IAEA Safety Standards

for protecting people and the environment

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

Safety Guide

No. NS-G-4.5

IAEA

International Atomic Energy Agency

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".

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

SAFETY GUIDE

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Sales and Promotion, Publishing Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
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FOREWORD

by Mohamed ElBaradei
Director General

The IAEA's Statute authorizes the Agency to establish safety standards to protect health and minimize danger to life and property — standards which the IAEA must use in its own operations, and which a State can apply by means of its regulatory provisions for nuclear and radiation safety. A comprehensive body of safety standards under regular review, together with the IAEA's assistance in their application, has become a key element in a global safety regime.

In the mid-1990s, a major overhaul of the IAEA's safety standards programme was initiated, with a revised oversight committee structure and a systematic approach to updating the entire corpus of standards. The new standards that have resulted are of a high calibre and reflect best practices in Member States. With the assistance of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its safety standards.

Safety standards are only effective, however, if they are properly applied in practice. The IAEA's safety services — which range in scope from engineering safety, operational safety, and radiation, transport and waste safety to regulatory matters and safety culture in organizations — assist Member States in applying the standards and appraise their effectiveness. These safety services enable valuable insights to be shared and I continue to urge all Member States to make use of them.

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

The IAEA takes seriously the enduring challenge for users and regulators everywhere: that of ensuring a high level of safety in the use of nuclear materials and radiation sources around the world. Their continuing utilization for the benefit of humankind must be managed in a safe manner, and the IAEA safety standards are designed to facilitate the achievement of that goal.

EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was developed under the IAEA programme for safety standards for research reactors, which covers all the important areas of research reactor safety. The Fundamental Safety Principles publication [1] establishes principles for ensuring the protection of workers, the public and the environment. Five of these principles[1] are directly addressed in this Safety Guide, which recommends how to meet, supplements and elaborates upon the safety requirements for the operating organization and for the recruitment, training and qualification of personnel that are established in paras 7.1–7.28 of the IAEA Safety Requirements on the Safety of Research Reactors [2].

1.2. Guidance on carrying out safety analyses and preparing the relevant documentation for research reactors is provided in Ref. [3]. Additional guidance on the safe operation of research reactors is provided in Ref. [4]. The specific recommendations provided in these two publications on the operating organization and on recruitment, training and qualification of personnel have been taken into account in this Safety Guide.

1.3. Two further IAEA Safety Standards Series publications have been used in the preparation of this Safety Guide, namely, those on The Operating Organization for Nuclear Power Plants [5] and on Recruitment, Qualification and Training of Personnel for Nuclear Powers Plants [6]. Many of the

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[1] These are principles 1, 2, 3, 8 and 9 (see Ref. [1]):

Principle 1: “Responsibility for safety: The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.”

Principle 2: “Role of government: An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.”

Principle 3: “Leadership and management for safety: Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.”

Principle 8: “Prevention of accidents: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.”

Principle 9: “Emergency preparedness and response: Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.”

recommendations provided in these Safety Guides are also applicable to research reactors, particularly research reactors with large operating organizations that support extensive operation and utilization programmes.

1.4. The overriding consideration in developing this Safety Guide was that the safe operation of research reactors requires an operating organization with an appropriate organizational structure that is clearly specified, and that is staffed with competent managers and qualified personnel who have a deep awareness of the technical and administrative requirements for safety and who support a strong safety culture.

1.5. This Safety Guide draws on hundreds of reactor-years of operating experience and on the best practices of the international research reactor community.

OBJECTIVE

1.6. The objective of this Safety Guide is to provide general guidance both on meeting the requirements on the operating organization of a research reactor and on the recruitment, training and qualification of personnel on the basis of international best practices. Specific arrangements for different reactor types and different operating situations may be derived from this general guidance. The target audience for this Safety Guide includes senior managers of organizations responsible for the planning and operation of research reactor facilities, regulatory bodies, other persons involved in research reactor operation, and those involved in educational programmes on nuclear science and technology.

SCOPE

1.7. This Safety Guide describes the typical organization of research reactor facilities. While the organization for decommissioning of a research reactor may differ from that for the operational phase, the guidance provided in this publication related to the responsibilities of the operating organization and the establishment of a management system and effective communication system within the operating organization is also applicable to the decommissioning phase. The scope of this Safety Guide also covers the recruitment process and the qualifications to be required in terms of education, training and experience; the initial training programme and continuing training programme; the authorization process for individuals whose duties have an immediate bearing on safety; and the process involved in the requalification and reauthorization of such individuals. The focus is mainly on research reactors having power levels of up to a few tens of megawatts. The level of detail in the organizational structure and staffing may therefore be substantially reduced for low power research reactors and for reactors with limiting characteristics (e.g. with very low excess reactivity or a large negative temperature coefficient).

1.8. The sections on staffing in this Safety Guide focus mainly on the training of operating personnel, including the reactor manager, reactor supervisor, shift supervisors, reactor operators, radiation protection personnel and maintenance personnel, but also include recommendations for the training of other facility personnel such as support personnel[2] and reactor users.

1.9. Research reactor facilities demonstrate a wide variety of designs, a wide range of power levels, different modes of operation and uses, differences in siting and differences in operating organizations. This variety of characteristics means that recommendations can only be stated in general terms; their implementation will require some flexibility, in particular when dealing with the organizational structure of the reactor operating organization and its staffing with competent personnel.

1.10. While all recommendations in this Safety Guide should be considered for application to any research reactor, a graded approach should be used. An organizational structure and staffing that are acceptable for a low power research reactor with limiting characteristics will be very different from those acceptable for a reactor with an intermediate or high power level. For these reasons, the recommendations in this Safety Guide should be graded[3] for their applicability to any particular research reactor (see Ref. [2], paras 1.11–1.14). Depending on the complexity of the design, the hazard potential and the planned use of the reactor, grading may be of assistance in determining the required levels of education for the various staffing positions, the contents and the duration of the initial training and continuing training, and the nature of the assessment on completion of the training.

[2] Support personnel are operating personnel other than the reactor manager and the reactor operating personnel.

[3] The recommendations should be graded, for example, by considering — using sound engineering judgement — the safety and operational importance of the topic, and the maturity and complexity of the area of research involved.

STRUCTURE

1.11. This Safety Guide consists of six sections and two annexes. Section 2 describes the organizational structure and the duties and responsibilities of the staff, and briefly summarizes the organizational considerations that determine the staffing recommendations for research reactor facilities. These recommendations form the basis for the specification of the required qualifications and of the prerequisites for the recruitment of individuals. Section 3 provides guidance on the factors to be taken into account in the recruitment and selection process. Section 4 provides guidance on the knowledge and experience that operating personnel in various positions (such as reactor operators, senior reactor operators and shift supervisors) are required to have, and describes training systems and training programmes, including continuing training and requalification, that may be used to ensure that operating personnel meet these requirements. Factors that should be considered for the training and qualification of support personnel are also presented. Section 5 deals with authorization and reauthorization of reactor operators by the operating organization and the regulatory body. Section 6 deals with the maintenance of training records.

1.12. Annex I contains an explanation of the systematic approach to training (SAT)[4]. Annex II presents an example of a training curriculum covering the main topics for the initial training and continuing training of reactor operators and senior reactor operators at a large research reactor facility.

2. THE OPERATING ORGANIZATION

GENERAL

2.1. The safety requirements on the operating organization of a research reactor facility are set out in paras 4.1–4.16 (management and verification of safety), paras 7.1–7.26 (organizational provisions) and para. 7.38 (administrative requirements) of Ref. [2]. The following requirements

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[4] The SAT is a logical progression from the identification of the competences required for performing a job to the development and implementation of training to achieve these competences, and the subsequent evaluation of this training.

excerpted from Ref. [2] are reproduced here for reference, as they form the basis for the guidance provided in this section:

> "The operating organization 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 and construction, through to commissioning, operation, utilization, modification and decommissioning. In order to ensure rigour and thoroughness at all levels of the staff in the achievement and maintenance of safety, the operating organization shall:
>
> (a) Establish and implement safety policies and ensure that safety matters are given the highest priority;
> (b) Clearly define responsibilities and accountabilities with corresponding lines of authority and communication;
> (c) Ensure that it has sufficient staff with appropriate education and training at all levels;
> (d) Develop and strictly adhere to sound procedures for all activities that may affect safety, ensuring that managers and supervisors promote and support good safety practices while correcting poor safety practices;
> (e) Review, monitor and audit all safety related matters on a regular basis, implementing appropriate corrective actions where necessary;
> (f) Be committed to safety culture on the basis of a statement of safety policy and safety objectives which is prepared and disseminated and is understood by all staff" (Ref. [2], para. 4.1).
>
> "The operating organization shall establish an appropriate management structure for the research reactor and shall provide for all necessary infrastructures for the conduct of reactor operations. The organization for reactor operation (the reactor management[27]) shall include the reactor manager and 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 inspection, periodic testing and maintenance, radiation protection, quality assurance and relevant support services" (Ref. [2], para. 7.1).

"[27] The reactor management comprises the members of the operating organization to whom the responsibility and the authority for directing the operation of the research reactor facility have been assigned."

> "The operating organization shall have the overall responsibility for the safety of the research reactor, which shall not be delegated. The reactor manager shall have the direct responsibility and the necessary authority for the safe operation of the research reactor. However, the regulatory body shall retain the authority to prohibit certain activities or to require their reconsideration if it so considers. A system for reviewing and reporting abnormal occurrences shall be established" (Ref. [2], para. 7.2).

> "The operating organization shall assign direct responsibility and authority for the safe operation of the reactor to the reactor manager. The primary duties of the reactor manager shall comprise the discharge of this responsibility … The reactor manager shall have overall responsibility for all aspects of operation, inspection, periodic testing and maintenance, and utilization and modification of the reactor" (Ref. [2], para. 7.11).

