and decommissioning of the research reactor are performed in accordance with established codes, standards, specifications, procedures and administrative controls (see para. 4.16 of SSR-3 [1]). In addition, the operating organization is responsible (a) for establishing procedures and arrangements to ensure control of the research reactor in all operational states and, to the extent possible, in accident conditions, (b) for ensuring that safety related functions are performed by competent and motivated personnel, and (c) for ensuring control of the fissile material and radioactive material used or generated.

2.40. The descriptions of the structure of the operating organization, the lines of responsibility, authority and communication, and the functions to be performed by individual departments (and by individuals in those departments, as appropriate) should be unambiguous and should leave no scope for improvisation in any operational state or in accident conditions. To ensure that there is a clear understanding of responsibilities, and of relationships between organizational units and between personnel within the operating organization, detailed job specifications should be defined. In particular, these relationships should be clearly defined for all activities that have a bearing on safety.

2.41. The operating organization is required to foster a working environment in which safety is given the highest priority (see para. 4.4 of SSR-3 [1]). Safety and nuclear security should be considered matters of personal accountability for all operating personnel. The working environment should be such as to encourage the achievement of high levels of safety in the operation and utilization of the research reactor as well as to ensure awareness of the interface between safety and security (see Requirement 90 of SSR-3 [1]). Management at all levels should promote the consistent application of safety standards.

2.42. The operating organization is responsible for providing all equipment, personnel, procedures and training and for establishing the management practices necessary for safe operation.

2.43. In accordance with Requirement 69 of SSR-3 [1], the operating organization assigns direct responsibility for safe operation to the reactor manager, who has day to day control of the research reactor. The operating organization should monitor the effectiveness of the reactor manager in discharging this responsibility and should take any necessary measures to ensure that safety is maintained at the levels established by the design, construction and commissioning of the research reactor, and as approved by the regulatory body.

2.44. Responsibilities and authorities that are delegated within the operating organization should be specified at the appropriate levels of management.

2.45. The operating organization should ensure that an adequate number of personnel possess the knowledge, training and skills necessary to supervise and evaluate the work of contractor personnel and temporary personnel. Supervision of contractors is the responsibility of the operating organization (see para. 7.1 of SSR-3 [1]). The operating personnel who supervise contractor personnel or other temporary personnel should be clearly specified. The operating organization should ensure that contractor personnel and temporary personnel who conduct activities on items important to safety are qualified to perform their assigned tasks. Documented assurance should be obtained that contractor personnel have the necessary qualifications prior to their involvement in these activities.

2.46. A wide range of contractual arrangements between the operating organization and suppliers is possible, from procurement of individual items to a turnkey contract. For procurement, the operating organization should assign knowledgeable and skilled personnel in the pre-operational stage of the research reactor to perform this task. For turnkey contracts, the supplier plays a wider role in the construction and testing of the reactor. However, since the operating organization retains prime responsibility for the design, construction, commissioning and safe operation of the structures, systems and components of the reactor, it should assign a sufficient number of knowledgeable and skilled personnel in each of these stages, especially prior to operation. Examples of areas where close cooperation with the supplier should be ensured include the following:

(a) Training of operating personnel;
(b) Preparation of the safety analysis report;
(c) Commissioning of the reactor;
(d) Maintenance, periodic testing and inspection;
(e) Technical assistance during operation;
(f) Preparation of operating procedures and emergency procedures.

2.47. The operating organization should aim to develop a mutual understanding and respect between itself and the regulatory body, which supports a frank and open, yet formal, relationship. Further recommendations on the role of the regulatory body in relation to the operating organization are provided in SSG-20 (Rev. 1) [9] and GSG-13 [16].

2.48. The operating organization is required to develop and implement a procedure for reporting to the regulatory body all incidents of significance to safety (see para. 7.9(k) of SSR-3 [1]). The criteria for reporting such events are often included in the OLCs that establish administrative requirements. The operating organization is also required to submit or make available to the regulatory body documents and other information that it has requested (see para. 4.3 of SSR-3 [1]).

2.49. The operating organization is required to establish a programme for the analysis of operating experience to ensure that lessons are learned and that any necessary corrective actions are taken (see Requirement 88 of SSR-3 [1]). This programme is required to encourage the exchange of experience with national and international systems for the feedback of operating experience (see para. 7.126 of SSR-3 [1]). This programme will need to comply with any regulatory requirements.

Responsibilities of the reactor manager and other operating personnel

2.50. The operating personnel consist of the reactor manager and other individuals involved in the operation, maintenance and, in some cases, use of the research reactor. Their responsibilities include implementation of the safety policy of the operating organization; support of the operating organization in the establishment and fostering of a strong safety culture; and the performance, control and verification of safety related activities. Only operating personnel who hold an appropriate licence or authorization should be allowed to operate the research reactor controls (see also para. 5.9).

2.51. The reactor manager has direct responsibility for all aspects of the operation, utilization and modification of the research reactor. In discharging this responsibility, the reactor manager should ensure the overall coordination of technical support functions, irrespective of whether they are performed by site personnel, by personnel from other organizational units of the operating organization or by personnel from external organizations.

2.52. The reactor manager is required to ensure that operating personnel receive adequate initial training and retraining (see para. 7.15 of SSR-3 [1]).

2.53. The reactor manager should establish performance standards and management expectations for all activities relating to safe operation and utilization of the research reactor and should effectively communicate these standards and expectations throughout the operating organization. Managers themselves should meet these performance standards and should explain to the personnel why they are appropriate.

2.54. The reactor manager is responsible for overseeing the implementation of the operational policies of the operating organization and compliance with regulatory requirements. The reactor manager may be involved in providing information about the research reactor to experimenters and other users, in implementing public information activities and in maintaining relationships with local authorities.

2.55. The reactor manager (and, in larger operating organizations, senior managers) should recognize and help develop competences in leadership, managerial and technical skills (see para. 4.24 of GSR Part 2 [17]) that are needed by individuals at the research reactor. Adequate funds are required to be made available by the operating organization for the development and implementation of programmes to improve leadership, managerial and technical skills (see Requirement 9 of GSR Part 2 [17]).

2.56. In accordance with Requirement 69 of SSR-3 [1], reactor managers are required to ensure that the individuals to whom responsibilities for safety are assigned have the capabilities and the resources to discharge their responsibilities effectively. Managers are also required to ensure that personnel are made aware of and accept their responsibilities for safety (see para. 4.5 of SSR-3 [1]). Individuals should be aware of how their responsibilities relate to those of other individuals in the organization.

2.57. Paragraph 7.21 of SSR-3 [1] states that "Every licensed or authorized member of the operating personnel shall have the authority to shut down the reactor in the interest of safety."

2.58. Line managers should be responsible for the safety of all operations and activities under their control. The structure of the organization should reflect this responsibility and how it fits within the overall objectives of the organization.

2.59. Personnel external to the operating organization of the research reactor and who provide a service or advice should have no direct authority over operating personnel, although such external personnel are responsible for the quality of the service or advice they provide. Operating personnel should carefully consider any external advice provided before making related decisions.

2.60. The reactor manager should submit periodic summary reports on matters relating to safety to the reactor safety committee for its consideration and should consider any information provided in response.

MANAGEMENT SYSTEM FOR A RESEARCH REACTOR

2.61. Requirement 4 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall establish, implement, assess and continuously improve an integrated management system.**"

2.62. Approval of the management system (or parts thereof) by the regulatory body may be required (see para. 4.12 of SSR-3 [1]).

Management responsibility for a research reactor

2.63. The operating organization is required to establish and implement a management system that integrates safety, health, environmental, security, quality, as well as human and organizational factor, societal and economic elements for the research reactor (see Requirement 4 of SSR-3 [1]). General requirements for the management system are established in GSR Part 2 [17], and specific recommendations are provided in IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installations [18].

2.64. The management system should include the measures necessary to ensure that acceptable levels of safety and security are maintained throughout the lifetime of the research reactor, including the decommissioning stage. The management system should include those arrangements made by the operating organization that are necessary to promote a strong safety culture. It is the management's responsibility to recognize the safety significance of the organization's activities.

2.65. The management system should provide the framework that will enable individuals conducting activities at the research reactor to perform their tasks safely and successfully. The management system should include a description of the safety policy, identification of the main responsibilities within the operating organization, definition of the activities and competences necessary to ensure safety, and arrangements to ensure that the activities of the organization are conducted safely. The management system is required to make reference to regulatory requirements and safety standards and to ensure the provision of the resources necessary to attain the objectives of the operating organization (see paras 4.11 and 4.14 of SSR-3 [1]).

2.66. The management system should provide for monitoring of the effectiveness of safety management and should foster continual improvement in safety performance (see paras 2.79–2.85).

2.67. To maintain effective management of safety at the research reactor, managers are required to ensure that there is commitment to safety by all personnel (see para. 5.2(a) of GSR Part 2 [17]). The starting point for effective management of safety is the involvement of senior managers, in accordance with Requirement 2 of GSR Part 2 [17]. The safety policy of the operating organization (see paras 2.68–2.70) and the behaviour and attitudes of senior managers are required to demonstrate a commitment to excellent performance in all activities important to safety (see Requirement 3 of SSR-3 [1]). This commitment should permeate the operating organization at every level and extend to other organizations that perform tasks or provide services important to safety. There should be no complacency at any level about the need for continuous attention to safety. The management should foster an attitude of willingness to learn in relation to safety matters and should promote an open exchange of information upward, downward and horizontally in the organization.

2.68. The operating organization is required to establish a safety policy (see Requirement 3 of SSR-3 [1]). This policy is required to be implemented by the senior management, and all personnel in the operating organization are required to be made aware of the policy (see para. 4.5 of SSR-3 [1]).

2.69. Paragraph 4.4 of SSR-3 [1] states:

> "The safety policy established and implemented by the operating organization shall give safety the highest priority, overriding all other demands, including the demands of production and of reactor users. The safety policy shall promote a strong safety culture, including a questioning attitude and a commitment to excellent performance in all activities important to safety."

2.70. Paragraph 4.12 of SSR-3 [1] states:

> "The documentation of the management system shall be reviewed and made subject to approval at appropriate levels of management in the operating organization and shall be submitted to the regulatory body for review and assessment as requested."

The safety policy should also be documented and made available to the regulatory body and to interested parties (including the public), as necessary.

2.71. There are specific management responsibilities in relation to the recruitment and training of research reactor personnel: these responsibilities are described in Sections 3–6 of this Safety Guide.

Resource management at a research reactor

2.72. Paragraph 4.15 of SSR-3 [1] states that (footnote omitted): "Resource management shall ensure that the resources essential to the implementation of the organizational strategy and the achievement of the organization's objectives are identified and made available."

This includes maintaining the reactor in a safe operational state and providing the necessary tools and equipment (see para. 4.15(c) of SSR-3 [1]) and a sufficient number of competent personnel (supplemented by consultants, contractors and vendors, as necessary (see para. 4.15(a) and (b) of SSR-3 [1])). In particular, sufficient resources should be made available for performing the activities at the research reactor in a safe manner, so that undue physical or mental stress on individuals is avoided.

Process implementation at a research reactor

2.73. Safety related activities are required to be analysed and controlled to ensure that they can be performed safely and effectively (see Requirement 72 of SSR-3 [1]). Paragraph 7.44 of SSR-3 [1] states:

> "All routine and non-routine operational activities shall be assessed for potential risks associated with harmful effects of ionizing radiation. The level of assessment and control shall depend on the safety significance of the task."

The purpose of the assessment, which may be qualitative or quantitative, is to evaluate the acceptability of the proposed activity and to determine appropriate and necessary control measures. The outcome of the assessment should be incorporated into work instructions or control documentation associated with the activity (e.g. the documentation presented to the reactor safety committee for review).

2.74. Processes should be established by the operating organization to ensure that, where appropriate, certain activities important to safety are performed by specially authorized persons, such as the reactor operator or a qualified maintenance worker. Certain activities, such as conducting tests and experiments, should be authorized in advance and should involve the use of a work permit system (see also para. 7.69 of SSR-3 [1] with regard to maintenance, periodic testing and inspection). Personnel who perform infrequent activities may need retraining prior to performing the activity. Other control measures, such as the use of hold points and verification stages for complex tasks, should be considered as part of this process.

2.75. All safety related activities are required to be performed in accordance with approved procedures (see para. 7.45 of SSR-3 [1]). The procedures should describe how the activity is to be performed and, where appropriate, should describe the steps to be taken in response to an abnormal event. The procedures are required to be issued and controlled in accordance with the management system for the research reactor (see Requirement 82 of SSR-3 [1]).

2.76. Proposed repairs and modifications (including organizational changes) to the research reactor should be thoroughly planned in accordance with Requirements 77 and 83 of SSR-3 [1]. The operating organization should establish a procedure to ensure that any change to the research reactor is categorized on the basis of its safety significance prior to its implementation. This process should also ensure compliance with the OLCs and with applicable codes and standards. Further recommendations are provided in SSG-24 (Rev. 1) [10].

2.77. A process should be established for the preparation of procedures for situations outside normal operation, including anticipated operational occurrences and abnormal findings from inspections and special tests. Such procedures should ensure that appropriate control is maintained and that due consideration is given to maintaining the safety of the research reactor.

2.78. An emergency plan, with procedures for its implementation, should be prepared in accordance with para. 7.90 of SSR-3 [1] and the requirements established in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [19]. This plan and procedures are required to cover on-site and, where necessary, off-site responses, including the timely notification of appropriate government, regulatory and support organizations.

Measurement, assessment and improvement at a research reactor

2.79. Paragraph 4.20 of SSR-3 [1] states:

> "The effectiveness of the management system shall be regularly measured and assessed through independent assessments and self-assessments. Weaknesses in processes shall be identified and corrected. The operating organization shall evaluate the results of such assessments and shall determine and take the necessary actions for continuous improvements."