2.2. For the purpose of this Safety Guide, the term 'operating organization' is used to designate an academic institution, corporation, institute, centre, national laboratory or other entity that is authorized by the appropriate authority of the State to operate a research reactor and to be responsible for its safety. In accordance with the legal system 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 may arise in connection with the operation of the research reactor. The individual serving in the position generically termed 'reactor manager'[5] may hold the title of department head, centre director or any of various other titles.

2.3. The senior management of the operating organization should take an active interest in and should participate in supervising overall 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 reactor personnel, and should therefore maintain close oversight of operations.

[5] The reactor manager is the single member of the reactor facility management who has been delegated direct responsibility and authority by the operating organization for the operation of the reactor and whose duties consist primarily in the discharge of this responsibility.

2.4. The operating organization is authorized to operate a research reactor through the licensing system in accordance with the national regulations. More information on the authorization and licensing of operating organizations is provided in section 5 of Ref. [7]. 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.

2.5. The function of a research reactor operating organization is to support an effective utilization programme. Experimenters and other users of research reactors are frequently 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, and for training of experimenters and other users in the safe design, construction, installation, operation, utilization and modification of experimental facilities.

ORGANIZATIONAL PLAN

2.6. Relevant requirements for the organizational plan are established in paras 7.3, 7.12, 7.13 and 7.16 of Ref. [2].

2.7. The operating organization should examine the various functions necessary for safe operation of the reactor, and should assign authority and responsibility to the appropriate internal organizational position or should make arrangements for external support personnel to perform the designated tasks or programmes.

2.8. On the basis of its examination and all applicable regulatory requirements, the operating organization should prepare a written organizational plan that specifies 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 necessary for safe operation of the reactor and their required qualifications. In preparing the organizational plan, the operating organization should take into account both operational states and accident conditions. 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 reactors. The safety committee (see para. 2.24 of this

Safety Guide) should review the initial organizational plan and any significant changes to the plan.

2.9. 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 for the required organization can be completed as necessary for the commissioning stage and, in all cases, before the commencement of routine operation. The organizational plan should form the basis for the initial recruitment and training programme and for all subsequent recruitment and training programmes.

2.10. The organizational plan should provide for the preparation of individuals for promotion to each key position to ensure a smooth transition without a detrimental loss of institutional knowledge when key individuals leave the organization.

STRUCTURE OF THE ORGANIZATION

2.11. The factors that should be considered in determining the organizational structure and staffing of a research reactor operating organization include, but are not limited to, the following:

(a) The need to ensure that all levels of the defence in depth concept are properly implemented[6];

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[6] The International Nuclear Safety Group (INSAG) defines five levels of defence in depth:

- Level 1: Prevention of abnormal operation and failures;
- Level 2: Control of abnormal operation and detection of failures;
- Level 3: Control of accidents within the design basis;
- Level 4: Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of a severe accident;
- Level 5: Mitigation of the radiological consequences of significant external releases of radioactive material.

(b) The need to ensure that structures, systems and components (SSCs) important to safety[7] remain in accordance with their design assumptions and intent;
(c) The need for radiation protection measures and related 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[8], and to contain the radioactive material in all operational states and in design basis 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 plans for the research reactor with those of the regulatory body, public authorities and other organizations that may be required to take actions in response to an emergency;
(h) The need to minimize and control radioactive releases and to provide for environmental monitoring;
(i) The need to control access to the reactor and to certain areas on the site to ensure radiological safety and to protect individuals and the reactor against actions that could jeopardize safety;
(j) The need to conduct activities affecting items important to safety in accordance with the requirements of the management system, including the need to verify whether activities have been performed as specified;
(k) The need for emphasis on training and retraining of personnel to achieve and maintain adequate levels of competence, and to promote a strong safety culture in the organization;

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[7] An item important to safety is an item that is part of a safety group and/or whose malfunction or failure could lead to radiation exposure of site personnel or members of the public. Items important to safety include:
- Those SSCs whose malfunction or failure could lead to undue radiation exposure of site personnel or members of the public;
- Those SSCs that prevent anticipated operational occurrences from leading to accident conditions;
- Those features that are provided to mitigate the consequences of malfunction or failure of SSCs.

[8] Experimental devices are devices installed in or around the reactor to utilize neutron flux and ionizing radiation from the reactor for research, development, isotope production or certain other purposes.

(l) The need to consider all organizational factors that could affect human performance, so that work can be carried out 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 the requirements of the regulatory body, to be in a position to make proposals for meeting the 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 activities such as fuel management, reactor chemistry control, in-service inspection, and monitoring and improvement of the performance of the 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 research objectives.

2.12. In addition, the organizational structure should be such as to ensure the following:

(a) That technical services and expertise, including those required for emergencies, 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 use.

2.13. The document describing the reactor's organizational structure should indicate the staffing arrangements in the categories of operating personnel and support personnel[9]. Clear lines of authority should be established to deal with matters having a bearing on safety. The extent to which support functions are self-sufficient or are dependent on services from outside the operating organization should be specified in functional organizational plans. Such organizational plans should specify human resource allocations and the duties and responsibilities of key personnel.

2.14. The description of the organizational structure and of the functions to be performed, as well as of the lines of responsibility, authority and communication, should be clear and unambiguous. This description should be included in the safety analysis report and in the documentation of the management system. Functions to be performed by external organizations or consultants should be indicated in the description, together with the relevant lines of communication and authority. This description is often included in the section of the operational limits and conditions that establishes administrative requirements. Activities undertaken by the reactor facility management (referred to as the organization for reactor operation) should be subject to approval by the regulatory body in accordance with national practices.

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[9] Personnel are:

Direct operating personnel: Those persons reporting to the reactor manager having direct responsibility for the safe day to day running of the facility assigned to them by the operating organization. Included are the reactor supervisor, shift supervisor, senior reactor operator and reactor operator.

Operating personnel: Individual workers engaged in the operation of an authorized facility. Operating personnel in a research reactor facility include the reactor manager, reactor supervisor, shift supervisors, senior reactor operators, reactor operators, maintenance staff and radiation protection staff (see also direct operating personnel and support personnel).

Operator: Any organization or person applying for authorization or authorized and/or responsible for nuclear, radiation, radioactive waste or transport safety when undertaking activities, or in relation to any nuclear facilities or sources of ionizing radiation. This includes, inter alia, private individuals, governmental bodies, consignors or carriers, licensees, hospitals and self-employed persons.

Reactor management: See footnote 27 to para. 2.1 of this Safety Guide.

Reactor manager: See footnote 5.

Site personnel: All persons working in the site area of an authorized facility, either permanently or temporarily.

Support personnel: See footnote 2.

2.15. The response time for obtaining services from off-site sources should be taken into account when determining the structure of the organization, in particular for a research reactor sited at a remote location. In this case, the on-site organization should be capable of rendering all services that may be necessary immediately.

2.16. Descriptions of positions or equivalent procedural guidance should be used to supplement the organizational chart. Descriptions of positions should clearly define the authorities and responsibilities of and the competences necessary for each position within the reactor organization. The descriptions of key positions may include deputizing arrangements for periods when the incumbent is not available. A brief description of the key positions (e.g. reactor manager, senior reactor operator, reactor operator, radiation protection officer, reactor maintenance personnel) and their deputizing arrangements is often included in the section of the operational limits and conditions that establishes administrative requirements.

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

2.18. Proposed changes to staffing levels, ways of working or the organizational structure should be subject to analysis and independent review. 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 section of the operational limits and conditions that establishes administrative requirements.

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

2.20. The operating organization should provide for adequate training and retraining of those operating personnel whose positions require an authorization[10] in accordance with national regulations and the requirements of the regulatory body. In particular, the reactor manager and designated operating personnel should hold authorizations issued by an appropriate authority. Operating personnel that should hold authorizations may include the reactor manager, the reactor supervisor, shift supervisors, senior reactor operators and reactor operators, as appropriate. For higher level positions (e.g. the facility director), an authorization may be required if the incumbent will be expected to operate the reactor.

2.21. The operating organization should review each management function discussed in paras 2.52–2.68 of this Safety Guide and should ensure that each function is adequately addressed and staffed. Special consideration should be given to ensuring that the reactor manager has the necessary authority over internal and external support personnel and experimenters performing activities relating to safety.

2.22. 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 supporting services. Examples of functions of supporting services that may be available to a research reactor facility include, but are not limited to, 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 review of safety management;
(g) Core management and fuel handling, including arrangements for procurement;
(h) Design, construction and commissioning of major modifications.

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[10] Authorization is the granting by a regulatory body or other governmental body of written permission for an operator to perform specified activities. Authorization could include, for example, licensing or registration. The term authorization is also sometimes used to describe the document granting such permission. In some Member States an authorization is referred to as a licence or a certificate.

Note that in some cases, such as for radiation protection and for emergency preparedness, a research reactor facility should have its own plan, which may also be part of the plan for the entire institute or centre and may make use of services provided by the institute or centre.

2.23. The operating organization should ensure that the separate operation management programmes discussed in paras 2.70–2.96 are integrated with each other to ensure the safe operation and utilization of the research reactor. In order for the coordinated activities to contribute to safety and to assist in the prevention or resolution of conflicts, this integration should be undertaken throughout the reactor organization under the direction of persons in designated positions of authority (e.g. reactor manager, reactor supervisor). The safety committee should review all such proposed management programmes.

2.24. A safety committee for reviewing the safety of reactor operations, including modifications to the reactor and to operating procedures and the experimental programme, should be included in the organizational plan. There should be a written charter that defines the function, composition and communication channels of the safety committee. The safety committee should be advisory to the operating organization. The chairperson of the 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 making up a quorum at the meetings of the safety committee should be from outside the line of control of the reactor manager. The safety committee should be consulted in preparing the organizational plan for the reactor. For requirements in respect of the safety committee, see paras 4.15, 7.18, 7.25 and 7.26 of Ref. [2]. Minimum requirements for the safety committee are often included in the section of the operational limits and conditions that establishes administrative requirements.

COMMUNICATION

2.25. Management should encourage and foster effective communication between all levels of the operating organization. Downward communication should clearly explain management's objectives and expectations; upward communication should facilitate the communication of problems to management and their identification; and horizontal communication should support effective coordination of work and collaboration.

2.26. Effective means of communication should be put in place to assist in the understanding of safety policy and the implementation of an effective management system for safety. Through communication, personnel should be able to understand why particular standards of safety are required and to accept these standards of safety. 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, both in normal operation and in emergencies. Horizontal communication should be fostered to establish open lines of communication between interacting groups that work together in performing specific functions.

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

2.28. In addition to good communication within the operating organization, good communication should be established with external organizations (e.g. 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 put in place. External communication should take into account the broader social framework within which the organization operates, and a constructive dialogue should be maintained with the representatives of groups affected by the activities of the operating organization and with other interested parties.

RESPONSIBILITIES

Responsibilities of the operating organization

2.29. The operating organization should be structured so as to facilitate the discharge of its responsibilities as follows:

(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 with a view to achieving proper management and minimizing interface problems.
(b) Ensuring that the previously established decision making process gives adequate consideration to the selection of priorities and the organization of activities.
(c) Establishing safety policies, limits and requirements to effectively implement a management system for safe operation (see paras 2.52–2.68 of this Safety Guide) and verifying their effectiveness.
(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, addressing physical and mental fitness and aspects such as the use of drugs or tobacco and alcohol abuse, in accordance with national regulations. This policy should apply to all employees, contractors, experimenters and other users, as applicable. Similar provisions should be incorporated into the policy for access of visitors to the facility.
(g) Liaising with design, construction, commissioning, manufacturing and other organizations involved with the research reactor, to ensure proper transfer and understanding of the reactor design intent and assumptions, information and experience.
(h) Liaising with public authorities and the regulatory body for the purposes of understanding and ensuring compliance with regulatory requirements.
(i) Providing adequate information for the purposes of liaison with the public.
(j) Ensuring the collection, evaluation, implementation and dissemination of operating experience.

The documentation describing the operating organization should include statements of these responsibilities.

2.30. The overall responsibility for the safety of a research reactor is required to rest with the operating organization. The operating organization is responsible for establishing safety criteria and for ensuring that the design, construction, commissioning, operation and decommissioning of the research reactor meet the safety criteria. In addition, it is responsible for the establishment of procedures and arrangements to ensure control of the reactor in all operational states and to the extent possible in accident conditions, for the establishment and maintenance of competent and motivated personnel, and for control of the fissile material and radioactive material utilized or generated. The discharge of these responsibilities should be in accordance with the safety objectives and requirements established or approved by the regulatory body.

2.31. The operating organization should be structured with clear lines of authority and communication and with well defined responsibilities. Its safety and security policies should be understandable to and applied by all personnel. However, the assignment of tasks should not reduce or divide the overall responsibility for safety, which must always lie with the operating organization. The operating organization should therefore remain in a supervisory position for delegated tasks.

2.32. 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 having a bearing on safety.

2.33. The operating organization should foster a working environment in which safety and also security are seen as vital factors and matters of personal accountability for all 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. Management at all levels should promote the consistent application of safety standards.

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

2.35. The operating organization delegates authority for operation to the management of the research reactor facility (the organization for reactor operation), which has direct day to day control of the facility. The operating organization should monitor the effectiveness of the organization for reactor operation and should take any necessary measures to ensure that safety is maintained at the levels established by the design, construction and commissioning of the facility and approved by the regulatory body.

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

2.37. The operating organization should include an adequate number of personnel who possess the knowledge, training and skills necessary to supervise and evaluate the work of contractor personnel and temporary personnel. Supervision of contractor personnel should be the responsibility of the reactor manager. Members of the operating organization who supervise contractors or other temporary personnel should be clearly specified. The operating organization should ensure that contractors and temporary personnel who conduct activities on SSCs important to safety are qualified to perform their assigned tasks. Documented assurance should be obtained that contractors have the required qualifications prior to their involvement in these activities.

2.38. A wide range of contractual arrangements between the operating organization and suppliers is possible, from individual procurement to a turnkey contract. For procurement, the operating organization has a major task and will need the resources to accomplish it. The operating organization should assign knowledgeable and skilled personnel in the pre-operational stage to perform this task. For turnkey contracts, the supplier plays a more wide ranging 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 SSCs of the reactor, it should assign a sufficient number of knowledgeable and skilled personnel in the pre-operational stage. 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 normal operating procedures and emergency operating procedures.

2.39. The safety of the research reactor is subject to review, assessment and surveillance by a regulatory body that is required to be independent of the operating organization. For the achievement of the common objective of the regulatory body and the operating organization, namely, the safe operation and use of the research reactor, there should be a mutual understanding and respect that supports a frank and open, yet formal, relationship. Further recommendations on the role of the regulatory body in review and assessment are provided in Refs [3, 8].

2.40. The operating organization should develop and implement a procedure for reporting to the regulatory body all incidents of significance to safety, in accordance with established criteria. These criteria are often included in the section of the operational limits and conditions that establishes administrative requirements. The operating organization should also submit or make available to the regulatory body documents and other information, in accordance with the regulations and requirements. The operating organization should establish complementary programmes for the analysis of operating experience to ensure that lessons are learned and acted upon. Such experience should be shared with relevant national and international bodies. These programmes should be in compliance with the requirements of the regulatory body.

Responsibilities of the reactor manager and other operating personnel

2.41. The operating personnel consist of the reactor manager and other individuals involved in the operation, maintenance and, in some cases, use of the reactor. Their responsibilities include, inter alia, implementation of the safety policy of the operating organization, establishment and fostering of a safety culture, and control and verification of safety related activities. Only those operating personnel who hold an appropriate licence or authorization may manipulate the reactor controls.

2.42. The reactor manager has direct responsibility for all aspects of the operation, utilization and modification of the reactor. In discharging this responsibility, the reactor manager should also be responsible for the overall coordination of technical support functions, irrespective of whether they are performed by site personnel or by personnel from other organizational units of the operating organization or of external organizations. The reactor manager is responsible for the qualification (including adequate initial training and continuing training) of the operating personnel.

2.43. The reactor manager should establish performance standards and management expectations for all activities relating to safe operation and utilization of the reactor, and should effectively communicate these standards throughout the operating organization.

2.44. The reactor manager is responsible for ensuring compliance with the requirements of the operating organization and the regulatory body. In addition, the reactor manager may be involved in providing technical information about the reactor to potential experimenters and other users, in public information activities and in maintaining relationships with local authorities.

2.45. To improve performance, the reactor manager and, where relevant, senior managers in larger reactor operation organizations should recognize, and help to meet, the need to develop the managerial and technical skills of all individuals involved in activities relating to the reactor facility. Adequate funds should be made available by the operating organization for the development and implementation of programmes to improve managerial and technical skills.

2.46. The reactor manager should set performance standards and expectations for the operating personnel in all aspects of the safe management of the reactor. In addition, managers themselves should meet these performance standards and should explain to the personnel why they are appropriate.

2.47. In assigning responsibilities for safety, managers should ensure that the individuals to whom responsibilities are assigned have the capabilities and the resources to discharge their responsibilities effectively. Managers should also ensure that personnel are aware of and accept their responsibilities for safety. Individuals should be aware of how their responsibilities relate to those of other individuals in the organization.

2.48. Authorized reactor operators should have the authority and responsibility to shut down the reactor if necessary for safety.

2.49. Managers should be responsible for the safety of all operations under their control. The structure of the organization should reflect this accountability of line managers for safety. However, the management structure should also reflect the specific requirements of the organization. The roles, responsibilities and authorities of managers of units within the organization for reactor operation should be clearly specified and should be compatible with each other.

2.50. Personnel external to the organization for reactor operation that provide a service or provide advice should have no direct authority over reactor personnel, although such external personnel may be personally or professionally responsible for the quality of the service or advice that they give. Operating personnel should first give careful consideration to any specialist advice provided and to any particular aspects before making any decisions.

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

MANAGEMENT SYSTEM

2.52. The operating organization is required to establish and implement an integrated management system to ensure quality in all activities that may have an influence on the safe operation of the reactor [9]. Safety requirements for the management system are established in Refs [2, 9], and guidance on implementing the requirements is provided in Ref. [10]. The content of documents describing the management system should be made available to the regulatory body, as required.

Management responsibility

2.53. 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 and to achieve and maintain acceptable levels of safety. It is the management's responsibility to recognize the safety significance of the organization's activities. Safety objectives, concepts and principles are considered in section 2 of Ref. [2], and requirements for the management and verification of safety are established in section 4 of Ref. [2].

2.54. The management system should include such organizational elements as: the definition of the safety policy; identification of the main responsibilities within the 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 should provide for monitoring of the implementation of management plans and should foster continuous improvement in safety performance on the basis of lessons learned at the reactor facility and at other reactor facilities. In addition, the management system should provide the framework that will enable individuals conducting activities at the reactor to carry out their tasks safely and successfully.