2.80. The safety performance of the operating organization should be periodically monitored to ensure that an adequate level of safety is being maintained. A review and audit system should be established to verify that the safety policy of the operating organization is being implemented effectively and that lessons from operating the research reactor and experience from other facilities are taken into account.

2.81. The organizational structure, including the reactor management, should be taken into consideration when monitoring and assessing the safety performance of the management of the research reactor. In addition, safety reviews should be performed (e.g. as part of the in-service inspection programme) to verify the continued safe and reliable operation and utilization of the reactor. The results of such safety reviews should be used, for example, for the following purposes:

(a) To confirm that the research reactor or individual systems or items can be operated safely for a defined period of future operation (e.g. the period between reviews);
(b) To identify and evaluate factors that could limit safe operation in the period between reviews;
(c) To take into account new or revised safety standards and regulatory requirements after determining their implications for the safety analysis of the research reactor;
(d) To provide input to the ageing management programme (see paras 2.136 and 2.137).

2.82. The operating organization should establish a self-evaluation programme supported by periodic external reviews conducted by experienced peers.[4] The external review should be independent of the operation of the reactor and should be conducted at a frequency sufficient to verify that the reactor management has established verifiable and authorized processes and procedures and has implemented improvements, as necessary. Particular consideration should be given to the feedback of operating experience in accordance with Requirement 88 of SSR-3 [1]. The reports containing such feedback should be formal and should be provided to the operating organization and the reactor manager. The periodic external reviews should include a review of human and organizational factors to verify that these correspond to accepted good practice and support safety.

[4] An example is the Integrated Safety Assessment of Research Reactors (INSARR) reviews conducted by the IAEA [20].

2.83. The review of management system processes should include the following:

(a) Reviewing the safety related aspects of normal operation of the research reactor;
(b) Reviewing malfunctions, failures and accident precursors to assess their significance for safety, and suggesting actions to prevent their recurrence;
(c) Reviewing proposals for modifications to ascertain whether the safety implications have been adequately addressed;
(d) Reviewing the implementation of the safety management system against international best practices;
(e) Reviewing corrective actions and/or modifications undertaken.

2.84. As part of the management system, processes and procedures for safety review should be maintained by the operating organization to provide an ongoing surveillance and audit of the operational safety of the research reactor and to support the management of the research reactor in discharging its overall responsibility for safety.

2.85. Reviews of the management system should be conducted in sufficient depth to ensure that all issues and questions raised are satisfactorily resolved. The reviews should be performed by personnel who have the education, experience, expertise and training to allow a thorough understanding and evaluation of processes reviewed. The progress in implementing improvements should be monitored to ensure that actions are completed within an appropriate time period. The corrective actions should be reviewed after completion to assess whether they have adequately addressed the issues identified.

PROGRAMMES FOR OPERATION OF A RESEARCH REACTOR

Training, retraining and qualification

2.86. Requirement 70 of SSR-3 [1] states that “**The operating organization for a research reactor facility shall ensure that safety related functions are performed by suitably qualified, competent and fit-for-duty personnel.**”

2.87. The operating organization is required to establish a qualification, training and retraining programme (see paras 7.29–7.31 of SSR-3 [1]). For each category of personnel, the requirements for qualification and competence (including whether a formal authorization or licence is required for certain operating positions) are to be defined (see para. 7.28 of SSR-3 [1]). Further recommendations are provided in Section 4 of this Safety Guide.

Operating procedures

2.88. Requirement 74 of SSR-3 [1] states:

> "**Operating procedures for the research reactor shall be developed that apply comprehensively (for the reactor and its associated facilities) for normal operation, anticipated operational occurrences and accident conditions, in accordance with the policy of the operating organization and the requirements of the regulatory body.**"

2.89. For safe operation of the research reactor, OLCs are required to be established (see Requirement 71 of SSR-3 [1]) that include administrative controls and operating procedures. The operating organization should establish a process for the review and approval of operating procedures, particularly at the management level. The administrative controls should be established before the commencement of operation. Where possible, the need to facilitate eventual decommissioning should be considered in the development of operating procedures.

2.90. The operating organization should provide for the development of operating procedures that have the following attributes:

(a) The procedures cover all activities that might affect the safe operation of the research reactor (an indicative list of operating procedures for a research reactor is provided in appendix II to SSG-83 [5]).
(b) The procedures are designed to ensure compliance with OLCs and regulatory requirements.
(c) The procedures are written and verified by properly qualified persons in accordance with the management system.
(d) The procedures are written in clear and understandable language and avoid any confusion and ambiguities.
(e) The procedures are in accordance with the design assumptions and intent.
(f) The procedures provide sufficient detail for a qualified person to perform the activity without direct supervision.
(g) The procedures are controlled, reviewed and revised periodically in accordance with the management system.

2.91. Operating procedures should be developed to ensure that shift turnovers follow a prescribed routine and that critical information — such as reviews of log books and log sheets, operations in progress, equipment out of service and experiments using the reactor — is passed from one shift to another. This applies to continuous operations where one shift relieves another in a routine manner, to emergencies and to situations where one shift shuts down the reactor and another shift resumes operation later.

2.92. Further recommendations on OLCs and operating procedures are provided in SSG-83 [5].

Commissioning

2.93. Requirement 73 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall ensure that a commissioning programme for the research reactor is established and implemented.**"

2.94. The objectives of the commissioning programme (see paras 7.47–7.56 of SSR-3 [1]) include the following:

(a) To confirm that the as-built reactor and experimental facilities are consistent with the design intent and the design requirements stated in the safety analysis report;
(b) To verify that the reactor meets regulatory requirements;
(c) To demonstrate the validity of OLCs, operating instructions and procedures, and to provide an opportunity for operating personnel to improve their competence;
(d) To supply the information and data necessary for verifying the adequacy of provisions made to implement the programmes for operation of the research reactor.

2.95. Further recommendations on the commissioning of research reactors are provided in SSG-80 [2].

Maintenance, periodic testing and inspection

2.96. Requirement 77 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall ensure that effective programmes for maintenance, periodic testing and inspection are established and implemented.**"

2.97. The programmes for maintenance, periodic testing and inspection are required to ensure that the level of reliability and effectiveness of all reactor structures, systems and components important to safety remain in accordance with the safety analysis report and OLCs, and that the safety status and configuration of the research reactor are not adversely affected by maintenance activities (see paras 7.68, 7.72 and 7.74 of SSR-3 [1]).

2.98. The periodic testing (surveillance) programme should ensure that items important to safety continue to perform in accordance with the original design assumptions and intent and in accordance with changes that have been appropriately incorporated into the operation of the reactor on the basis of operating experience. The programmes should include inspections and reviews for detecting any degradation or ageing of structures, systems and components that could lead to unsafe conditions. This should include monitoring, checks, calibrations, testing and inspection that are complementary to the in-service inspection programme.

2.99. The inspection programme should determine whether items important to safety are in an acceptable condition for the continued safe operation of the reactor or whether remedial measures are necessary. Emphasis should be placed on the examination of key systems and components such as the primary coolant system of the reactor.

2.100. Further recommendations on maintenance, periodic testing and inspection are provided in SSG-81 [3].

Core management and fuel handling

2.101. Requirement 78 of SSR-3 [1] states that "**Core management and fuel handling procedures for a research reactor facility shall be established to ensure compliance with operational limits and conditions and consistency with the utilization programme.**"

2.102. Special consideration should be given to the safety aspects of core management, for which the operating organization is responsible, such as experiment design, fuel procurement, on-site storage, and irradiation, handling and transport of fuel. In particular, the core management programme should cover the following:

(a) The establishment of detailed specifications and management system processes for the procurement of fuel and experimental devices, including assurance of compliance with design requirements and manufacturing requirements;

(b) Special studies to be undertaken to demonstrate the ability of new or modified fuel to meet the provisions of the safety analysis report, especially when fuel from different suppliers is to be placed in the reactor core;
(c) Arrangements to ensure safety in the transport, storage and handling of new and irradiated fuel and in-core experimental devices, including considerations of the interface between safety and security;
(d) Establishment of core calculation programmes to define loading patterns for fuel, experimental devices and absorbers, for ensuring compliance with reactivity limits, temperature limits and irradiation or burnup limits;
(e) Verification that core parameters indicative of conformance with the design and with the OLCs are monitored, analysed for trends and evaluated to detect abnormal behaviour;
(f) Verification that the integrity of the fuel cladding is monitored and maintained under all core operating conditions;
(g) Implementation of applicable requirements for the examination of irradiated fuel and use of the results for monitoring of fuel performance;
(h) Verification of the startup testing methods and establishment of associated criteria for surveillance.

2.103. Further recommendations on core management and fuel handling are provided in SSG-82 [4].

Fire safety

2.104. Requirement 79 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall make arrangements for ensuring fire safety.**"

2.105. The operating organization is required to make provisions for fire safety on the basis of a comprehensive fire hazard analysis that is periodically reviewed and, if necessary, updated (see paras 7.85–7.87 of SSR-3 [1]). The review should include reanalysis of the concept of defence in depth; assessment of the impact on fire safety of modifications to and use of the reactor; ongoing control of combustibles and ignition sources; inspection, maintenance and testing of fire protection measures; review of the in-house firefighting capability; retraining of reactor personnel; conduct of periodic fire drills; and ongoing liaison with and training of the public fire department.

Emergency preparedness

2.106. Requirement 81 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall prepare emergency arrangements for preparedness for, and response to, a nuclear or radiological emergency.**"

2.107. The operating organization is required to establish an emergency plan, and procedures for its implementation, in accordance with para. 7.90 of SSR-3 [1] and the requirements established in GSR Part 7 [19], that includes the following:

(a) The ability to identify and classify a nuclear or radiological emergency;
(b) Maintenance of emergency equipment;
(c) The organizational structure and assigned responsibilities for responding to emergencies;
(d) Timely notification and alerting of trained and qualified emergency response personnel and off-site authorities, as appropriate;
(e) Provision of the necessary information to and cooperation with the relevant public authorities.

Records and reports

2.108. Requirement 82 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall establish and maintain a system for the control of records and reports.**"

2.109. Documentation for the research reactor is required to be controlled by the operating organization in accordance with the management system (see para. 7.97 of SSR-3 [1]). This includes the preparation, modification, review, approval, release and distribution of documents. Procedures and checklists for performing these activities should be prepared and controlled.

2.110. A system should be established to ensure the retention of all documents and records relevant to the safe and reliable operation of the research reactor, including documents on the design, commissioning and operational history of the reactor, as well as general and specific procedures. The operating organization is required to ensure that only correct, up to date versions of documents are available to operating personnel for day to day use and that obsolete versions of documents are marked and archived (see para. 7.97 of SSR-3 [1]). The research reactor management should prepare periodic reports summarizing the operational history, modifications and utilization of the reactor for review by the reactor safety committee and the regulatory body.

2.111. Retention times of records should be established in accordance with regulatory requirements. Records should be easily retrievable and readable for the duration of the retention time of each record. The operating organization should ensure appropriate conditions (e.g. fire protection, security, environmental conditions, duplication of records and separate storage) for the storage of safety related records for permanent retention to prevent their deterioration.

Feedback of operating experience

2.112. Requirement 88 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall establish a programme to learn from events at the reactor facility and events in other research reactors and from the nuclear industry.**"

2.113. An effective programme for the feedback and analysis of operating experience should include appropriate analytical methods, and in-house events and events at similar facilities should be analysed to identify specific actions necessary to prevent recurrence. Events at the research reactor that would be of interest to the operating organizations of other research reactors should be shared with peers so that appropriate actions can be taken. The effectiveness of the programme for the feedback of operating experience should be assessed periodically to identify areas of weakness that need improvement.[5]

2.114. Further recommendations on feedback of operating experience are provided in IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations [21].

Reactor utilization and modifications

2.115. Requirement 83 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall establish and implement a programme to manage utilization and modifications of the reactor.**"

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[5] The IAEA operates an Incident Reporting System for Research Reactors that provides a mechanism for the reporting of incidents and analyses of events and for the dissemination of information to participating Member States of the IAEA. The Incident Reporting System for Research Reactors facilitates worldwide feedback of operating experience. SSG-72 [12] provides recommendations on feedback of operating experience from nuclear power plants, and some of these recommendations may also be relevant for research reactors.

2.116. The operating organization is required to ensure the proper design, review, implementation and control of all permanent and temporary modifications to structures, systems and components and to experimental devices (see paras 7.101, 7.103 and 7.106 of SSR-3 [1]). This programme should ensure that the design basis of the research reactor is maintained, OLCs are observed, and applicable codes and standards are met.

2.117. Paragraph 7.103 of SSR-3 [1] states that "The reactor manager shall establish a procedure, in accordance with accepted engineering practice, for the review and approval of proposals for experiments and modifications and for the control of their performance." A record of the review should be made available to the regulatory body, as required. The operating organization has responsibility for the safety implications of modifications and for obtaining the appropriate approval from the regulatory body, if required.

2.118. Requests for modifications and new experiments should be evaluated on the basis of their impact on reactor safety and reliability, reactor operation and performance, personnel safety and regulatory requirements.

2.119. Personnel involved in making a proposed modification or in conducting a proposed utilization are required to be suitably trained, qualified and experienced (see para. 7.99(d) of SSR-3 [1]). Consideration should also be given to the training of personnel with respect to the impact of any modifications on operation and utilization and on operating procedures.

2.120. Further recommendations on reactor utilization and modifications are provided in SSG-24 (Rev. 1) [10].

Radiation protection

2.121. Requirement 84 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall establish and implement a radiation protection programme.**"

2.122. The radiation protection programme is required to ensure the control of occupational exposures and public exposures (including the monitoring of individual doses, where necessary) and to ensure that doses to individuals remain within applicable limits and are as low as reasonably achievable (see paras 7.107–7.114 of SSR-3 [1]).

2.123. The radiation protection programme is required to comply with Requirement 24 and other relevant requirements established in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [22]. The recommendations presented in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [23], should also be followed.