2.55. To maintain effective management of safety at the reactor, the operating organization should ensure that there is commitment to safety by all personnel. The starting point for effective management of safety is the involvement of senior managers. The lead in safety matters should come from the highest levels of management. The safety policy of the operating organization and the behaviour and attitudes of senior managers should be exemplary and should permeate the operating organization at every level and extend to other organizations that perform delegated tasks. 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.

2.56. The operating organization should develop a safety policy to be implemented by all personnel in the operating organization. The safety policy should demonstrate the organization's commitment to a high level of safety and should be supported with reference to safety standards, the setting of targets and the provision of the resources necessary to attain these targets.

2.57. The safety policy should give priority to safety, overriding, when necessary, the demands of schedules for operation and use of the reactor. The policy should require a commitment to excellence in all reactor activities important to safety and should encourage a questioning attitude and a rigorous and prudent approach to all safety related activities. The formal statement of the safety policy should be documented and made available to the regulatory body and to interested parties (including the public), as necessary.

2.58. The safety policy should be endorsed and actively supported by senior managers, who should be involved in disseminating the policy throughout the organization. All personnel in the organization should understand the safety policy and should be aware of their function in ensuring that safety is maintained.

Resource management

2.59. The operating organization should ensure that adequate resources are made available to implement the safety policy. This should include maintaining the reactor in a safe operational state and providing the necessary tools and equipment and a sufficient number of competent personnel (supplemented as necessary by consultants or contractors, including the reactor vendors). In particular, sufficient resources should be made available for carrying out the activities at the reactor facility in a safe manner, so that undue physical or mental stress on individuals is avoided.

Process implementation

2.60. Safety related activities should be properly planned to ensure that they can be carried out safely and effectively. Suitable analysis of the possible effects on health and safety that may arise from particular activities should be carried out. The nature of the assessment will depend on the importance to safety of the activity and may be qualitative or quantitative. The purpose of the assessment 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(s) for review).

2.61. Arrangements should be put in place to ensure that safety related activities are adequately controlled. The level of control should depend on the safety significance of the task. A specially authorized person, such as the reactor operator or a qualified maintenance worker, may be required to carry out safety significant tasks. In addition, certain critical activities such as conducting tests and experiments should be authorized in advance and should involve the use of a work permit system. Personnel who are to carry out an activity that is performed infrequently may require retraining prior to performing the activity. Other control measures may include the use of hold points and verification stages for complex tasks.

2.62. All safety related activities should be carried out in accordance with approved procedures. The procedures should define how the activity should be carried out and, where appropriate, should identify the steps to be taken in the event of an abnormal occurrence. The procedures should be issued and controlled in accordance with the organization’s management system.

2.63. Proposed reactor repairs and modifications (including organizational changes) should be thoroughly planned. The operating organization should establish a procedure to ensure that any change is categorized on the basis of its safety significance prior to its implementation. This procedure should ensure compliance with the operational limits and conditions, and with applicable codes and standards. Additional guidance is provided in Ref. [4].

2.64. Procedures should be prepared for situations that fall 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 the safety implications of the situation. An emergency plan with procedures for its implementation should be prepared. These procedures should cover on-site and, where necessary, off-site responses, including the timely notification of appropriate government, regulatory and support organizations.

Measurement, assessment and improvement

2.65. The safety performance of the operating organization should be periodically monitored to ensure that safety levels are 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 learned from the organization's own experience and from that of others are implemented. The structural and management features of the organization should be taken into consideration when monitoring and assessing the safety performance of the organization for reactor operation. 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:

(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 accommodate new or revised safety standards and requirements after determining their implications for the safety analysis of the reactor;
(d) To provide input to ageing management studies.

2.66. The operating organization should provide a means for independent safety review. Key to this process is the establishment of a self-evaluation programme supported by periodic external reviews conducted by experienced peers.[11] The principal objective is to ensure that accountability for safety is supported by arrangements that are independent of the pressures of operation and utilization of the reactor. The external safety review should be independent of the operation of the reactor and should be conducted at a frequency sufficient to verify that the organization for reactor operation has established verifiable and authorized practices and has implemented changes as required. Particular consideration should be given to the feedback from experience. The reports containing such feedback should be formal and should be provided to the operating organization and the reactor manager. The safety review process should cover activities such as:

(a) Reviewing the safety related aspects of normal reactor operation;
(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 their safety implications;
(d) Reviewing the effectiveness of the safety management system and its implementation against international best practices;
(e) Undertaking corrective actions and/or modifications.

2.67. Procedures for safety review should be maintained by the operating organization to provide an ongoing surveillance and audit of operational safety of the reactor facility and to support the organization for reactor operation in discharging its overall responsibility for safety.

2.68. Safety reviews should be conducted in sufficient depth to ensure that all issues and questions raised are satisfactorily resolved. Activities for safety review should be performed by personnel who have the education, experience, expertise and training to allow a thorough understanding and evaluation of items reviewed. Appropriate corrective actions for deficiencies identified in the monitoring and review of safety performance should be decided upon and implemented. The progress of implementation should be monitored to ensure

[11] An example is the Integrated Safety Assessment of Research Reactors (INSARR) reviews conducted by the IAEA. For details, see INTERNATIONAL ATOMIC ENERGY AGENCY, Guidelines for the Review of Research Reactor Safety, IAEA Services Series No. 1, IAEA, Vienna (1998).

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 in the audits and reviews.

PROGRAMMES FOR OPERATION OF A RESEARCH REACTOR FACILITY

2.69. Programmes inherent to the operating organization of a research reactor facility are discussed in numerous publications. Paragraphs 2.70–2.96 below provide recommendations for these programmes. Requirements on these programmes are established in Ref. [2]. The cited references to requirements and detailed recommendations should be consulted in conjunction with the guidance presented here.

Training, retraining and qualification (see Ref. [2], paras 7.27–7.28)

2.70. The operating organization should establish a training and qualification programme to ensure that its needs are met. Only qualified persons should be entrusted with carrying out functions important to the supervision and safe operation and maintenance of the reactor. For each category of personnel, there should be the requirement to develop and maintain an appropriate competence through education, experience and formal training. A retraining and requalification programme should be established for all operating personnel. Guidance on meeting the requirements on training and retraining is provided in Section 4 of this Safety Guide.

Operations and procedures
(see Ref. [2], paras 7.10(m), 7.19, 7.20, 7.29–7.41 and 7.51–7.55, and Ref. [11])

2.71. For safe operation of the reactor, operational limits and conditions should be established that include administrative controls and requirements for operating procedures. Requirements for the review and approval of operating procedures, particularly at the management level, should be specified. 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 operational limits and conditions and operating procedures.

2.72. The operating organization should provide for the development of operating procedures that:

(a) Ensure that all activities affecting safe operation are subject to appropriate procedures (see Ref. [11] for a list of procedures);
(b) Ensure compliance with operational limits and conditions and regulatory requirements;
(c) Are written and verified by properly qualified persons in accordance with relevant management system requirements;
(d) Are written in clear and understandable language and avoid any confusion and ambiguities;
(e) Are in accordance with the design assumptions and intent;
(f) Provide sufficient detail for the qualified person assigned to perform the activity to do so without direct supervision;
(g) Are controlled and revised in accordance with the management system.

2.73. Shift turnover should follow a prescribed routine to ensure that critical information, such as reviews of logbooks and log sheets, operations in progress, equipment out of service and experiments using the reactor, is passed from one crew to another. This applies to continuous operations where one shift relieves another in a routine manner, to emergencies and to situations where one crew secures the reactor and another crew resumes operation later.

Commissioning
(see Ref. [2], paras 6.44, 7.6, 7.10(c) and 7.42–7.50, and Ref. [12])

2.74. The operating organization, in view of its role in the subsequent operational and utilization stage of the reactor, should verify that the characteristics of the reactor and experimental facilities are checked in the commissioning programme. Specifically, the commissioning programme should be such as to do the following:

(a) To confirm that the as-built reactor and experimental facilities are consistent with the design intent and the requirements as stated in the safety analysis report;
(b) To verify that the reactor meets the regulatory requirements;
(c) To demonstrate the validity of operational limits and conditions, 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 for implementing the management programmes.

Maintenance, periodic testing and inspection
(see Ref. [2], paras 6.45–6.47 and 7.56–7.64, and Ref. [13])

2.75. The maintenance programme should ensure that the level of reliability and effectiveness of all reactor SSCs important to safety remain in accordance with the current reactor safety analysis report and operational limits and conditions, and that the safety status and configuration of the reactor are not adversely affected by maintenance activities.

2.76. 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 with changes that have been appropriately incorporated into the operation of the reactor on the basis of operating experience. The programme should include evaluation and review elements for detecting degradation and ageing of SSCs that could lead to unsafe conditions. This programme should cover monitoring, checks and calibrations, testing and inspection that are complementary to in-service inspection.

2.77. In-service inspection should be carried out to determine whether the SSCs important to safety are in an acceptable condition for the continued safe operation of the reactor or whether remedial measures are necessary to remedy any deterioration. Emphasis should be placed on examination of critical systems and components such as the primary coolant system of the reactor. Safety reviews are frequently performed in conjunction with in-service inspections.

Core management and fuel handling
(see Ref. [2], paras 7.7, 7.17 and 7.65–7.70, and Ref. [14])

2.78. The core management programme should address those activities that are necessary to allow optimum operation and utilization of the reactor without compromising the limits imposed by design safety considerations. 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:

(a) The establishment of detailed specifications and management system requirements 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 emplaced 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 (see Ref. [14]);
(d) Establishment of core calculation programmes to define loading patterns for fuel, experimental devices and absorbers, for maintaining compliance with reactivity limits, temperature limits and irradiation or burnup limits;
(e) Monitoring to ensure that core parameters that are indicative of conformance with the design and with the operational limits and conditions are monitored, analysed for trends and evaluated to detect abnormal behaviour;
(f) Monitoring to verify that the integrity of the fuel cladding is maintained under all core operating conditions;
(g) Implementation of applicable requirements for the examination of irradiated fuel and use of the results for monitoring fuel performance;
(h) Verification of the startup testing methods and establishment of associated requirements for surveillance.