2.124. As part of the radiation protection programme, each individual who is allowed access to the reactor building should be given training in radiation protection commensurate with that individual's responsibilities.

2.125. Further recommendations on radiation protection at research reactors are provided in SSG-85 [6].

Management of radioactive waste

2.126. Requirement 85 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall establish and implement a programme for the management of radioactive waste.**"

2.127. The programme for the management of radioactive waste is required to ensure that gaseous, liquid and solid radioactive waste arising from operation of the research reactor is satisfactorily monitored and controlled so that authorized limits on discharges are complied with (see para. 7.117 of SSR-3 [1]).

2.128. The operating organization should ensure that the radioactive waste management programme includes provisions for the following (see paras 7.115–7.119 of SSR-3 [1]):

(a) Measures to keep the generation of radioactive waste to the minimum practicable, in terms of both activity and volume;
(b) Appropriate characterization, classification and segregation of waste;
(c) Possible reuse and recycling of materials;
(d) Collection and safe storage of radioactive waste;
(e) Adequate storage capacity for the radioactive waste expected to be generated;
(f) Pretreatment, treatment and conditioning of radioactive waste to ensure safe storage and disposal;
(g) Safe handling and transport of radioactive waste;
(h) Adequate control of effluent discharge to the environment;
(i) Monitoring of effluent discharge, and of the environment, for demonstration of regulatory compliance.

2.129. Recommendations on radioactive waste management at research reactors are provided in SSG-85 [6]. Further recommendations are provided in IAEA Safety Standards Series No. SSG-40, Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors [24].

Interfaces between safety and nuclear security

2.130. Requirement 90 of SSR-3 [1] states:

> "**The interfaces between safety and security for a research reactor facility shall be addressed in an integrated manner throughout the lifetime of the reactor. Safety measures and security measures shall be established and implemented in such a manner that they do not compromise one another.**"

2.131. Programmes in which the interfaces between safety and security need to be considered include training, retraining and qualification of personnel; operating procedures; commissioning; maintenance, periodic testing and inspection; core management and fuel handling; fire safety; emergency preparedness; utilization and modification; radiation protection; management of radioactive waste; ageing management; and extended shutdown.

2.132. The operating organization should establish a programme for the physical protection of nuclear material and the research reactor. The aim of this programme is to prevent unauthorized access, intrusion, theft, or internal or external sabotage of nuclear material or of systems important to safety. The physical protection programme should provide measures and procedures for access controls around the site and within the reactor building; entry, exit and parking controls on vehicles; access rules to be observed for different zones of the site; procedures for authorization of access; communication systems; and selection and training of personnel. The physical protection programme should be implemented prior to the commencement of commissioning, and in any case before the receipt of fuel at the site. Further guidance is provided in IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5) [25].

Safety assessment and the safety analysis report

2.133. Requirement 1 of SSR-3 [1] states:

> "**A safety analysis report shall be prepared by the operating organization for a research reactor facility. The safety analysis report shall provide a justification of the site and the design and shall provide a basis for the safe operation of the research reactor. The safety analysis report shall be reviewed and assessed by the regulatory body before the research reactor project is authorized to progress to the next stage. The safety analysis report shall be periodically updated over the research reactor's operating lifetime to reflect modifications made to the facility and on the basis of experience and in accordance with regulatory requirements.**"

2.134. The OLCs and the postulated accidents for the research reactor should also be reviewed periodically and should be updated on the basis of experience feedback and the updating of the safety analysis report.

2.135. Further recommendations on safety assessment and preparation of the safety analysis report are provided in SSG-20 (Rev. 1) [9].

Ageing management

2.136. Requirement 86 of SSR-3 [1] states:

> "**The operating organization for a research reactor facility shall ensure that an effective ageing management programme is implemented to manage the ageing of items important to safety so that the required safety functions of structures, systems and components are fulfilled over the entire operating lifetime of the research reactor.**"

2.137. The ageing management programme for a research reactor should include the following elements:

(a) Screening of structures, systems and components for ageing;
(b) Identification and understanding of degradation mechanisms;
(c) Minimization of ageing effects;
(d) Detection, monitoring and analysis of trends in ageing effects;
(e) Mitigation of ageing effects;
(f) Acceptance criteria;
(g) Corrective actions;

(h) Continual improvement of the ageing management programme, where practicable;
(i) Record keeping.

Further recommendations on ageing management for research reactors are provided in SSG-10 (Rev. 1) [7].

Extended shutdown

2.138. Requirement 87 of SSR-3 [1] states:

> "**If an extended shutdown is planned or occurs, the operating organization for a research reactor facility shall establish and implement arrangements to ensure the safe management, planning, effective performance and control of work activities during the extended shutdown.**"

2.139. If a research reactor enters a state of extended shutdown (i.e. the reactor is shut down and there are no approved plans and no resources committed for resuming operation or commencing decommissioning), the operating organization should prepare and implement a programme to maintain the reactor's integrity, safety and security in accordance with the requirements established in paras 7.123–7.125 of SSR-3 [1]. Approval by the regulatory body should be sought, especially if changes are made to the safety analysis report or the OLCs.

2.140. Paragraph 7.123 of SSR-3 [1] states:

> "The operating organization shall take appropriate measures during an extended shutdown to ensure that materials and components do not seriously degrade. The following measures shall be considered:
>
> (a) Unloading the fuel elements from the reactor core to appropriate and safe storage conditions;
> (b) Changing the operational limits and conditions in accordance with the requirements for the shutdown reactor;
> (c) Removing components for protective storage;
> (d) Taking measures to prevent accelerated corrosion and ageing;
> (e) Retaining adequate staff in the facility for the purposes of performing the necessary maintenance, periodic testing and inspection."

2.141. The measures for an extended shutdown should also include the following:

(a) If the fuel elements are not to be unloaded, arrangements to ensure that the reactor core remains subcritical;
(b) Modifications to the safety analysis report;
(c) Revised emergency arrangements;
(d) Techniques for fulfilling licence conditions and maintaining qualifications and authorizations of operating personnel;
(e) Security arrangements for as long as nuclear fuel or other radioactive material is present at the research reactor.

2.142. Further safety considerations for research reactors in extended shutdown are presented in Ref. [26].

Planning for decommissioning

2.143. General requirements for the decommissioning of facilities are established in IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [27], and specific recommendations are provided in IAEA Safety Standards Series No. SSG-47, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities [28].

2.144. Requirement 89 of SSR-3 [1] states:

> "**The operating organization for a research reactor facility shall prepare a decommissioning plan and shall maintain it throughout the lifetime of the research reactor, unless otherwise approved by the regulatory body, to demonstrate that decommissioning can be accomplished safely and in such a way as to meet the specified end state.**"

2.145. Measures to facilitate decommissioning are required to be considered at the design stage of the research reactor (see Requirements 15 and 33 of SSR-3 [1]). The decommissioning plan is required to be prepared at the design stage (see para. 8.1 of SSR-3 [1]). This plan should be updated periodically on the basis of operating experience and the latest developments in decommissioning techniques.

2.146. Paragraph 8.3 of SSR-3 [1] states:

> "For some operating research reactors, where the need for their ultimate decommissioning was not taken into account in their design, a

decommissioning plan shall be prepared to ensure safety throughout the decommissioning process.”

In such cases, the operating organization should begin to plan for eventual decommissioning by estimating the costs and considering options for decommissioning of the research reactor and the associated experimental devices.

2.147. Documentation and information that will facilitate decommissioning (see para. 8.3 of SSR-3 [1]) should be compiled, categorized for retention and stored so that the information is retrievable for future use. When implementing operational strategies, new experiments or reactor modifications, potential problems for decommissioning (e.g. decontamination and the ultimate disposal of waste; see IAEA Safety Standards Series No. SSR-5, Disposal of Radioactive Waste [29]) should be considered. Such considerations may lead to the operating organization performing activities such as minimization of the contamination of structures, systems and components; segregation of waste of different categories; and/or application of protective coatings.

2.148. When a decision is made to decommission the research reactor, the operating organization should ensure that all options for decommissioning are considered and that the decommissioning plan covers all stages from the start of decommissioning until the site and its adjacent areas have been released (i.e. for restricted or unrestricted use).

2.149. The decommissioning plan should include a description of the organizational structure for decommissioning, which may differ from the organizational structure for the operational stage. The decommissioning plan is required to be submitted to the regulatory body for review and approval prior to the commencement of decommissioning (see para. 8.2 of SSR-3 [1]).

3. STAFFING, RECRUITMENT AND SELECTION OF OPERATING PERSONNEL FOR A RESEARCH REACTOR

3.1. Paragraph 7.2 of SSR-3 [1] states that “The operating organization shall establish an appropriate management structure for the research reactor and shall provide for all necessary infrastructure for the conduct of reactor operations.”

3.2. Paragraph 7.14 of SSR-3 [1] states:

> "The reactor manager shall specify the minimum staffing requirements for the various disciplines required to ensure safe operation for all operational states of the research reactor in accordance with the operational limits and conditions."

3.3. The operating organization of the research reactor is required to be staffed with competent managers and a sufficient number of suitably qualified and experienced personnel — supplemented, as necessary, by consultants or contractors — so that duties can be performed safely (see para. 4.21 of GSR Part 2 [17]). The aim should be to ensure that safety related activities can be performed without undue haste or pressure.

3.4. The operating organization is required to ensure that its operating personnel are appropriately qualified (see Requirement 70 of SSR-3 [1]). The operating organization should ensure that, at the time of commencing duties at the research reactor, these personnel have acquired a combination of education, training and experience commensurate with their level of responsibility. National regulations may also specify requirements for the recruitment of operating personnel.

3.5. The operating organization is required to define the minimum levels of education and experience to be met by candidates for specific operating positions at the research reactor (see para. 7.28 of SSR-3 [1]). In the recruitment of operating personnel, it should also be ensured that individuals who are selected for positions are reliable. An appropriate background check may be required by national regulations as a condition of employment for new operating personnel.

3.6. The physical and mental health of all operating personnel should be such that they are capable of safely operating the research reactor in different operational states and in accident conditions. Psychometric tests and psychological tests may be used in recruitment, where appropriate. Further information on the evaluation of physical and mental health in the recruitment of operating personnel for research reactors is provided in Ref. [30].

3.7. In addition to adhering to the provisions established in national regulations and practices relating to occupational health and safety, operating personnel should have a medical examination at the time of recruitment and at designated times in the course of their employment to ensure that their state of health is compatible with the duties and responsibilities assigned to them. Personnel who are occupationally exposed to radiation at the research reactor may be required to be subject to workers' health surveillance in accordance with Requirement 25 of GSR Part 3 [22]. The results of any medical examinations might necessitate restrictions on the activities that an individual may perform.

3.8. In the recruitment policy for research reactor operating personnel, account should be taken of the need for continuity of organizational expertise as new operating personnel replace experienced personnel (see para. 2.19 of this Safety Guide). The unanticipated loss of key personnel and ways of minimizing the impact of this on the operation of the research reactor should also be taken into account, including for situations where a large number of personnel might be unavailable, such as during an epidemic or a pandemic affecting areas in which personnel live. In small operating organizations, the loss of a key individual may necessitate the shutting down of the research reactor until the training of a replacement can be completed. This situation should be avoided by means of effective strategic planning, succession planning and the development of a staffing plan. In general, effective documentation also minimizes the impact of the loss of key personnel. The staffing of the research reactor should be assessed and updated periodically and whenever organizational changes are made or the mission of the research reactor changes.

3.9. The operating organization should establish the necessary arrangements to ensure the safety of personnel and the safe operation of the research reactor during situations in which a large number of personnel might be unavailable, such as during an epidemic or a pandemic affecting areas in which personnel live. Such arrangements should include the following:

(a) Retaining a minimum number of qualified personnel on the site to ensure safe operation of the research reactor;
(b) Ensuring that a minimum number of qualified backup personnel remain available off the site;
(c) Adapting means of communication and transportation for personnel, arranging the delivery of food and water to the site, and providing for beds and essential hygiene on the site;
(d) Establishing additional measures to prevent the spread of an infection on the site, in accordance with national and international guidance (e.g. cancelling physical meetings, adapting controls at the entrance to the site, maintaining appropriate physical distance between individuals, wearing a mask);
(e) Enabling remote working for non-essential personnel and maintaining regular contact with those personnel who are off the site, by phone or videoconference.

3.10. Action (or lack of action) by operating personnel might have an immediate effect on the safety of the research reactor. This aspect should be considered in the selection, training and authorization of operating personnel. Appropriate aptitude tests may be devised to assist in the selection of operating personnel.

STAFFING ARRANGEMENTS FOR A RESEARCH REACTOR

Reactor manager

3.11. Because of the duties and responsibilities of the reactor manager (see paras 7.13–7.19 of SSR-3 [1]), candidates should have a university degree in an engineering or scientific discipline and several years of appropriate nuclear experience[6]. The reactor manager should have demonstrable management skills, including analytical, supervisory, leadership and communication abilities. The selected individual is required to receive training in accordance with Requirement 70 of SSR-3 [1] and should have facility specific knowledge commensurate with the responsibilities and duties of the position.

Reactor supervisor

3.12. An individual recruited for the reactor supervisor position should have a university degree, or equivalent, in an engineering or scientific discipline and several years of relevant nuclear experience. The reactor supervisor should have demonstrable management skills. The individual selected is required to receive training in accordance with Requirement 70 of SSR-3 [1]; this training should be facility specific and commensurate with the responsibilities and duties of the position.

Shift supervisor

3.13. Individuals recruited for a shift supervisor position may be selected from among the senior reactor operators (see para. 3.14) and should be selected by the reactor manager in consultation with the reactor supervisor. A shift supervisor should have several years of experience as an authorized senior reactor operator.

[6] Nuclear experience in this context means experience gained during commissioning, maintenance or operation of a nuclear power plant, test reactor, research reactor or production reactor, or of a critical assembly or subcritical assembly. On the job training at a research reactor or subcritical assembly may qualify as equivalent nuclear experience. Appropriate research or teaching experience, or both, may also qualify as nuclear experience.

Individuals selected for this position are required to receive training in accordance with Requirement 70 of SSR-3 [1]. This should include adequate supplementary training in fundamental nuclear topics and facility specific training commensurate with the responsibilities and duties of a shift supervisor.

3.14. A shift supervisor should be a senior reactor operator and should have demonstrable supervisory skills.

Senior reactor operator

3.15. Individuals recruited for a senior reactor operator position should have a university degree or equivalent. Individuals recruited for a senior reactor operator position are normally selected from among the reactor operators. A senior reactor operator should be selected by the reactor manager in consultation with the shift supervisors. Selection should be made on the basis of past performance, and the individuals selected should have a specified period of experience as reactor operators at the facility. The individuals selected should receive adequate supplementary training at the research reactor to enable authorization as a senior reactor operator.

3.16. The reactor supervisor and the shift supervisors, who will be directly supervising reactor operators, should also be senior reactor operators. Any other individual who directly supervises reactor operators in the performance of their duties, including the reactor manager if appropriate, should also be a senior reactor operator.

Reactor operator

3.17. Individuals recruited for a reactor operator position should have at least a high school diploma or vocational education in a technical field. Previous job related experience or training should also be considered in the selection process. These considerations should be the determining factors for recruitment to the position. The individuals selected should receive sufficient training at the research reactor (or at other appropriate facilities) to enable authorization as a reactor operator.

Maintenance personnel

3.18. Maintenance personnel should be selected on the basis of specified qualifications, and the individuals selected should be able to demonstrate appropriate competence. They should have a number of years of experience in their areas of specialty and should receive facility specific training commensurate with the responsibilities of the position. In cases where reactor operators perform maintenance work, they should be appropriately trained and qualified. Further recommendations on the selection, training and qualification of maintenance personnel are provided in SSG-81 [3].

Radiation protection personnel

3.19. Requirements relating to the duties, responsibilities and qualifications of radiation protection personnel are established in GSR Part 3 [22], and associated recommendations are provided in GSG-7 [23] and IAEA Safety Standards Series No. SSG-44, Establishing the Infrastructure for Radiation Safety [31].

Additional support personnel

3.20. Additional support personnel include highly qualified individuals such as training officers, safety officers and reactor chemists, as well as other personnel, such as labourers, cleaners and storeroom attendants. Recruitment criteria vary widely for these positions and will depend largely on the job descriptions. However, in addition to their job related experience and training, such personnel should receive facility specific training, including training in radiation protection, security and emergency procedures, at a level appropriate to the position.

SELECTION PROCESS FOR PERSONNEL FOR A RESEARCH REACTOR

3.21. The selection process for personnel for a research reactor should include the following steps:

(a) Establishing the criteria for accepting or rejecting applications and for classifying acceptable candidates (e.g. in terms of entry level competence and communication skills);
(b) Obtaining information about the candidates (e.g. through job applications and references);
(c) Interviewing the candidates;
(d) Objectively testing the candidates;
(e) Assessing the candidates against set criteria in order to reach a decision;
(f) Ensuring medical and psychological fitness for duty in the position (see paras 3.6 and 3.7) and security clearance, as appropriate.

3.22. The selection process for management and supervisory positions should include evaluation of the following additional elements:

(a) Management skills, including analytical, supervisory, leadership and communication abilities;
(b) Management experience;
(c) Education and training;
(d) Knowledge of research reactor operations;
(e) Medical and psychological fitness (see paras 3.6 and 3.7);
(f) Attitudes towards safety and quality management;
(g) Attitudes towards self-study;
(h) Attitudes towards training and career development for subordinates.

3.23. Personnel who may have to respond to an emergency should be evaluated for their behaviour in an emergency (e.g. by means of drills and exercises) and their ability to work in a team.

4. TRAINING AND QUALIFICATION OF OPERATING PERSONNEL FOR A RESEARCH REACTOR

4.1. The operating organization for the research reactor is responsible for ensuring that operating personnel and contractors are appropriately trained and retrained (see paras 7.29–7.31 of SSR-3 [1]).

4.2. A formal authorization issued by the regulatory body or by another body delegated or authorized by the appropriate authority may be required before a person is assigned to a designated position (see paras 7.5 and 7.28 of SSR-3 [1]). Recommendations on the authorization of personnel for specific duties are provided in Section 5 of this Safety Guide.

4.3. The operating organization is required to define the competence requirements for each position important to safety (see para. 7.28 of SSR-3 [1]). These competence requirements will depend on the level of responsibility and the specific duties of a position. Persons with competence in the operation of research reactors and experience in training activities should prepare and document these competence requirements. Reference [30] provides additional guidance.

4.4. The training programme should be designed to provide and maintain the necessary competences of both operating personnel and contractors. The basic principles of safety culture should be taught to all personnel, and refresher training on general topics should also be periodically provided.

APPROACH TO THE TRAINING OF RESEARCH REACTOR PERSONNEL

4.5. The approach to the training of research reactor personnel should be systematic and should include analysis, design, development, implementation and evaluation of both initial training and continuing training to ensure that all job competence requirements are established and maintained. References [32, 33] provide further guidance, and Annex I to this Safety Guide describes the concept of the systematic approach to training.

4.6. In the development of a training programme, a training plan that meets the long term needs and goals of the research reactor should be prepared, and learning objectives should be compiled that state the expected performance of trainees. Training materials that support the learning objectives should be developed, and training methods and activities should subsequently be specified. The training should include testing of trainees.

4.7. The progress of trainees should be assessed and documented. Means of assessment of the performance of trainees may include written examinations, oral questioning and demonstrations of performance.

4.8. Although some of the competence requirements will be common to all positions, the operating organization should design, develop and implement separate initial and continuing training programmes for each position. Each programme should ensure that trainees develop and maintain the knowledge, skills and attitudes necessary to perform the tasks of their position under all conditions.

4.9. The most widely used training methods are classroom instruction, self-study, laboratory and/or workshop training, and on the job training[7]. An appropriate combination of these methods should be used to ensure that trainees obtain all the knowledge and skills necessary for their jobs. Alternating between these methods can maintain trainees' motivation and enhance their ability to learn.

4.10. Classroom instruction is the most widely adopted training method. Its effectiveness is enhanced by the use of training media such as written materials; audio, video and computing devices; models; and functional simulators.

4.11. Self-study can be undertaken at home and at the workplace. In all cases, the trainees should receive guidance from a designated expert.

4.12. Laboratory and/or workshop training is necessary to ensure safe work practices. Training mock-ups[8] should be provided for training in activities that have to be performed quickly and skilfully and that cannot be practised on the actual equipment or systems at the research reactor.

4.13. On the job training should be conducted in accordance with documented guidelines by qualified individuals who have been trained to deliver this form of training. Progress should be monitored, and an independent assessor should evaluate the effectiveness of the training. On the job training should involve the use of learning objectives and trainee assessment and should be conducted and evaluated in the working environment in the research reactor. The ability of qualified individuals to deliver on the job training should be evaluated on a regular basis.

4.14. Paragraph 7.31 of SSR-3 [1] states that "Procedures shall be put in place for the validation of the training to verify its effectiveness and the qualification of the staff." The training programmes and training facilities and materials should be periodically reviewed and, if necessary, modified. The review should cover the adequacy and effectiveness of the training, with due consideration of the

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[7] On the job training involves participation in activities at the research reactor (e.g. during startup (including pre-operational, hot functional and startup tests), operation and maintenance, or during the provision of technical services) as a trainee under the direction of qualified personnel. On the job training is of particular importance since it develops in trainees the necessary job related knowledge and skills in the actual working environment. On the job training provides hands-on experience and allows trainees to become familiar with routines at the research reactor.

[8] A mock-up is a model (to scale or full size) of equipment or systems that is used for training or development purposes.

actual performance of individuals in their jobs. The review should also examine the training needs, training programmes, training facilities and training materials necessary to deal with changes to regulatory requirements, changes to the organization or the research reactor, changes to experimental devices, and lessons from the feedback of operating experience. Where possible, persons other than those directly responsible for the training should undertake the review.

INITIAL TRAINING PROGRAMMES FOR RESEARCH REACTOR PERSONNEL

4.15. All new employees should be introduced to their working environment in a systematic and consistent manner. General training programmes should be used to give new employees a basic understanding of their responsibilities and of safe work practices. Such general training programmes usually include elements of radiation protection, security and basic emergency procedures.

4.16. The training programmes for operating personnel with direct responsibility for the safe operation of the research reactor — including the reactor manager, shift supervisors, senior reactor operators and reactor operators — should provide a thorough understanding of the basic principles of nuclear technology, nuclear safety and radiation protection, and of the design bases, assumptions and theoretical basis for the research reactor and its use. The training programme for such operating personnel should include the necessary on the job training.

4.17. The training programme for operating personnel should also include training in the effects of radiation exposure and in the technical and administrative means necessary to ensure that exposures are as low as reasonably achievable.

Training of operating personnel

4.18. All operating personnel — including the reactor manager, the reactor supervisor, shift supervisors, reactor operators and radiation protection personnel — should receive initial training covering the relevant technical subjects to the levels necessary for their organizational and operational responsibilities. This initial training should develop a thorough theoretical and practical knowledge of the research reactor systems and their functions, layout and operation. The training should emphasize the importance of maintaining the reactor within the OLCs, the consequences of violating the OLCs, and the potential consequences of procedural errors. Trainees should, whenever possible, participate in the pre-operational stage and in the startup of the reactor as part of this training.

4.19. The extent, scope and depth of the initial training for specific positions at the research reactor will depend on the size and complexity of the facility and on the impact on the public and on the environment that might result from its operation. The duration of the training will depend on the initial competence of the trainees. For a very small and simple research reactor, training — including facility specific training and on the job training — may typically be completed in three months. For a large, complex and highly utilized facility, the training programme should be more extensive and may take over a year to complete.

4.20. A classroom based and self-study training programme for reactor operators (including senior reactor operators, shift supervisors, the reactor supervisor and the reactor manager) at a research reactor should typically include the following items (items marked with an asterisk (*) should include drills, laboratory and/or workshop training, and/or on the job training):

(a) Refresher courses. Refresher courses in such areas as mathematics, physics and chemistry are sometimes necessary to ensure that all the trainees have the prerequisite technical knowledge to complete the training programme successfully.
(b) Background courses. Background courses may be added to the training programme, as necessary. These background courses may cover the following subjects:
    (i) Safety culture;
    (ii) Human factors and use of human performance tools;
    (iii) *Computer software;
    (iv) *Interpretation of technical drawings;
    (v) Non-radiation-related safety;
    (vi) *First aid;
    (vii) *Fire safety;
    (viii) Basic electricity.
(c) Reactor theory and related subjects. These subjects provide the basis for understanding reactor theory and technology and may include the following:
    (i) *Fundamentals of nuclear physics;
    (ii) *Fundamentals of reactor theory, including the fission process, neutron multiplication, source effects, control rod effects, criticality indications, reactivity coefficients and poison effects;
    (iii) *Reactor kinetics;
    (iv) Nuclear safety;
    (v) *Radiation protection principles and procedures;
    (vi) *Radiation monitoring methods and survey equipment;
    (vii) *Principles of radiation shielding;

(viii) Heat transfer, thermodynamics and fluid mechanics;
(ix) Materials technology, including the effects of radiation damage on the behaviour of reactor structures.

(d) Reactor technology. This should include all subjects necessary for understanding the design and operation of the research reactor, the functions of different systems and the testing of these systems. These subjects generally include the following:
(i) *General arrangement and layout of the facility;
(ii) *General features of the reactor core, including core structures, fuel elements, control rods, as applicable, and materials;
(iii) General features of the reactor, including the following:
— Reactor instrumentation systems;
— Reactor control systems;
— Reactor protection systems;
— Safety systems;
— Reactor cooling systems, as applicable;
— Ventilation systems;
— Auxiliary systems;
— Containment and/or confinement systems.

(e) Facility specific systems. This should include a detailed description of all the systems in the research reactor and related service facilities, and their functions and modes of operation, including the following:
(i) *Experimental devices and irradiation facilities in the core and outside the core;
(ii) *Isotope production facilities;
(iii) *Beam tube utilization;
(iv) *Cold neutron sources and hot neutron sources;
(v) *Neutron radiography facilities.

(f) Reactor operation and safety. This should cover specific reactor characteristics and the requisite knowledge for safe operation of the reactor and includes the following:
(i) *Reactor operating characteristics in steady state and transient conditions;
(ii) Results of the safety analysis;
(iii) *Anticipated operational occurrences;
(iv) Review of the safety analysis report;
(v) *OLCs;
(vi) *Performance of critical experiments (or verification of subcriticality for subcritical assemblies);
(vii) *Implementation of the surveillance requirements of OLCs (e.g. instrument checks and calibration, control rod calibration);

(viii) *Thermal balance, as applicable;
(ix) *Monitoring and control of core safety limits;
(x) *Procedures for normal operation and anticipated operational occurrences;
(xi) *Emergency plans and procedures;
(xii) *Recognition of the onset of an emergency;
(xiii) Core management and reactivity control;
(xiv) *Fuel handling facilities and procedures;
(xv) *Chemical control;
(xvi) *Radiation protection;
(xvii) *Handling and disposal of radioactive material and effluents;
(xviii) History of incidents at the research reactor as well as at other facilities.

(g) Administrative requirements. This covers additional administrative measures to ensure the safe management of the research reactor and includes the following:
(i) Administrative requirements of the OLCs;
(ii) Staffing requirements;
(iii) Operational procedures;
(iv) Maintenance requirements and scheduling;
(v) Administrative procedures;
(vi) Access control for the research reactor;
(vii) The interface between safety and nuclear security;
(viii) Fire protection;
(ix) Nuclear criticality safety;
(x) Nuclear material accountancy and control;
(xi) Initial qualification and requalification requirements;
(xii) Retention of operational records[9];
(xiii) Configuration and change control.