Fire safety (see Ref. [2], para. 7.71)

2.79. The operating organization should make provisions for ensuring fire safety on the basis of a periodic fire hazard analysis. 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; control of combustibles and ignition sources; inspection, maintenance and testing of fire protection measures; establishment of an in-house firefighting capability; training of reactor personnel; conduct of periodic fire drills; and liaison with and training of the public fire department.

Emergency planning (see Ref. [2], paras 6.48, 6.49, 7.10(e) and 7.72–7.78)

2.80. The operating organization should establish an emergency plan, and procedures for its implementation, that includes:

(a) The ability to identify and characterize emergencies;
(b) Maintenance of emergency equipment;
(c) The organizational structure and assigned responsibilities for responding to emergencies;
(d) Timely notification and alerting of emergency response personnel;

(e) Provision of the necessary information to and cooperation with the relevant public authorities.

Records and reports
(see Ref. [2], paras 7.2, 7.9, 7.10(k, l) and 7.81–7.88, and Ref. [9])

2.81. Documentation should be controlled throughout the reactor facility and the operating organization in a manner consistent with the management system. This includes the preparation, modification, review, approval, release and distribution of documents. Lists and procedures for these functions should be prepared and controlled.

2.82. A records administration and documentation system should be established to ensure the retention of all documents relevant to the safe and reliable operation of the reactor, including documents on the design, commissioning and operational history of the reactor, as well as general and specific procedures. Particular care should be taken to ensure that only correct, up to date versions of documents are available to site personnel for day to day use. Superseded versions of documents should be marked and archived. The organization for reactor operation should prepare periodic reports summarizing the operational history, modifications and utilization of the reactor for review by the safety committee and the regulatory body.

Feedback of operating experience (see Ref. [2], paras 7.2 and 7.10(o))

2.83. An effective programme for the feedback and analysis of operating experience should be established. Analytical methods should be provided, and both in-house events and events at similar facilities should be analysed to identify specific actions necessary to prevent recurrence. Events at the facility that would be of interest to the operating organizations of other research reactors should be shared with peers to prevent recurrence. The effectiveness of the programme for the feedback of operating experience should be assessed periodically to identify areas of weakness that need improvement.[12]

[12] The IAEA operates an Incident Reporting System for Research Reactors (IRSRR) 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 IRSRR facilitates worldwide feedback of operating experience. In addition, paras 6.62–6.71 of Ref. [5] provide guidance on the feedback of operating experience with nuclear power plants, and some of this guidance may also be relevant for research reactors.

Reactor utilization and modifications
(see Ref. [2], paras 6.65–6.67, 6.131–6.135 and 7.87–7.94, and Ref. [4])

2.84. The operating organization should establish a procedure to ensure proper design, review and control and implementation of all permanent and temporary modifications to SSCs and to experimental facilities. This procedure should ensure that the reactor's design basis is maintained, operational limits and conditions are observed, and applicable codes and standards are met. 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 providing for review by and obtaining the appropriate approval from the regulatory body, if required.

2.85. 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. Consideration should be given to training of personnel with respect to the change as well as its impact on operation and utilization procedures and practices.

Radiation protection
(see Ref. [2], paras 7.5, 7.10(d), 7.22 and 7.93–7.107, and Refs [15, 16])

2.86. The radiation protection programme should cover the control of exposures and the monitoring of doses, and should ensure that doses to individuals remain within prescribed limits; its objective should be to keep individual and collective doses as low as reasonably achievable. The radiation protection programme should be established in accordance with the requirements established in Ref. [15] and the guidance presented in Ref. [16]. Notwithstanding the existence of a radiation protection programme, each individual given access to the reactor building should be given training in radiation protection commensurate with his or her responsibilities and need for access to the reactor building.

Management of radioactive waste
(see Ref. [2], paras 6.162–6.166 and 7.106, and Ref. [17])

2.87. The operating organization should establish a radioactive waste management programme. This programme should 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; the activity and volume of radioactive waste should be kept as low as reasonably achievable, in accordance with the requirements established in Ref. [15]. The radioactive waste management programme should include, inter alia, provisions for:

(a) Keeping the generation of radioactive waste to the minimum practicable, in terms of both activity and volume;
(b) Appropriate classification and segregation of waste;
(c) Possible reuse and recycling of materials;
(d) Collection, characterization and safe storage of radioactive waste;
(e) Adequate storage capacity for the radioactive waste expected to be generated;
(f) Treating, re-treating and conditioning 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.

Physical protection (see Ref. [2], paras 7.79 and 7.80)

2.88. The operating organization should establish a physical protection programme that prevents unauthorized access, intrusion, theft and internal or external sabotage of systems important to safety and nuclear material. The physical protection programme should provide for: measures and procedures that take access controls around the site and within the reactor area into account; 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 for physical protection. 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.

Safety analysis and the safety analysis report
(see Ref. [2], paras 6.72–6.78 and 7.10(b), and Ref. [3])

2.89. The operating organization should conduct a safety analysis of the research reactor, including an analysis of postulated accidents, and should prepare a safety analysis report prior to construction of the reactor. The safety analysis report should be reviewed periodically and should be updated as subsequent changes to the facility design or operational changes are analysed.

2.90. The operational limits and conditions, which are sometimes contained in a document separate from the safety analysis report, should also be reviewed periodically and should be updated on the basis of experience and the updating of the safety analysis report.

Management of ageing (see Ref. [2], paras 6.68–6.70 and 7.109, and Ref. [18])

2.91. Managing the safety aspects of reactor ageing requires the implementation of effective programmes for timely detection and mitigation of ageing degradation of SSCs important to safety, so as to ensure their integrity and functional capability throughout the lifetime of the reactor.

2.92. The programme to manage the ageing process should contain, but not be limited to, the following elements:

(a) Identification of degradation processes that could adversely affect safety;
(b) Identification of components that are susceptible to ageing degradation and that could thus affect safety;
(c) Adequate and current methods for detecting ageing problems;
(d) Appropriate records to enable the ageing process to be tracked;
(e) Methodology for taking corrective actions in order to mitigate and/or remedy ageing effects;
(f) Changes to the programme of maintenance, periodic testing and inspection to reflect the analysis of test results for ageing.

Extended shutdown (see Ref. [2], paras 6.71, 7.111 and 7.112, and Ref. [19])

2.93. 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 committed resources in place for resuming operation or commencing decommissioning), the operating organization should prepare and implement a preservation programme to maintain the reactor's integrity and safety. Approval by the regulatory body should be sought, especially if changes are made to the safety analysis report or the operational limits and conditions. The preservation programme should include:

(a) Arrangements to unload the core and to store the reactor fuel safely, or otherwise to ensure that the reactor core remains subcritical;
(b) Measures to prevent accelerated corrosion;
(c) Modifications to the safety analysis report and the operational limits and conditions;

(d) Regular surveillance and maintenance, and periodic testing and inspection;
(e) Revised emergency planning arrangements;
(f) The staffing necessary to ensure safety and to maintain the necessary knowledge base;
(g) Techniques for fulfilling licence conditions and maintaining qualifications and authorizations of operating personnel.

Decommissioning
(see Ref. [2], paras 6.50, 6.51, 7.8 and 8.1–8.8, and Refs [20–22])

2.94. Measures to facilitate decommissioning should be considered in the design stage of the research reactor. In the operational stage, a plan should be developed for the reactor's eventual decommissioning; this plan should be amended periodically on the basis of operating experience and the latest developments in decommissioning techniques.

2.95. Even if there are no definite plans to decommission the reactor facility, the operating organization should begin to plan for eventual decommissioning by estimating the costs and considering options for decommissioning of the facility and the associated experiments. Documentation that will facilitate decommissioning 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) should be considered. Such considerations may lead to the operating organization carrying out such activities as minimization of the contamination of SSCs, segregation of waste of different categories or application of protective coatings.

2.96. When a decision is made to decommission, the operating organization should ensure that all options for decommissioning are considered and that a decommissioning plan is developed that covers all stages from the start of decommissioning until the site and its adjacent areas have been released for restricted or unrestricted use. This plan should include a description of the organizational structure for decommissioning, which may differ from that for the operational stage. The decommissioning plan should be submitted to the regulatory body for review and approval prior to the commencement of decommissioning.

3. RECRUITMENT AND SELECTION OF OPERATING PERSONNEL

GENERAL

3.1. “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” (Ref. [2], para. 7.1). “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” (Ref. [2], para. 7.13).

3.2. The operating organization of the reactor should be staffed with competent managers and a sufficient number of experienced personnel, supplemented, as necessary, by consultants or contractors so that duties relating to safety can be performed without undue haste or pressure. The operating organization should ensure that its operating personnel are appropriately qualified and that they have acquired, at the time of commencing duties at the facility, a combination of education, training and experience commensurate with their level of responsibility. The presence of properly qualified personnel provides reasonable assurance that decisions made and actions taken in all operational states will be such that the reactor is operated in a safe manner. National regulations may also require that individuals who are recruited as reactor personnel meet specific requirements. The minimum requirements in terms of education and experience that must be met by candidates for specific operating positions in a research reactor facility should also be defined. In the recruitment of operating personnel, it should be ensured that only qualified and reliable individuals are selected for all positions. An appropriate background check may be required by national regulations as a condition of employment for new operating personnel.