(h) Regulatory requirements. This includes the following:
(i) Mandatory documentation (e.g. operating and maintenance manuals);
(ii) Relevant national legislation;
(iii) Regulatory bodies and authorities;
(iv) Relevant regulatory requirements;
(v) Relevant codes and standards;
(vi) Authorizations and conditions of licences;
(vii) Reporting requirements.

[9] Operational records include documents such as instrument charts, certificates, log books, computer printouts and digital storage media that have been created to maintain an objective operational history of a research reactor.

An example of a training programme for research reactor operators is presented in Annex II.

4.21. The background and refresher courses should contain similar contents for all research reactors; however, a graded approach should be applied to the facility specific training, depending on the potential hazards associated with the research reactor, the technology adopted, and the specific design.

4.22. The initial training of operating personnel should consist of formal training in the classroom interspersed with laboratory and/or workshop training, on the job training and practical training. Reactor operators should acquire extensive experience in the following:

(a) Reactor operations;
(b) Reactivity manipulations, including startup and shutdown;
(c) Operation of reactor systems;
(d) Utilization of procedures (e.g. fuel handling, sample insertion and removal);
(e) Troubleshooting;
(f) Teamwork;
(g) Administrative tasks.

The training programme should specify the minimum number of reactivity manipulations that a trainee should perform.

4.23. In addition to the technical training, individuals — especially senior reactor operators, shift supervisors, the reactor supervisor and the reactor manager — should undergo training to develop their knowledge and skills in relation to administrative policies and procedures, management responsibilities and limits of authority, techniques for supervision, interpersonal communications, problem analysis, and decision making. Their training should, in general, be broadly based and at a depth commensurate with the roles and responsibilities of the job.

4.24. For the position of senior reactor operator, consideration should be given to experience, leadership and communication skills. In addition to the training described in paras 4.20–4.23, the candidate should be provided with any additional training needed to develop the knowledge and skills necessary to competently perform the duties of senior reactor operator. Consequently, additional training should be provided on the supervisory aspects of the following:

(a) Administrative requirements of the operating organization and the basis for them;

(b) OLCs;
(c) Procedures for making changes to the core configuration and to the system configuration, including supervision of critical (or subcritical multiplication in case of subcritical assemblies) experiments;
(d) The emergency plan and the emergency procedures;
(e) Decontamination procedures;
(f) Management training.

4.25. A senior reactor operator should receive additional specific training, as appropriate (e.g. on the transport of radioactive material, on radiation protection).

4.26. A shift supervisor should receive the training indicated in paras 4.20–4.25. The shift supervisor should receive additional training in the handling of abnormal occurrences and in management and communication skills.

4.27. Non-routine activities may be performed at a research reactor, such as experiments that involve unusual manipulations of the controls by a reactor operator or the preparation and transport of spent fuel assemblies. For non-routine activities, a training programme for the personnel involved should be developed, implemented and completed before the activity is commenced.

4.28. Radiation protection personnel and personnel in other functions should undergo training and have levels of competence appropriate to their jobs and responsibilities. Such training should be conducted using an organized approach, as described in paras 4.18–4.21. Requirements relating to the training of radiation protection personnel are established in GSR Part 3 [22], and associated recommendations are provided in GSG-7 [23] and SSG-44 [31].

Training of support personnel

4.29. Initial training of support personnel should aim to develop knowledge of the following, to the depth needed by the position: facility layout and the general features and functions of research reactor systems; the management system; maintenance procedures and practices, including surveillance and inspections; and special maintenance skills. The training of support personnel should be task related and should emphasize the possible consequences for safety of technical or procedural errors. Feedback experience from failures caused by such errors should be reviewed as part of this training. Specific recommendations for the training of maintenance personnel for research reactors are provided in SSG-81 [3].

4.30. In some research reactors, support work is performed by personnel who are not part of the permanent workforce at the facility. Such personnel should receive facility orientation training, task related instruction, and specific instructions on elements including radiation protection, security and emergency procedures at the research reactor. These individuals should also be familiar with and understand the safety culture at the research reactor. For short term support personnel, most of this training may be replaced by close supervision by operating personnel at the research reactor.

Training of experimenters and other users

4.31. Each new research reactor utilization project should address the training needs associated with the project. This information should be taken into account in the relevant training programmes for operating personnel and be used to develop appropriate training for experimenters and other users. Experimenters and other users should not be allowed to conduct work activities in the research reactor before their specific training has been satisfactorily completed. In addition, the utilization project should not be conducted before the operating personnel have satisfactorily completed any additional training necessary for the project.

4.32. At a minimum, each experimenter or other user who has been granted access to the research reactor should receive basic training in radiation protection, fire safety, non-radiation-related safety and emergency response commensurate with that user's responsibilities and conditions of access (i.e. escorted or unescorted) to the research reactor.

ASSESSING THE COMPETENCE AND QUALIFICATION OF RESEARCH REACTOR PERSONNEL FOLLOWING TRAINING

4.33. When operating personnel have completed their training, their competence should be assessed by the reactor manager (or by a qualified person designated by the reactor manager) before they perform the duties of the position for which they were trained. In the case of the reactor manager, an individual from the operating organization with specific knowledge of the reactor manager's duties should conduct the assessment of competence. Standards of performance should be established against which the competence of operating personnel will be assessed. An assessment can consist of one or more of the following:

(a) Assessment of practical skills by means of performance demonstrations;

(b) Assessment of knowledge of the research reactor and of recall and comprehension by means of a written examination;
(c) Assessment of knowledge of the research reactor and of recall and comprehension by means of an oral examination (this may take place in a classroom and/or as part of a facility walkthrough[10]);
(d) Assessment of performance under stress (e.g. under simulated emergency conditions).

4.34. The reactor manager should be informed of any deficiency in the performance of trainees found in the assessment of competence. Deficiencies should be remedied by one or more of the following measures:

(a) Identifying where the on the job training, classroom training and/or self-study are not adequate;
(b) Adopting measures to ensure that the necessary competence is reached;
(c) Providing remedial training for those individuals showing a deficiency;
(d) Removing individuals from their positions.

CONTINUING TRAINING AND REQUALIFICATION OF RESEARCH REACTOR PERSONNEL

4.35. Continuing training in accordance with an organized approach should be provided by the operating organization to ensure that the knowledge, skills and attitudes of research reactor personnel are maintained. Continuing training should also be used for career development and succession planning purposes. All personnel whose functions are important to the safe operation of the research reactor should participate in continuing training.

4.36. A programme of continuing training should be delivered over a set period (e.g. one or two years) and should be followed on a regular basis by successive continuing training programmes. The programme should include selected topics from the initial training (see paras 4.18–4.22) relevant to safety related activities that are infrequently performed or that are difficult to perform. The topics for continuing training should be commensurate with the responsibilities

[10] A walkthrough is a supervised exercise conducted in a working environment in which actions are simulated for the purpose of training or verification of procedures and an evaluation is made of the performance of the trainee or the suitability of the procedure.

and duties of the incumbents. Topics for a continuing training programme could include the following:

(a) Nuclear technology and principles of reactor operation;
(b) Nuclear safety principles;
(c) Reactor design and operating characteristics;
(d) Instrumentation and control systems;
(e) Reactor protection systems;
(f) Experimental devices and auxiliary reactor systems;
(g) OLCs;
(h) Operating procedures for operational states and accident conditions;
(i) Radiation protection;
(j) The emergency plan;
(k) Physical protection of nuclear material;
(l) The interface between safety and security.

4.37. Personnel with supervisory responsibilities (see paras 4.23 and 4.24) should receive continuing training that emphasizes the supervisory aspects of their position.

4.38. Personnel who are occupationally exposed to ionizing radiation should receive periodic retraining in radiation protection.

4.39. A continuing training programme should also include regular drills and exercises on emergency procedures. All relevant personnel should participate in these drills and exercises. Drills and exercises are also required to involve off-site personnel, if such personnel are part of the emergency plan (see para. 6.31 of GSR Part 7 [19]).

4.40. In addition to the training topics recommended in paras 4.36 and 4.39, continuing training programmes should address the need for new knowledge and skills, for example because of the following:

(a) Changes in reactor systems and equipment;
(b) Changes in operating procedures and emergency procedures;
(c) Changes in the licence or in documents referred to in the licence (e.g. changes in the safety analysis report and in OLCs);
(d) Accumulated operating experience, including from events that have occurred during operation at the research reactor and other relevant facilities;
(e) Weaknesses detected in the performance of operating personnel;
(f) Individual requests for additional training.

4.41. As part of the continuing training programme, reactor operators who are seeking requalification to demonstrate their continuing competence should have performed a minimum number of reactivity manipulations. In addition, as part of the programme, individuals who hold specific positions should have performed the duties of the position for a specified minimum amount of time.

4.42. Following completion of each set period for the continuing training programme (see para. 4.36), a requalification examination should be arranged to verify that operating personnel have maintained the knowledge and skills necessary for their duties. The examiner should be independent from the persons who provided the continuing training. In some cases, the examination might be administered by the regulatory body. The interval between successive requalification examinations may vary between one and five years. To meet the requirements established in para. 7.30 of SSR-3 [1], operating personnel who have been absent from active duties for a considerable time (e.g. several consecutive months) should successfully complete an appropriate retraining programme, including a reassessment of their competence, before reassuming their duties.

5. AUTHORIZATION OF OPERATING PERSONNEL AT A RESEARCH REACTOR

5.1. Paragraph 7.28 of SSR-3 [1] states that “Certain operating positions may require formal authorization or a licence.” In this context, authorization is the granting by the regulatory body or other appropriate authority of written permission for a person to conduct specified activities. In some Member States, authorization is limited to activities performed at a specific research reactor.

5.2. Paragraph 7.21 of SSR-3 [1] states that “Every licensed or authorized member of the operating personnel shall have the authority to shut down the reactor in the interest of safety.” This authority should be clearly defined by the operating organization and understood by operating personnel.

5.3. The operating organization should establish procedures for applying for the authorization of operating personnel in compliance with regulatory requirements. These procedures should provide for an assessment of the competence of persons to be authorized, including successfully passing an examination based on the training programme and regulatory requirements. The regulatory body may conduct the examination and issue an authorization or a licence to the successful candidates. Alternatively, the operating organization may be responsible for conducting the examination, possibly with a representative of the regulatory body present as an observer.

5.4. Independent of any authorization issued, it is the responsibility of the operating organization to ensure that all personnel have the necessary qualifications for their positions.

OPERATING PERSONNEL AT A RESEARCH REACTOR WHO REQUIRE AUTHORIZATION

5.5. The operating organization should establish processes and procedures by which persons controlling or supervising changes in the operational status of the research reactor, or with other duties that have a direct bearing on safety, are authorized before they are allowed to perform those duties. This authorization may be achieved in different ways. For example, the operating organization may propose to the regulatory body the activities to be covered by the authorization. Alternatively, the regulatory body may determine the activities that need to be authorized and grant authorizations accordingly.

5.6. Paragraph 7.5 of SSR-3 [1] states:

> "The staff positions that require a licence or certificate shall be determined in accordance with the legal framework of the State.… In particular, in accordance with regulatory requirements, the reactor manager[39], the shift supervisors and the reactor operators shall hold an authorization (a licence or certificate) issued by the regulatory body, operating organization or other competent authority.
>
> "[39] The reactor manager does not necessarily need to hold a licence to operate the reactor but needs to have completed a training programme".

5.7. The regulatory body may require documented evidence of the competence of other personnel who are not authorized by the regulatory body but whose duties have a significant, though not direct, bearing on safety.

CONDITIONS OF AUTHORIZATION FOR PERSONNEL AT A RESEARCH REACTOR

5.8. Each authorization for an individual should specify the research reactor and position to which the authorization applies. In addition, any conditions derived from medical or other findings (e.g. the wearing of corrective eyeglasses during the performance of duties) should be specified in the licence. If an authorized individual moves to a different research reactor or to a different authorized position at the same facility, the person should satisfy the specific competence requirements for the new position before being authorized to assume their duties.

5.9. The operating organization should ensure that only individuals who hold a specific authorization are allowed to operate reactor controls that directly affect the reactivity of the core. However, individuals enrolled in a training programme that leads to such an authorization, or students in a formal educational programme, may — under the supervision of an authorized person — operate such controls. In addition, suitably qualified persons may be permitted to perform preapproved, limited actions that might affect the reactivity of the core, with the permission of the authorized person at the controls (e.g. a researcher placing a sample into the reactor using a pneumatic conveyor).

5.10. To maintain an authorization, an individual should perform the duties of the authorized position on a regular basis. If an individual has not performed the duties of the position for a certain period of time (typically three to six months), an authorized representative of the research reactor should certify that the individual still meets the requirements of the authorization prior to the individual's resumption of duties. In some cases, retraining should be performed and competence should be reassessed (see para. 4.42).

5.11. All authorized individuals should undergo a periodic medical examination to assess physical health and mental health. The results of this examination should be used by the management of the research reactor to help in determining whether individuals are still capable of performing the functions for which they are authorized (see also para. 3.6 and Ref. [26]).

REAUTHORIZATION OF OPERATING PERSONNEL AT A RESEARCH REACTOR

5.12. The competence of authorized operating personnel should be reviewed periodically. Consideration should be given to the need for periodic reauthorization.

In many States, authorizations issued by the regulatory body are valid for a limited time, typically from one to six years. An authorization may be withdrawn or not renewed if the individual no longer meets the requirements for the authorized position or is no longer needed to perform the authorized duties. The decision to reauthorize an individual should be based, in part, on continuing medical fitness for duty. Authorized individuals should successfully complete the continuing training programme appropriate to their positions, should be confirmed as still having the necessary competences and should pass the reauthorization examination.

5.13. Particular consideration should be given to reauthorization if an authorized person has been absent for an extended time and changes in the research reactor, in procedures or in other areas have occurred. This reauthorization may be approached in a graded manner with retraining, reassessments of competence and examinations commensurate with the duration of the absence, the complexity of the research reactor, and the changes to the facility and its operation during the absence of the individual.