3.3. In addition, the physical and mental health of all operating personnel should be such that they are capable of operating the facility under normal, abnormal and emergency conditions without putting at risk the facility, the health and safety of personnel at the site or of the public, or the environment. Psychometric and psychological tests may be used where applicable. Examples of reasons relating to physical and mental health that may disqualify candidates or members of the operating personnel can be found in some national standards and regulations [23].

3.4. In addition to the provisions established in national regulations and practices relating to occupational health and safety, all members of the direct operating personnel, as a minimum, 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 may be occupationally exposed to radiation at the reactor facility may be required to have periodic medical examinations. The results of the medical examinations may necessitate restrictions on the activities that an individual may perform.

3.5. 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. 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. In small operating organizations, the loss of a single key individual may necessitate the shutting down of the facility until the training of a replacement can be completed. This situation should be avoided by means of effective strategic planning and succession planning. In general, effective documentation also minimizes the impact of the loss of key personnel. The facility staffing level should be assessed and updated periodically and whenever organizational changes are made or the mission of the facility changes.

3.6. Action, or lack of action, by operating personnel may have an immediate direct effect on the behaviour of the reactor and its systems, and could affect the safety of personnel and have consequences for the environment. 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

3.7. The operating organization is responsible for the recruitment of operating personnel who can meet the established competence requirements. The positions often associated with the operation of a research reactor are discussed in the following paragraphs.

Reactor manager

3.8. Because of the duties and responsibilities of the reactor manager position, it is desirable that candidates have a university degree in an engineering or scientific discipline and several years of appropriate nuclear experience[13]. The reactor manager should have demonstrable management skills including analytical, supervisory, leadership and communication abilities. The selected individual should receive sufficient training and should have facility specific knowledge commensurate with the responsibilities and duties of the position.

Reactor supervisor

3.9. Individuals 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 should receive facility specific training commensurate with the responsibilities and duties of the position.

Shift supervisor

3.10. An individual recruited for the shift supervisor position may be selected from among the senior reactor operators at the facility 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. Individuals selected for this position should receive adequate supplementary fundamental and facility specific training to be qualified as a shift supervisor.

3.11. In all cases, the shift supervisor should have demonstrable management skills. Since the shift supervisor will supervise other licensed reactor operators, the incumbent should be a senior reactor operator.

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

Senior reactor operator

3.12. An individual recruited for the senior reactor operator position is generally selected from among the reactor operators at the facility. Senior reactor operators 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 individual selected should have a specified period of experience as a reactor operator at the facility. The individual selected should receive adequate supplementary training at the facility to satisfy the requirements for authorization as a senior reactor operator.

Reactor operator

3.13. An individual recruited for the 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. Individuals selected should receive sufficient training at the facility or elsewhere to satisfy the requirements for authorization at the appropriate level.

Maintenance personnel

3.14. 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 site specific training commensurate with the responsibilities of the position. More guidance on the selection and training of maintenance personnel is provided in Ref. [13]. In cases where reactor operators are charged with the performance of maintenance work, they should be appropriately trained and qualified.

Radiation protection personnel

3.15. The duties, responsibilities and qualifications of radiation protection personnel that need to be specified for an effective radiation protection programme, as well as the criteria for selecting appropriate candidates, are provided in Refs [15, 16, 24].

Additional support personnel

3.16. Additional support personnel may or may not be part of the reactor personnel, but if they are, they may include highly qualified personnel such as training officers, safety officers and reactor chemists as well as personnel not subject to qualification, such as labourers, cleaners and storeroom attendants.

3.17. Recruitment requirements 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 site specific training, including training in radiation protection, security and emergency procedures, at a level appropriate to the position.

SELECTION PROCESS

3.18. The selection process for the recruitment of individuals for positions at a research reactor facility should include the following steps:

(a) Establishing the criteria for accepting or rejecting applications and for classifying acceptable candidates (e.g. entry level competence, communication skills);
(b) Obtaining information about the candidates (e.g. recommendations);
(c) Interviewing the candidates;
(d) Objective testing of the candidates;
(e) Assessing information on the candidates against set criteria in order to reach a decision;
(f) Applying the requirements for medical and psychological fitness for duty in the position (see paras 3.3 and 3.4 of this Safety Guide) and those for security clearance.

3.19. 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 facility operations;
(e) Psychological characteristics and state of health (see paras 3.3 and 3.4 of this Safety Guide);

(f) Attitudes towards safety and quality;
(g) Attitudes towards self-study;
(h) Attitudes towards training and career development for subordinates.

3.20. 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 together as a team.

3.21. The final selection process should be based on predetermined criteria.

4. TRAINING AND QUALIFICATION OF OPERATING PERSONNEL

GENERAL

4.1. The operating organization is responsible for ensuring that the reactor operating personnel and contractors are appropriately trained and retrained (see Ref. [2], paras 7.10(g), 7.14, 7.15, 7.27 and 7.28). 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 as described in Section 5 of this Safety Guide (see Ref. [2], para. 7.4).

4.2. The operating organization should document the competence requirements for each position important to safety. These requirements depend on (or vary in accordance with) the level of responsibility and the specific duties of a position. Persons having specific competence in the operation of reactor facilities and experience in training activities should prepare the requirements. Reference [23] provides additional guidance in this area. Training should be designed to provide and maintain the required levels of competence of the operating personnel and contractors.

TRAINING SYSTEM

4.3. The approach to training should be well organized and should include analysis, design, development, implementation and evaluation of both initial and continuing training to ensure that all job competence requirements are established and maintained. References [25, 26] and Annex I of this Safety Guide present a specific process that is one means of following this recommendation.

4.4. In the development of a training programme, 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 culminate in testing.

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

4.6. Although some of the required competences 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 for performing the tasks of the position under all conditions.

4.7. The most widely used training methods are classroom instruction, self-study, laboratory and/or workshop training, and on the job training[14]. A combination of these methods should be used to ensure that trainees obtain all the knowledge and skills required for their respective jobs. Alternating between these methods has been found to maintain trainees' motivation and to enhance their ability to learn.

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

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

[14] On the job training involves participation in research reactor startup (including pre-operational, hot functional and startup tests), operation, maintenance or technical services as a trainee under the direction of experienced personnel.

4.10. Laboratory and/or workshop training is necessary to ensure safe work practices. Training mock-ups[15] and models should be provided for training in activities that have to be carried out quickly and skilfully, and that cannot be practised using actual equipment.

4.11. On the job training should be conducted in accordance with documented guidelines by trainers who have been trained to deliver this form of training. Progress should be monitored, and an independent assessor should carry out an assessment.

4.12. 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 facility. On the job training does not mean just working in the job or position under the supervision of a qualified individual, but also involves the use of learning objectives and trainee assessment. Such training should be conducted and evaluated in the working environment by qualified individuals. The ability of such qualified individuals to train the trainee should be evaluated on a regular basis.

4.13. The training programmes and training facilities and materials should be periodically reviewed and modified if necessary. The review should cover the adequacy and effectiveness of the training, with due consideration of the actual performance of persons in their jobs. It should also examine the training needs, training programmes, training facilities and materials necessary to deal with changes to regulations, changes in the facility, changes to experimental facilities, and lessons learned from the feedback of operating experience. Where possible, persons other than those directly responsible for the training should undertake the review.

INITIAL TRAINING PROGRAMMES

General

4.14. All new employees should be introduced to their working environment in a systematic and consistent manner. General employee training programmes

[15] A mock-up is a model of equipment or systems that is used for training or development purposes.

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.

4.15. The training programme for direct operating personnel should provide a thorough understanding of the basic principles of nuclear technology, nuclear safety and radiation protection, of the design bases and assumptions, and of the theoretical basis for the reactor facility and its use. The training programme for direct operating personnel should include the necessary on the job training.

4.16. The training programme for direct operating personnel should also include training in the effects of radiation exposure and in the technical and administrative means necessary to prevent undue exposure and to keep unavoidable exposures as low as reasonably achievable (see Refs [15, 24, 25]).

Training of operating personnel

4.17. The training of all operating personnel, including the reactor manager, reactor supervisor, shift supervisors, reactor operators and radiation protection personnel, should cover areas of technology to the levels necessary for the task to be performed. It should develop a thorough theoretical and practical knowledge of reactor systems and their functions, layout and operation. The training should emphasize the importance of maintaining the reactor within the operational limits and conditions, the consequences of violating these operational limits and conditions, and the potential consequences for safety of procedural errors. Participation by trainees, whenever possible, in the pre-operational stage and in the startup of the reactor should be highly encouraged since it provides a valuable opportunity for training in the above-mentioned areas.

4.18. It is common practice for research reactor facilities to supplement the general employee training programmes by developing initial training programmes for qualifying operating personnel that are specific to the position held. The extent, scope and depth of these specific programmes will depend on the size and complexity of the facility and on the impact on the public and on the environment that may result from its operation. While the duration of the training will be strongly dependent on the initial competence of the incumbent, for a very small and simple facility, training, including site specific training and on the job training, may typically be completed in three months. For a large, complex and highly used facility, the training programme will be more extensive and may require over a year to complete.

4.19. To the extent applicable to the facility, a classroom and self-study training programme for reactor operators (including senior reactor operators, shift supervisors, the reactor supervisor and the reactor manager) at research reactor facilities 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 course*. Refresher courses in such areas as mathematics, physics and chemistry are sometimes necessary to ensure that all the candidates have the prerequisite 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:
   (i) Safety culture;
   (ii) *Computer knowledge;
   (iii) *Interpretation of technical drawings;
   (iv) Industrial safety;
   (v) *First aid;
   (vi) *Fire hazards;
   (vii) Basic electricity.
(c) *Reactor theory and related subjects*. These subjects provide the basis for understanding reactor theory and technology, and may include:
   (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 safety principles and procedures;
   (vi) *Radiation monitoring methods and survey equipment;
   (vii) *Principles of shielding;
   (viii) Heat transfer, thermodynamics and fluid mechanics;
   (ix) Materials technology, including the effects of radiation on the behaviour of reactor structures.
(d) *Reactor technology*. This area should include all subjects necessary for the understanding of the reactor's design and operation, the functions of its different systems and the testing of these systems. These subjects generally include:

(i) *General arrangement and layout of the facility;
(ii) *General features of the core, including core structures, fuel elements, control rods and materials;
(iii) General features of the reactor, including:
— Reactor instrumentation systems;
— Reactor control systems;
— Reactor protection systems;
— Safety systems;
— Reactor cooling systems;
— Ventilation systems;
— Auxiliary systems;
— Containment and/or confinement systems.

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

(f) *Reactor operation and safety*. This area covers specific reactor characteristics and the requisite knowledge for safe operation of the reactor and includes:
(i) *Facility 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) *Operational limits and conditions;
(vi) *Performance of critical experiments;
(vii) *Implementation of surveillance requirements of operational limits and conditions (instrument checks and calibration, control rod calibration);
(viii) *Thermal balance;
(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 facility as well as at other facilities.

(g) *Administrative requirements*. This area covers additional administrative measures to ensure the safe management of the facility and includes:
(i) Administrative requirements of the operational limits and conditions;
(ii) Staffing requirements;
(iii) Operational procedures;
(iv) Maintenance requirements and scheduling;
(v) Administrative procedures;
(vi) Access control for the facility;
(vii) Security;
(viii) Fire protection;
(ix) Nuclear criticality safety;
(x) Nuclear material accountability;
(xi) Initial qualification and requalification requirements;
(xii) Retention of operational records[16];
(xiii) Configuration and change control.

(h) *Rules and regulations*. This area includes:
(i) Mandatory facility 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) Licences and conditions of licences;
(vii) Reporting requirements.

4.20. The training should consist of periods of formal training in the classroom interspersed with intervals of laboratory and/or workshop training, on the job training and practical training. Reactor operators should acquire extensive experience in reactor operations; reactivity manipulations, including startup and shutdown; operation of reactor systems; utilization of procedures (e.g. fuel

[16] Operational records include documents such as instrument charts, certificates, logbooks, computer printouts and magnetic tapes that have been created to maintain an objective operational history of a research reactor.

handling, sample insertion and removal); troubleshooting; teamwork; and administrative tasks. The training programme should specify the minimum number of reactivity manipulations that an incumbent must perform in training.

4.21. 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 of, and the skills necessary to carry out, administrative policies and procedures, management responsibilities and limits of authority, supervisory techniques, interpersonal communications, problem analysis and decision making. Their training should in general be more broadly based and at a depth commensurate with the responsibilities of the job and the judgement required.

4.22. 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 4.19–4.21, the candidate should also undergo training to develop the knowledge and skills necessary to perform the duties of the new position competently. While the initial training includes the following subjects, the additional training should emphasize their supervisory aspects:

(a) Administrative requirements imposed by the operating organization and the basis for them;
(b) Operational limits and conditions;
(c) Procedures for making core configuration changes and system configuration changes, including supervision of critical experiments;
(d) The emergency plan;
(e) Emergency procedures;
(f) Decontamination procedures;
(g) Management training.

4.23. A senior reactor operator position may require a university degree or equivalent and/or additional training in specific fields (e.g. rules and practices for shipping radioactive material, radiation protection practices).

4.24. The reactor supervisor and the shift supervisors, who will be directly supervising reactor operators, should be senior reactor operators. Any other incumbent who directly supervises reactor operators in the performance of their licensed duties, including the reactor manager if he or she performs this function, should also be a senior reactor operator.

4.25. A shift supervisor should receive the training indicated in paras 4.19–4.23. This individual should receive additional training in the handling of abnormal occurrences and in management and communication skills.

4.26. From time to time, non-routine activities are performed at a research reactor. One example of a non-routine activity is an experiment that requires specific or unusual manipulations of the controls by a reactor operator. Another example is the preparation and shipment off the site 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.

4.27. 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 with an organized approach as described in paras 4.17–4.20 for the operating personnel. Specific guidance for training radiation protection personnel in research reactor facilities is provided in Refs [15, 17, 24].

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

Training of support personnel

4.29. Initial task related training of support personnel should develop knowledge of the facility layout and the general features and functions of reactor systems, management systems, maintenance procedures and practices including surveillance and inspections, and special maintenance skills to the depth required by the position. Training of support personnel should emphasize the possible consequences for safety of technical or procedural errors. Experience from failures caused by such errors should be reviewed. Specific guidance for training maintenance personnel in research reactor facilities is provided in Ref. [13].

4.30. In some facilities, support work is performed by personnel who do not belong to the reactor facility personnel. These individuals should receive facility orientation training, task related instruction and site specific instruction on elements including radiation protection, security and emergency procedures. For short term support personnel, most of this training may be replaced by close supervision by a member of the reactor facility operating personnel.

Training of experimenters and other users

4.31. Each new research reactor utilization project should address training requirements unique to the project, providing information about the project that should be added to the training programme for the operating personnel and describing the appropriate training for experimenters and other users. Experimenters and other users should not be allowed to conduct work activities in the facility before their specific training has been satisfactorily completed. The utilization project should not be conducted before the operating personnel have satisfactorily completed training unique to the project.

4.32. As a minimum, each experimenter or other user who has been granted access to the research reactor facility should receive basic training in radiation protection and emergency response commensurate with his or her responsibilities and conditions of access (escorted or unescorted) to the reactor building.

QUALIFICATION

4.33. Once training is completed, operating personnel should be assessed by the reactor manager, or by a person designated by the reactor manager, prior to applying for or receiving authorization to perform the duties of the position for which they were trained. An individual from the operating organization with specific knowledge of the reactor manager's duties and required competences should carry out the assessment of the reactor manager. Standards of performance should be established against which 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 facility and recall and comprehension by means of a written examination;
(c) Oral examination (may take place in a classroom and/or as part of a facility walkthrough[17]);

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[17] 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.

(d) Assessment of performance under stress (e.g. under simulated emergency conditions).

4.34. The operating organization should perform an assessment to ensure that the incumbent possesses the required competences and is qualified to fill the position. If a licence or authorization is required for the position, the operating organization should request an examination by the appropriate authority.

4.35. The regulatory body may conduct the qualification examination and issue a licence or authorization to the successful candidate(s). Alternatively, the operating organization may be responsible for conducting the examination, possibly with a representative of the regulatory body present as an observer.

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

(a) Identifying the areas where the on the job training, classroom training and/or self-study are not adequate;
(b) Adopting measures to ensure that the required competence is reached;
(c) Providing remedial training for those individual(s) showing a deficiency;
(d) Removing the incumbent from his or her position.

CONTINUING TRAINING AND REQUALIFICATION

4.37. Continuing training based on an organized approach is essential to ensuring that the knowledge, skills and attitudes of research reactor personnel are maintained. Continuing training should also be used for career development purposes. All personnel whose functions are important to the safe operation of the facility should participate in continuing training.

4.38. 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 4.19–4.22) that involve tasks important to safe operation of the reactor facility that are infrequently performed or that are difficult to perform. The topics for continuing training should be commensurate with the level of authorization of the incumbent. Topics for a continuing training programme could include the following:

(a) Nuclear theory and principles of reactor operation;
(b) Reactor design and operating characteristics;
(c) Instrumentation and control systems;
(d) Reactor protection systems;
(e) Experimental and auxiliary reactor systems;
(f) Operational limits and conditions;
(g) Operating procedures for normal, abnormal and emergency conditions;
(h) Radiation control and safety;
(i) Emergency plan;
(j) Security plan.

4.39. Site personnel occupationally exposed to ionizing radiation should receive periodic retraining in radiation protection.

4.40. A continuing training programme should also include regular training drills and exercises on the emergency procedures. All site personnel should participate in these drills as appropriate.

4.41. In addition to the training topics recommended in paras 4.38 and 4.40, continuing training programmes should cover knowledge and skills identified through:

(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 operational limits and conditions);
(d) Facility experience gained and events that have occurred during operation at the reactor facility and elsewhere;
(e) Weaknesses detected in the performance of the reactor operator;
(f) Individual requests.

4.42. As part of the continuing training programme, reactor operators who are seeking requalification should have performed a minimum number of reactivity manipulations. In addition, as part of the programme, individuals who hold specific titles should have carried out the duties of the title for a specified minimum amount of time.

4.43. Following completion of the continuing training programme, a requalification examination should be administered by the facility to verify that operating personnel have maintained the knowledge and skills required for the position. The examiner should not be the same person who administered the training for requalification. In some cases, the regulatory body may administer the examination. The interval between successive requalification examinations may vary between one and five years. Operating personnel who have been absent from active duties for a considerable time (e.g. several consecutive months) should be required to successfully complete an appropriate retraining programme, including examination, before reassuming the duties of their position.

5. AUTHORIZATION OF OPERATING PERSONNEL

GENERAL

5.1. Authorization is the granting by a regulatory body or other appropriate authority of written permission for a reactor operator to perform specified activities. In some States, authorization is limited to activities performed at a specific reactor.

5.2. "Every licensed or authorized reactor operator shall have the authority to shut down the reactor in the interest of safety" (Ref. [2], para. 7.20).

5.3. The operating organization should establish procedures that lead to authorization in compliance with regulatory requirements. These procedures should provide for an assessment of the capabilities of persons to be authorized, including successfully passing a comprehensive examination based on the training programme.

5.4. Independent of any authorization issued, it is the responsibility of the operating organization to ensure that all on-site and off-site personnel have the required qualifications for their positions.