6. RECORDS OF RECRUITMENT, TRAINING AND QUALIFICATION OF PERSONNEL AT A RESEARCH REACTOR

6.1. For each individual at a research reactor, the operating organization should maintain records of the following:

(a) Education;
(b) Experience;
(c) Training and retraining;
(d) Qualification and requalification;
(e) Results of examinations and tests;
(f) Authorization and reauthorizations;
(g) Employment history;
(h) Performance history;
(i) Medical records.

A list of job requirements for the position of each individual should also be maintained.

6.2. The main purpose of the records listed in para. 6.1 (which may be made available to the regulatory body, if necessary) is to provide the following:

(a) Documentation of the qualifications and competences of all persons whose duties have a bearing on safety;
(b) Documentation of authorizations of individuals;
(c) Historical information for the review of the training programme and for implementation of corrective actions, if necessary;
(d) Documentation needed to meet regulatory requirements.

These records may also be used as an independent source of information for career development purposes.

6.3. The records listed in para. 6.1 should be collected and archived in accordance with the management system for the research reactor (see paras 2.61–2.85).

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Annex I

THE SYSTEMATIC APPROACH TO TRAINING

I–1. The systematic approach to training is a useful concept initially introduced for the preparation and implementation of training programmes and the evaluation of training programmes and trainees at nuclear power plants. Such an approach is also applicable to research reactors, particularly those with large operating organizations. Detailed information on the systematic approach to training can be found in Refs [I–1, I–2]. This annex contains a brief description of this approach.

I–2. The overall goal of the systematic approach to training is to develop the necessary competences to safely operate and maintain the research reactor. The systematic approach to training provides a logical progression from the identification of the competences necessary to perform a job, to the development and implementation of training to achieve these competences, to subsequent evaluation of the effectiveness of the training.

I–3. The systematic approach to training applies quality management techniques to training to ensure the competence of personnel. The competence requirements for every job in the research reactor are established (e.g. through a job and/or task analysis), and personnel are trained and evaluated using the techniques described in Ref. [I–1]. The quality management characteristics of the approach enable a demonstration that all necessary competences have been attained. The control and accountability features of the process provide the management of the operating organization as well as the regulatory body with the means of applying standard quality management procedures and processes at any stage of the training process.

I–4. An overview of the systematic approach to training is given in Fig. I–1.

I–5. As shown in Fig. I–1, the systematic approach to training consists of five interrelated phases, as follows:

(a) Analysis: The analysis phase comprises the identification of training needs and of the competences necessary to perform a particular job.
(b) Design: In the design phase, the identified competences are converted into training objectives. These objectives are organized into a training plan.
(c) Development: The development phase comprises preparation of all training materials so that the training objectives can be achieved.

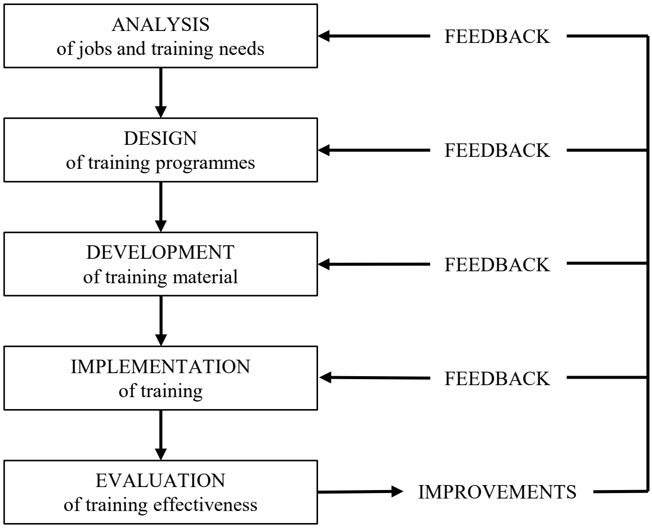

FIG. I–1. Overview of the systematic approach to training.

(d) Implementation: In the implementation phase, training is conducted using the training materials that have been developed.

(e) Evaluation: In the evaluation phase, all aspects of the training programme are evaluated on the basis of the data collected in each of the other phases. This is followed by suitable feedback, leading to improvements in the training programme. The evaluation of the training programme may also identify necessary improvements in procedures, equipment and organization at the research reactor.

IMPLEMENTATION OF THE SYSTEMATIC APPROACH TO TRAINING

I–6. Experience has shown that implementation procedures are necessary for each of the phases of the systematic approach to training to ensure quality and consistency. These implementation procedures specify in detail the steps to be taken to complete each phase and identify the responsibilities and qualifications of the personnel who perform the work of each phase. Figure I–2 illustrates the implementation of the systematic approach to training and summarizes the most important inputs and outputs for each phase from sources internal and external to the process.

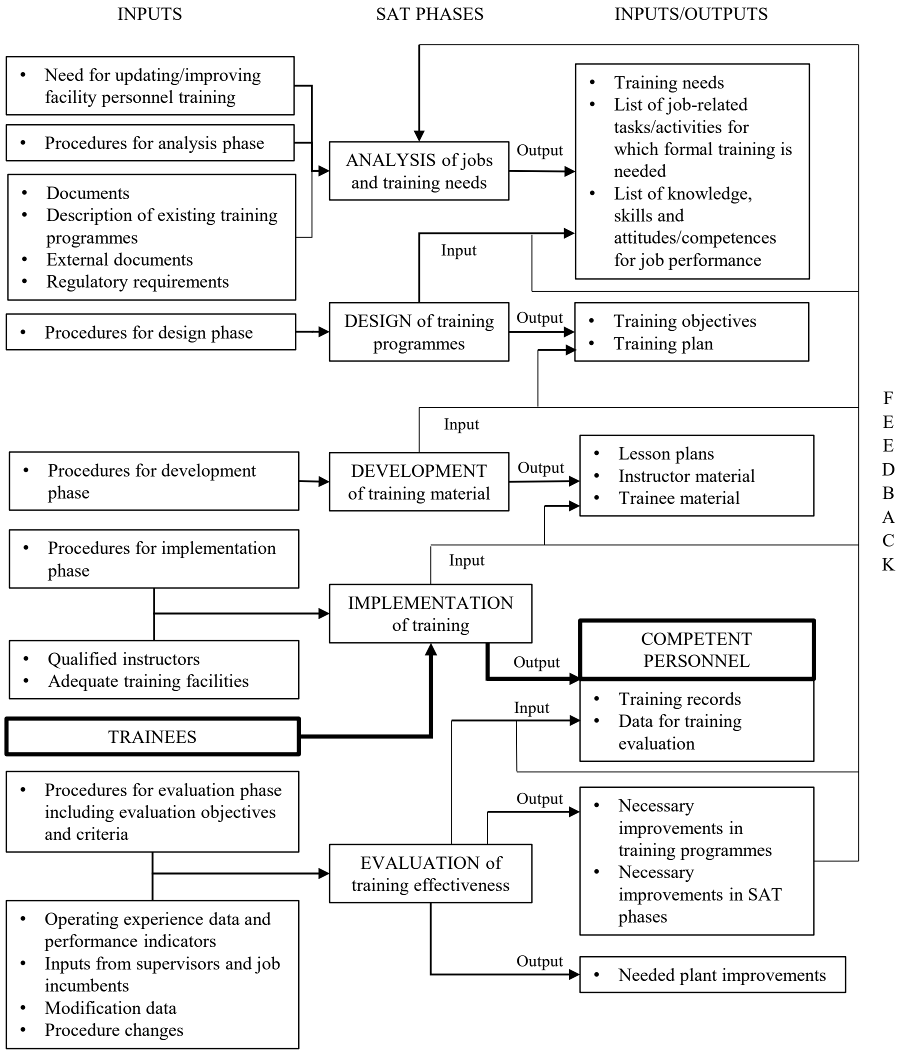

FIG. I–2. Implementation of the systematic approach to training (SAT), including inputs and outputs.

I–7. The analysis phase of the process is based on the characteristics of the research reactor and will therefore be facilitated by good documentation. If the systematic approach to training is to be prepared for a research reactor that is in the pre-operational stage, design documents and/or documentation from a facility of similar design should be used.

I–8. References [I–1, I–2] present guidance on the introduction by management of training based on the systematic approach to training and on the process for the training of operating personnel, maintenance personnel, managers, emergency workers and instructors. The reactor management may find it beneficial to apply the systematic approach to training to personnel in all areas of operation.

REFERENCES TO ANNEX I

[I–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Systematic Approach to Training for Nuclear Facility Personnel: Processes, Methodology and Practices, IAEA Nuclear Energy Series No. NG-T-2.8, IAEA, Vienna (2021).

[I–2] INTERNATIONAL ATOMIC ENERGY AGENCY, Analysis Phase of Systematic Approach to Training (SAT) for Nuclear Plant Personnel, IAEA-TECDOC-1170, IAEA, Vienna (2000).

Annex II

EXAMPLE OF A CURRICULUM FOR A TRAINING COURSE FOR RESEARCH REACTOR OPERATORS

II–1. This annex provides information on establishing a new training course for operating personnel of research reactors and provides a comparative basis for reviewing existing training courses. It is adapted from materials used at a large research reactor in a Member State. The training topics for a specific research reactor may vary from those given in this annex. All aspects of safety need to be covered in the training. Training is one of the means to promote safety culture and needs to be fully encouraged and supported by plant managers who are also trained in safety culture. Some of the topics listed are not applicable to subcritical assemblies and low power level reactors (e.g. those with natural convection cooling and without the need for emergency core cooling or active decay heat removal).

INITIAL TRAINING FOR RESEARCH REACTOR OPERATORS

II–2. All reactor operators are expected to have knowledge of the reactor areas under their control and to be trained to assess the effects of their actions on reactor systems. Senior reactor operators and shift supervisors are expected to have an in-depth understanding of the reactor and of the interactions between its various systems, as well as knowledge of the administrative and organizational provisions regarding their fields of duty. In addition, the necessary knowledge of reactor operators, senior reactor operators and shift supervisors may include items specified by national regulations or determined by the needs for facility management.

II–3. Table II–1 presents the broad headings in a sample course outline for an initial training programme. It consists of two parts: (a) fundamental knowledge of nuclear topics and (b) facility specific knowledge. Paragraphs II–10 and II–11 expand this outline by listing individual topics presented under each heading. The topics listed in para. II–11 are facility dependent; some might not be applicable to all research reactors.

TABLE II–1. COURSE OUTLINE FOR INITIAL TRAINING FOR RESEARCH REACTOR OPERATORS

Part A. Fundamental knowledge of nuclear topics

1. Fundamentals of nuclear physics
   1.1. Quantities, units and symbols
   1.2. Structure of the atom and radioactive decay
   1.3. Interaction of radiation with matter
2. Reactor physics
3. Energy release and thermohydraulics
4. Fundamentals of reactor engineering and reactor safety
5. Radiation protection
6. Occupational safety
7. Regulatory requirements
   7.1. National regulations and international codes and standards
   7.2. Radiation protection regulations

Part B. Facility specific knowledge

1. Facility engineering
   1.1. Buildings and equipment
   1.2. Layout, operating modes and functions of the reactor equipment
      1.2.1. Reactor core, tank and/or pool, and internals
      1.2.2. Reactor cooling system
      1.2.3. Reactor control
      1.2.4. Control rod drives
      1.2.5. Reactor protection system
      1.2.6. Reactor containment system or means of confinement
      1.2.7. Instrumentation and control systems, including alarm systems
      1.2.8. Reactor auxiliary systems
      1.2.9. Conventional service systems
      1.2.10. Cooling water systems
      1.2.11. Electric power supply systems and distribution systems
   1.3. Control room
      1.3.1. Control room and auxiliary control stations
      1.3.2. Control room engineering
      1.3.3. Computer systems
2. Facility operation
   2.1. Facility control
   2.2. Core management
   2.3. Abnormal operating events
      2.3.1. Malfunctions of important facilities
      2.3.2. Anticipated operational occurrences and incidents
      2.3.3. Unforeseen event sequences
   2.4. External events
   2.5. Radiation protection and monitoring

TABLE II–1. COURSE OUTLINE FOR INITIAL TRAINING FOR RESEARCH REACTOR OPERATORS (cont.)

	2.6.	Environmental monitoring	
	2.7.	Research reactor chemistry	
	2.8.	Access control	
3.	Administrative requirements		
	3.1.	Conditions imposed and directives issued by the authorities	
	3.2.	Operating manual	
	3.3.	Organization of operation	
		3.3.1.	Control room and shift duty rules
		3.3.2.	Alert plans
		3.3.3.	Other operating rules

DURATION OF TRAINING FOR RESEARCH REACTOR OPERATORS

II–4. In many training programmes, candidates for the position of reactor operator are expected to participate in supervised operation of the reactor for a specified time (e.g. six months), with a portion of that time (e.g. two months) on shift, before authorization may be sought. Candidates for the position of shift supervisor are often expected to work as an authorized reactor operator for a minimum period (e.g. one year) at the research reactor where authorization as shift supervisor is sought. The necessary level of experience may vary in accordance with national regulations. For subcritical assemblies, the type of training and the training periods need to be adapted for each facility, in accordance with its potential hazard and complexity.

II–5. The amount of time needed for training can vary widely and depends on the complexity of the research reactor, the academic background and learning ability of the trainees and the teaching skills of the trainers. Table II–2 provides a typical schedule for instruction in fundamental knowledge of nuclear topics (the italicized items in para. II–10) for reactor operators.

TABLE II–2. EXAMPLE OF A SCHEDULE FOR TRAINING IN FUNDAMENTAL KNOWLEDGE OF NUCLEAR TOPICS FOR RESEARCH REACTOR OPERATORS

Topic		No. of hours
1.	Fundamentals of nuclear physics	32
2.	Reactor physics	41
3.	Energy release and thermohydraulics	48
4.	Fundamentals of reactor engineering and reactor safety	13
Two week self-study period		
4.	Fundamentals of reactor engineering and reactor safety (continued)	31
5.	Radiation protection	62
6.	Occupational safety	7
7.	Statutory basis	10
8.	Summary and recapitulation workshops	60
Total class hours		~300

ASSESSMENT OF TRAINING PROGRESS

II–6. To evaluate progress during training, separate examinations are often administered after the completion of specific classroom topics such as the following:

(a) Nuclear and reactor physics and thermohydraulics;
(b) Fundamentals of reactor engineering and reactor safety;
(c) Radiation protection.

II–7. At the conclusion of the course, a comprehensive written examination is taken, together with an oral examination. An example of an oral examination for a reactor operator is presented in Table II–3.

TABLE II–3. EXAMPLE OF A FACILITY SPECIFIC ORAL EXAMINATION FOR RESEARCH REACTOR OPERATORS

1. *Examination by means of questioning*

Duration: As long as necessary to reach supportable conclusions about the candidate.

1.1. Short description of the research reactor using plans or exploded view placards.

1.2. Three questions taken from the facility knowledge 'question catalogue', with emphasis on dealing with accidents and on procedures relating to radiation protection (using visual aids when appropriate, prepared beforehand).

2. *Examination by means of performance demonstrations and practical presentations*

Duration: As long as necessary. Place of examination: The control room and various locations in the reactor hall, as appropriate. Examinees are questioned individually on Sections 2.1–2.3, as follows. Note: When the reactor is in operation, some demonstrations may have to be simulated.

2.1. Explanations of selected components of the coolant circuitry and systems, the reactor protection system and the reactor instrumentation in their functional context. As applicable to the facility, each item below is discussed near the appropriate panel or observation point:

(a) Air conditioning panel;
(b) Fuel element temperature display panel;
(c) Nuclear instrumentation;
(d) Coolant circulation control panel;
(e) Power supply circuit panel;
(f) Fire extinguishing system;
(g) Leak detection indication panel and emergency core cooling system;
(h) Trip interlock panel;
(i) Radiation protection instrumentation panel;
(j) Test units for the coarse control rod bank and the fast shutdown system;
(k) Control desk.

2.2. Demonstration of knowledge of the system and procedures by performing a pre startup checkout; a reactor startup; a power adjustment (except in the case of a subcritical assembly) from low power to exactly full power using the basic stepwise procedure; and a reactor shutdown.

2.3. Discussion of an accident scenario; application of the operating manual with facility walkthrough as appropriate.

2.4. In the case of a subcritical assembly, discussion of amount, type and geometry of nuclear fuel and the effective multiplication factor.

CONTINUING TRAINING FOR RESEARCH REACTOR OPERATORS

II–8. The topics to be covered in a continuing training course and the appropriate duration are dependent on the research reactor and its utilization programme. The course materials focus on recent changes made to structures, systems and components; administrative procedures and operating procedures; regulations; and operational limits and conditions. Training also focuses on responses to anticipated operational occurrences and on emergency response.

II–9. An example of a continuing training course is outlined in Table II–4.

TABLE II–4. EXAMPLE OF A CONTINUING TRAINING COURSE FOR RESEARCH REACTOR OPERATORS, SENIOR REACTOR OPERATORS AND SHIFT SUPERVISORS

Main topic	Subtopics
Theoretical part	
Fundamental knowledge of nuclear topics	— Facility related reactor physics — Thermohydraulic aspects of the reactor — Operating procedures — Radiation protection aspects of the research reactor — Chemistry of the coolant circuit
Reactor engineering	— Power supply in the facility — Reactor protection system and observation of safety instructions — Instrumentation and electronic systems — Instrumentation and mechanical systems — Neutron absorbers in the reactor — Coolant system circuitry — Experience from other similar reactors — Experimental facilities — Reactor fuel — Physical and engineering principles of measurement techniques in research reactors — Recording and processing of data

TABLE II–4. EXAMPLE OF A CONTINUING TRAINING COURSE FOR RESEARCH REACTOR OPERATORS, SENIOR REACTOR OPERATORS AND SHIFT SUPERVISORS (cont.)

Main topic	Subtopics
Regulations and organization	— General safety rules at the centre; protection against external events — Organization, regulatory body and other competent authorities and responsibilities — Authorizations, notifications and reporting — Plans for maintaining professional knowledge — Administration — Regulations relating to accident prevention — Respiratory protection — Recapitulation of facility safety and radiation protection services
Special topics	— Operating procedures and operating manual — Service procedures and inspection manual — Fault analysis and reportable occurrences
Practical part	
Operational practice	— Handling and replacement of fuel elements, neutron absorbers and experiments — Use of portable radiation monitoring instruments in the facility — Employment of facility specific electronic data processing
Operational aspects of reactor coolant circuitry and related systems	— Applicable operational limits and conditions — Response to postulated anticipated operational occurrences — Response to postulated emergency conditions — Recent modifications to the coolant system
General practical topics	— Reactor alarm – exercise — Fire alarm – exercise — First aid – course
Special topics	— Performance of or partaking in periodic tests and in-service inspections in accordance with the inspection manual, under the supervision of the reactor manager or qualified operator

TOPICS FOR INITIAL TRAINING IN FUNDAMENTAL KNOWLEDGE OF NUCLEAR TOPICS FOR RESEARCH REACTOR OPERATORS

II–10. This paragraph provides a description of the individual topics presented in Table II–1 under 'Part A. Fundamental knowledge of nuclear topics'. The topics in italics apply to training for reactor operators, senior reactor operators and shift supervisors. The remainder apply only to training for senior reactor operators and shift supervisors. The numbering used reflects the structure in Table II–1.

1. *Fundamentals of nuclear physics:*
   1.1. *Quantities, units and symbols:*
      — *Explanation of the quantities used in nuclear engineering, including associated symbols.*
   1.2. *Structure of the atom and radioactive decay:*
      — *Structure and model of the atom, nuclear charge and mass number;*
      — *Definitions of 'isotope', 'nuclide', 'neutron', 'proton', 'electron' and 'gamma quantum';*
      — *Types of radiation (α, β, γ, n);*
      — *Changes in the nucleus and related energy transfer associated with α, β, γ and n decay;*
      — Decay laws for the chart of the nuclides and decay chains.
   1.3. *Interaction of radiation with matter:*
      — *Interaction of α and β radiation with matter;*
      — *Cross-sections;*
      — *Reaction rates;*
      — *Shielding of γ radiation;*
      — Interaction of γ radiation (e.g. energy transfer, secondary radiation, scattered radiation) and neutrons (scattering, capture, fission) with matter;
      — *Neutron sources;*
      — *Qualitative relationship between temperature and kinetic neutron energy;*
      — *Shielding against neutrons;*
      — *Process of nuclear fission and binding energy;*
      — Fission cross sections and their dependence on neutron energy;
      — *Definitions of 'fission product' and 'activation product';*
      — Breeding and conversion processes;
      — *Description of the most important fissile and fertile nuclides.*
2. *Reactor physics:*
   — *Chain reaction;*

- *The four-factor formula and its extension to the real reactor;*
- *Multiplication factors (*k_{eff}*,* k_∞*);*
- *Reactivity (in relation to the multiplication factor) and effects of moderator, reflector and coolant;*
- *Prompt and delayed neutrons (definitions, production and impact on control of the reactor);*
- Delayed neutrons of the most important fissile nuclides and delayed neutron fractions;
- *Approach to criticality;*
- *Definitions of 'critical' and 'prompt critical';*
- *Changes of neutron flux at or near the critical or prompt critical state;*
- *Definitions of 'stable period' and 'qualitative treatment of reactor period' or 'relative rate of flux change';*
- Definitions of 'stationary', 'transient' and 'transitional behaviour';
- *Relationship between neutron flux and reactor power;*
- *Methods of measuring neutron flux; impact of changes in the density of the moderator and reflector on the neutron flux;*
- *Qualitative treatment of the distribution of the neutron flux over the core and in the proximity of a fuel element and a control element;*
- *Dependence of reactivity on fuel temperature, coolant or moderator density (steam voids), reactor power, sample irradiation and reflecting materials, and time behaviour of the contributors to reactivity effects;*
- *Dependence of the reactivity coefficients on fuel burnup;*
- *Qualitative treatment of subcritical and critical reactor operating behaviour and behaviour in the various power ranges;*
- *Xenon poisoning (definition, buildup process via fission products, dependence on neutron flux and fuel loading, behaviour with time, and influence on reactivity);*
- *Reactor control, burnable absorbers and control elements;*
- *Monitoring of the core behaviour of the subcritical or critical reactor;*
- *Neutron source (purpose and effect);*
- *Reactivity balance (qualitative treatment), excess reactivity and shutdown margin;*
- *Conduct of critical experiments.*

3. *Energy release and thermohydraulics:*
   - *Properties of water;*
   - *Flow resistance in pipes and valves;*
   - Flow measurements by orifices;
   - *Operating principles of centrifugal pumps, operating limits,* pump operation in a pipeline and pump cavitation;
   - *Definitions of 'critical heat flux' and 'hot spot';*

- *Critical heat flux ratio, bulk boiling, nucleate boiling and film boiling;*
- *Mechanisms of heat transfer;*
- *Heat transfer from cladding to water;*
- *Heat transfer capability of heat exchangers;*
- *Heat conduction in the fuel and heat transfer from the fuel to the coolant (qualitative treatment);*
- Qualitative treatment of energy distribution in the fuel, moderator, coolant, core internals and shielding during operation and after shutdown, depending on the type of radiation and as a function of the reactor power history;
- *Generation of heat in fuel, moderator and reactor structures;*
- *Natural circulation (single phase) and limits of natural circulation;*
- Physical behaviour of air–steam mixtures (qualitative treatment).

4. *Fundamentals of reactor engineering and reactor safety:*
   - *Basic layout and characteristics of a research reactor;*
   - *Hazards and risks involved in the use of nuclear energy (fission product inventory and uncontrolled reactivity);*
   - *The concepts of normal operation, anticipated operational occurrences, and incidents or events;*
   - *Safety concepts, single failure criterion and quality assurance (management system);*
   - *Defence in depth;*
   - Common mode failure;
   - *Residual heat removal during normal operation, following the failure of the main heat sink and during loss of coolant accidents;*
   - *Basic layout and function of the barriers against the release of radioactive material into the building and to the environment;*
   - *Material ageing;*
   - Definitions of ‘inherent safety’, *‘redundancy’, ‘diversity’*, ‘fail safe principle’, ‘energize and de energize to trip principle’, ‘active fault’, ‘passive fault’ and *‘self reporting fault’ (with examples);*
   - *Mode of operation and purpose of important active and passive safety systems in research reactors;*
   - *Impact of faults on the measuring system for the display of data;*
   - *Conditions necessitating activation of the reactor protection system;*
   - *Anticipated typical event sequences that may pose hazards to the personnel in the building, to the facility* (including damage to the reactor core), *and to the environment during normal operation, anticipated operational occurrences, or incidents and events;*
   - Postulated initiating events;
   - Basis for operational limits and conditions.

5. *Radiation protection:*
   - *Hazards arising from radiation and the purpose of radiation protection;*
   - *Explanation of the terms 'activity', 'specific activity', 'activity concentration', 'half life', 'contamination', 'half value thickness', 'activation', 'intake', 'inhalation dose', 'ingestion dose', 'submersion dose', 'immersion dose', 'dose rate', 'equivalent dose', and 'effective dose';*
   - Modes of operation, *uses* and limitations *of radiation measuring instruments and equipment* (ionization chamber, proportional counter tube, Geiger–Müller tube, scintillation detector, semiconductor detector, neutron detector, *personal dosimeters (passive), multisphere dosimeter, and electronic personal dosimeters for measurement of dose rates, surface contamination and doses, as appropriate);*
   - Radiation fields;
   - Unsealed and sealed radioactive materials in the research reactor, and handling precautions;
   - Exposure to natural radiation (sources and intensity);
   - *Dose limits and dose constraints (a) for occupationally exposed persons in the research reactor, in the restricted access area and during events and (b) for the public due to the discharge of radioactive material to air or water;*
   - *The effects of high radiation doses;*
   - Limits for the maximum authorized activity of radioactive material discharged to air or water;
   - *Annual limits on intakes into the body;*
   - *Protective measures in the case of surface contamination of the workplace or objects;*
   - *Hazards arising from the intake of radioactive material (preventive and subsequent measures, intakes and measurement methods);*
   - *Measures to prevent contamination (of body, clothing, tools and equipment)* and decontamination measures;
   - Protective measures to be applied until the arrival of radiation protection personnel (control measures, security measures and decontamination of persons);
   - *Measures and equipment for individual monitoring,* time intervals for individual dose reviews, and medical examinations of persons exposed to radiation;
   - *Protective measures and behaviour (e.g. the use of time, distance, shielding, protective clothing and respirators) for optimizing radiation protection while working in radiation areas or contaminated areas (in*

exclusion areas and restricted access areas and during maintenance work);
- Cooperation with the radiation protection officer and staff.

6. Occupational safety:
   - Relationship between operational reliability and occupational safety;
   - *Compliance with occupational safety principles;*
   - Statutory basis for job related occupational safety, and provisions and rules important to occupational safety;
   - Characteristic hazards and the prevention of accidents;
   - *Persons responsible for occupational safety measures;*
   - *Duties and responsibilities of occupational safety officers and safety professionals;*
   - Basic measures and procedures for maintenance work (work permit procedures);
   - Measures in the case of personal injuries, focusing on accidents involving radiation;
   - Fundamentals of fire prevention and firefighting at research reactors, including *behaviour in fires and basic features of fire alarms.*
7. Regulatory requirements:

   7.1. National regulations and international codes and standards:
   - Licensing requirements;
   - Operating requirements;
   - Changes in the research reactor or in its operation that require regulatory review and approval;
   - Access authority of the agents of the regulatory body;
   - IAEA safety standards;
   - IAEA Code of Conduct on the Safety of Research Reactors[1];
   - Publications of the International Commission on Radiological Protection.

   7.2. Radiation protection regulations:
   - *Access to radiation protection regulations;*
   - Major provisions of the radiation protection regulations and their implications for the research reactor;
   - Positions and duties of the radiation protection personnel;
   - Radiation protection directives;
   - Measures to be taken during and following events to mitigate their consequences;

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Code of Conduct on the Safety of Research Reactors, IAEA/CODEOC/RR/2006, IAEA, Vienna (2006).

— Facility instructions, definitions of ‘controlled area’, ‘supervised area’ and ‘monitored area’;
— Protection of air, water and soil, and environmental surveys;
— Disposal of radioactive waste;
— *Occupational radiation exposure;*
— Accounting for other radiation exposures;
— Prohibitions and restrictions on work;
— Local dose measurements and control of access to supervised and controlled areas.

TOPICS FOR INITIAL TRAINING IN FACILITY SPECIFIC KNOWLEDGE FOR RESEARCH REACTOR OPERATORS

II–11. This paragraph provides a description of the individual topics presented in Table II–1 under ‘Part B. Facility specific knowledge’. The topics in italics apply to the training for reactor operators, senior reactor operators and shift supervisors. The remainder apply only to the training for senior reactor operators and shift supervisors. The numbering used reflects the structure in Table II–1.

1. Facility engineering:
   1.1. Buildings and equipment:
      — *Safety analysis report for the research reactor;*
      — *Layout and functions of buildings, access, locations of systems and components, with particular consideration of the engineered safety features (emergency cooling and residual heat removal);*
      — *Operation and functional modes of equipment important to safety (e.g. airlocks, escape doors, fire protection doors, fire alarms, firefighting equipment, smoke exhausts, emergency equipment);*
      — *Escape routes, meeting points, traffic routes, fences and surveillance equipment;*
      — *Accessibility of facility compartments during reactor operation and after shutdown;*
      — *Locations and functions of fire extinguishing equipment;*
      — *Location and operation of communication equipment and systems.*
   1.2. Layout, operating modes and functions of the reactor equipment:
      1.2.1. Reactor core, tank and/or pool, and internals:
         — *Tasks, functional modes, arrangement and layout of the major components (e.g. fuel elements, neutron sources, in*

core instrumentation, control elements including drives, and experimental facilities);

— *Interpretation of instrument data to determine the operating state.*

1.2.2. Reactor cooling system:

— *Tasks, functional modes, arrangement and layout of heat exchangers, pipes, reactor coolant pumps, isolation valves, safety valves and blowdown valves; design and operating data;*

— *Energy sources and sinks; heat transport during operation and after shutdown or in natural circulation mode;*

— *Interpretation of data for the determination of the operating state; modes of operation; effect of the mode of operation on components of the reactor cooling system and adjacent systems; initiation of corrective action in the case of malfunction.*

1.2.3. Reactor control:

— *Principles and functional modes;*

— *Effect of the control system on reactor systems; initiation of corrective action in the case of malfunction;*

— *Modes of operation (manual and automatic, normal and reduced power) and functions (limitations of the control system, maximum values and interlocks).*

1.2.4. Control rod drives:

— *Tasks and functional modes of control rod drives; scram mechanism and the scram system;*

— *Checks for operability; initiation of corrective actions in the case of malfunction;*

— *Rates of motion and drop times of the control elements.*

1.2.5. Reactor protection system:

— Postulated initiating events from the safety analysis report;

— *Tasks, layout, functional modes and logic, monitoring for operability and functionality, and detection of malfunctions;*

— *Initiation of reactor protection signals and interpretation of the facility status;*

— *In service inspections and surveillance.*

1.2.6. Reactor containment system or means of confinement:

— *Tasks and functional modes of confinement including building isolation, and arrangement of components and systems;*

— *Ventilation, and initiation of corrective actions in the event of malfunction;*
— *Containment design limits and maintenance of negative pressure;*
— *Arrangement of the building isolation valves;*
— *Effect of building isolation on other reactor systems.*

1.2.7. Instrumentation and control systems, including alarm systems:

— *Purpose of the instrumentation of active and passive safety systems and the associated alarm annunciation;*
— *Measuring methods;*
— Design limits of the instrumentation and alarm system.

1.2.8. Reactor auxiliary systems:

— *Purpose, modes of operation, layout of the components, interpretation of data for determination of the operating state of the auxiliary system, possible modes of operation, effects of system operation on other reactor systems, and initiation of corrective actions in the event of malfunction in any of the following systems:*
  - *Coolant purification and degassing system;*
  - *Reactor pool cleanup and purification system;*
  - *Residual heat removal system;*
  - *Emergency cooling system;*
  - *Containment spray system;*
  - *Ventilation system for the restricted access area and associated filter systems;*
  - *Shield cooling system;*
  - *Exhaust gas system;*
  - *Nuclear closed cooling system;*
  - *Off gas system;*
  - *Sampling systems;*
  - *Fuel pool cooling and purification system;*
  - *Coolant treatment and storage system;*
  - *Wastewater collection system.*

— *Initiation criteria and manual activation of the emergency cooling and residual heat removal system, containment spray system, ventilation system for the restricted access area, and off gas system.*

1.2.9. Conventional service systems:

— Purpose, modes of operation and location of the components *of the fire extinguishing systems, air conditioning systems* *and ventilation systems; purpose of the associated instrumentation.*

1.2.10. Cooling water systems:

— Purpose, modes of operation and location of the major components of the cooling water system; *purpose of the associated instrumentation.*

1.2.11. Electric power supply systems and distribution systems:

— Purpose, modes of operation and location of the components of the electrical systems;

— *Conditions requiring use of the emergency power supply with essential power supplies and bus bars;*

— *Emergency power loads essential for safety;*

— Auxiliary power supply and important loads and connections.

1.3. Control room:

1.3.1. Control room and auxiliary control stations:

— *Physical arrangement of the control room, including the location of systems and equipment; operation of recorders and parameters recorded by control room equipment and auxiliary control room equipment;*

— *Meaning of information displayed on the reactor protection panel;*

— Diagnosis of facility conditions from instrumentation readings on the reactor protection panel; purpose and location of the auxiliary control panels, including the supplementary control room; auxiliary control panel for experiments.

1.3.2. Control room engineering:

— *Meaning of displays, signals, codes and actuation equipment, and their association with respective systems or components;*

— *Meaning and operating conditions of key operated switches;*

— *Malfunctions of control room equipment and corrective actions;*

— *Operation and meaning of the annunciation system.*

1.3.3. Computer systems:

— Safety significant tasks of the computer systems at the research reactor;

— Interface of the computer systems with the rest of the facility;

— Interpretation of computer logs.

2. Facility operation:

2.1. Facility control:

- *Startup and shutdown of the reactor from various initial conditions, and operation at power in compliance with operating requirements;*
- *Operating transients and research reactor behaviour;*
- *Important data for startup and shutdown;*
- *Effect of changes in secondary side operating parameters on primary side operation;*
- *Critical heat flux;*
- *Operating procedures for individual systems, including surveillance and testing;*
- *Interpretation of and changes in data to determine the status of the research reactor, including detection of malfunctions in individual systems;*
- *Interpretation of signals that indicate system malfunctions and incidents; automatic actions that occur and possible manual actions;*
- *In service inspection of safety systems (and scope and dates of inspection);*
- Operation and monitoring of air locks and the ventilation system;
- *Operation of fire extinguishing equipment and respirators, and other firefighting measures; operation of the fire protection panel in the control room;*
- *Responsibilities of shift personnel in handling fuel elements during refuelling and critical experiments;*
- Prescribed measures in respect of the discharge of liquid and gaseous effluents.

2.2. Core management:

- *Core management programme, including core operation and monitoring;*
- *Refuelling process and refuelling programme;*
- *Handling and storage of fresh and irradiated fuel;*
- *Fuel handling facilities and procedures.*

2.3. Abnormal operating events:

2.3.1. Malfunctions of important facilities:

- *Identification, consequences and measures to be taken in the event of malfunctions of the following:*
  - *Circulation pumps;*
  - *Intermediate (closed) cooling system;*

- *Reactor control system;*
- *Reactor protection system;*
- *Reactor cooling system;*
- *Instrumentation;*
- *Means of confinement or containment isolation for the reactor;*
- *Radiation monitoring systems;*
- *Vents, drains and sumps containing radioactive material;*
- *Reactor auxiliary systems;*
- Coolant purification system;
- Emergency cooling and residual heat removal systems;
- Ventilation systems in areas of controlled access;
- Off gas system;
- Conventional service systems;
- *Cooling water systems;*
- *Emergency power supply systems and essential power supply bus bars.*

2.3.2. Anticipated operational occurrences and incidents:

— *Determination of the status of the research reactor with focus on subcriticality and removal of residual heat from the reactor core.*

— *Verification of the performance of safety systems.*

— Necessary measures for ensuring long term subcriticality and removal of residual heat from the reactor core.

— Interaction of various safety systems during anticipated operational occurrences and incidents.

— Manual actions during anticipated operational occurrences and incidents.

— *Identification and development of sequences leading to malfunctions and incidents and their effects on reactor operation, the facility and the environment.*

— Methods used for the determination of causes of incidents.

— Interpretation of annunciators and recorded data for the identification of causes of anticipated operational occurrences and incidents.

— Measures for elimination of the causes of incidents; minimization of effluents released; application of incident related procedures.

— *Abnormal sequences in operation and incidents that have occurred at the research reactor.*

- *Reactivity related incidents: malfunctions causing reactivity addition, unintentional withdrawal of the highest worth control element, the highest worth effective group or the bank of control elements in various operating states.*
- *Dropping out or ejection of a control element owing to malfunctions in power control.*
- *Malfunctions in heat removal: reduced cooling of the reactor core, failure of the heat sink, failure of the heat exchanger.*
- *Loss of coolant: loss of reactor coolant inside the reactor containment or means of confinement, rupture of a pipe containing reactor coolant, leakage from the reactor coolant pressure boundary and breakage of connecting pipes, malfunctions of valves, and loss of reactor coolant to adjacent systems.*
- *Other malfunctions: activation of alternative shutdown measures following failure of the protection system.*
- *Failure of the emergency power supply (short term and long term).*
- Incidents in the handling and storage of fuel elements.
- Incidents involving experiments and their effects on the research reactor.

2.3.3. Unforeseen event sequences:

- Design limits of components and systems important to event sequences and the safety of the research reactor, such as the reactor tank, heat exchangers, emergency core cooling systems, residual heat removal systems, and containment or means of confinement;
- The basis of protection to maintain subcriticality, to maintain coolant over the core, to ensure heat removal from the reactor cooling system, to ensure the confinement of radioactive material and to maintain the auxiliary power supply;
- The facility specific data ranges (safety parameters) that show that the basis of protection is met;
- The functions (safety functions) that provide the basis of protection — such as reactor scrams, emergency core cooling, containment isolation or isolation of the means of confinement — and conditions that could affect their effectiveness;

— Identification of incipient core damage, such as by means of core outlet temperatures and radioactivity in the primary system;
— Identification of limits (safety parameters) that, when exceeded, challenge the basis of protection and are indicative of failures or an ineffectiveness of safety functions, such as limits on neutron flux measurements, reactor vessel coolant level, reactor coolant outlet temperatures, fuel element temperature, main steam pressure, exhaust air activity and voltage of emergency bus bars;
— Acceptable substitutes for the safety functions important to the basis of protection;
— Use of substitute safety functions when critical states have been identified and primary safety functions have failed or are degraded.

2.4. External events:
— Identification of and measures to be taken in the case of external events (e.g. flooding, earthquake, aircraft crash, explosion, toxic or explosive gases in the environment).

2.5. Radiation protection and monitoring:
— Use of radiation monitoring instruments for individual monitoring and workplace monitoring;
— Arrangements for individual monitoring at the point of access to the restricted area;
— Functional modes and *use of the radiation monitoring instruments by shift personnel;*
— Identification of exclusion areas and provisions for access to them;
— Radiation protection measures when working on experiments;
— *Monitoring of levels of radiation, of airborne radioactive material and of effluents from exhaust systems.*

2.6. Environmental monitoring:
— Instruments for environmental monitoring (e.g. of liquid waste, gaseous effluents or meteorological data) and displays or alarms in the control room;
— Measures to be taken in the event of increasing activity in liquid waste or gaseous effluents, or in the activity of airborne radioactive material discharged via the research reactor stack.

2.7. Research reactor chemistry:
— Monitoring of the chemistry of various systems.

2.8. Access control:

- Control of access of shift personnel to individual buildings or compartments.

3. Administrative requirements:

3.1. Conditions imposed and directives issued by the authorities:

- Conditions imposed and directives issued with regard to shift operation (authorized limits in the licence, reactor protection limits and boundary conditions for operation);
- Measures in the event of violation of operational limits and conditions.

3.2. Operating manual:

- *Structure, contents and use of the operating manual, including safety specifications, additional plans, drawings and descriptions;*
- Surveillance of items important to safety in accordance with the inspection manual.

3.3. Organization of operation:

3.3.1. Control room and shift duty rules:

- *Safety culture;*
- *Mandatory documentation;*
- *Reactor log book content;*
- *Scope of duties of operating personnel on shift;*
- *Powers and authorities within a shift;*
- *Powers and authorities of senior management, other managers and radiation protection officers with respect to personnel on shift.*

3.3.2. Alert plans:

- *Alarms and alarm equipment at the research reactor;*
- *Identification of and response to alerts;*
- *Conditions and responsibilities for initiation of an alarm;*
- Notification of standby personnel and authorities.

3.3.3. Other operating rules:

- Details, duties and responsibilities of shift personnel for rules concerning *maintenance instructions and radiation protection instructions;*
- Security guard instructions and access instructions;
- First aid instructions;
- Fire safety instructions.

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