POSITIONS TO BE AUTHORIZED

5.5. The regulatory body is required to provide for issuing authorizations that specify the obligations of the operating organization with respect to its personnel (see Ref. [7], para. 3.2(3)(iii)). This requirement may be met in different ways. The operating organization may propose, for regulatory body approval, the activities for which personnel are required to be authorized by the regulatory body or the operating organization. Alternatively, the regulatory body may determine the activities that must be authorized and grant the authorization.

5.6. The operating organization should determine, in accordance with the requirements of the regulatory body, the operating personnel positions that require an authorization. "In particular, the reactor manager, the shift supervisors and the reactor operators shall hold a licence or certification issued by an appropriate authority" (Ref. [2], para. 7.4).

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

CONDITIONS OF AUTHORIZATION

5.8. Each authorization should specify the facility and position to which the authorization applies. In addition, conditions of the licence that are based on 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 reactor facility or to a different position at the same facility for which an authorization is required, the person should satisfy the specific qualification requirements for the new position before being authorized to assume the duties of the new position.

5.9. Only individuals holding a specific authorization to operate the controls of the reactor that directly affect the reactivity of the reactor core should be allowed to do so. 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 the controls of the reactor that directly affect the reactivity of the core. Qualified persons may be permitted to carry out pre-approved, limited actions that may 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. Where 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 facility should certify that the individual still meets the requirements of the authorization prior to the individual's resumption of the duties of the authorized position. In some cases, retraining and requalification should be carried out (see para. 4.43).

5.11. All authorized individuals should undergo a periodic medical examination that examines physical health and mental health. The results of this examination should be used by the facility's management to help in determining whether the individual is still capable of performing the functions for which he or she is authorized. As stated in para. 3.3, examples of reasons relating to physical and mental health that may disqualify candidates or members of the operating personnel can be found in some national standards and regulations (e.g. Ref. [23]).

REAUTHORIZATION

5.12. The competence of authorized persons should be reviewed periodically. Consideration should be given to the need for periodic reauthorization. In many States, authorizations issued by the regulatory body are generally 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 performing the duties of 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 the person's passing a medical examination. Each authorized individual should successfully complete the continuing training programme appropriate to his or her position and should pass the requalification examination.

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

6. TRAINING RECORDS

6.1. The operating organization should maintain for each individual adequate records of the individual's:

(a) Education;
(b) Experience;
(c) Training and retraining;
(d) Qualification and requalification;
(e) Test and examination results;
(f) Authorization and reauthorization;
(g) Employment;
(h) Performance history;
(i) Health and medical condition.

A list of requirements for the employee's position should also be maintained.

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

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

6.3. These records may also be used as an independent source of information for the justification of promotions.

6.4. The records should be collected and archived in accordance with the applicable management system requirements (see Ref. [9]).

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Annex I

THE SYSTEMATIC APPROACH TO TRAINING

I–1. The systematic approach to training (SAT) 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, as noted in para. 4.3 of this Safety Guide, particularly those with large operating organizations. Detailed information on the SAT can be found in the references cited at the end of this annex. The following is a brief description of this approach, based on Ref. [I–1].

I–2. The overall goal of the SAT and the facility management is to develop the necessary competence of personnel to operate and maintain the research reactor facility safely. The methodology of the SAT is one that 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, and to subsequent evaluation of the effectiveness of the training.

I–3. The SAT methodology applies quality management techniques (e.g. efficiency control and management control) to training to ensure the competence of personnel. The competences required for every job in the research reactor facility are established (e.g. through a job and/or task analysis), and personnel are trained and evaluated using the techniques provided 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 SAT 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 SAT process is given in Fig. I–1.

I–5. As shown in the figure, the SAT consists of five interrelated phases, which are as follows:

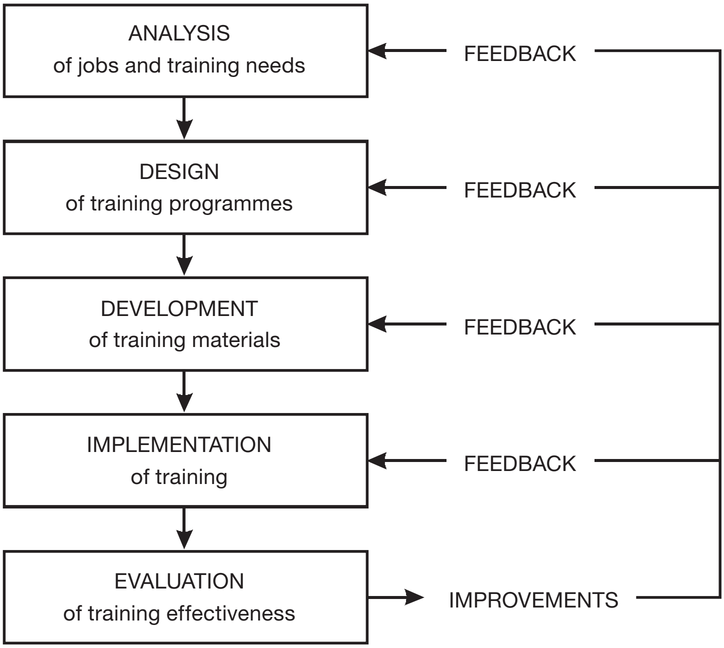

FIG. I–1. Overview of the SAT process.

ANALYSIS

I–6. The analysis phase comprises the identification of training needs and of the competences necessary to perform a particular job.

DESIGN

I–7. In the design phase, the identified competences are converted into training objectives. These objectives are organized into a training plan.

DEVELOPMENT

I–8. The development phase comprises preparation of all training materials so that the training objectives can be achieved.

IMPLEMENTATION

I–9. In the implementation phase, training is conducted using the training materials that have been developed.

EVALUATION

I–10. 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 facility.

Implementation of the SAT

I–11. Experience has shown that implementation procedures are necessary for each of the SAT phases to ensure quality and consistency. These 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 SAT process and summarizes the most important inputs and outputs for each SAT phase from sources internal and external to the SAT process. The analysis phase of the process is based on the characteristics of the facility and will therefore be facilitated by good documentation.

I–12. If the SAT is to be prepared for a research reactor facility that is in the pre-operational stage, design documents and/or documentation from a facility of similar design should be used.

I–13. References [I–1, I–2] present guidance on the introduction by management of SAT based training and on the SAT process for the training of operating, maintenance, management and emergency personnel and instructors. The facility management may find it beneficial to apply the SAT to personnel training programmes in all areas of operations.

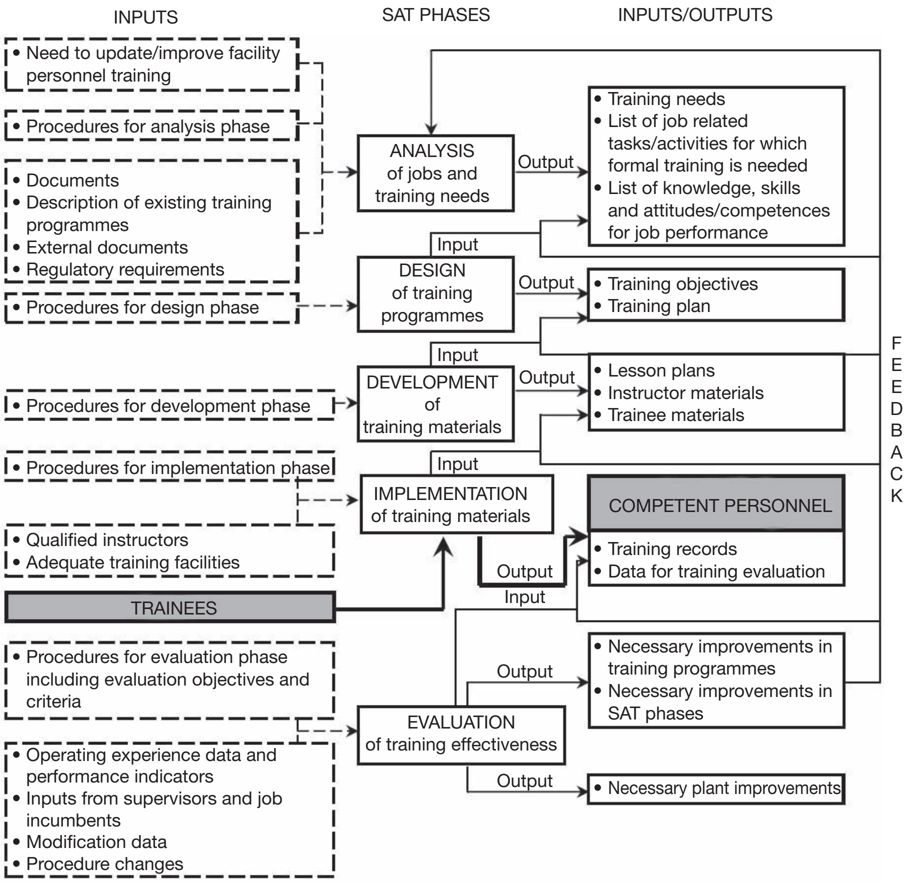

FIG. I–2. Implementation of the SAT process, including inputs and outputs.

REFERENCES TO ANNEX I

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Annex II

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

GENERAL

II–1. Annex II provides guidance on establishing a new training course for operators of research reactors and provides a basis for comparison for reviewing an existing training course. It is adapted from materials used at a large research reactor in a Member State. The training topics for a particular reactor may vary from those given in this annex. Operators of low power level reactors (e.g. those with natural convection cooling and without the need for emergency core cooling or active decay heat removal) may find that some topics listed are not applicable to such facilities.

INITIAL TRAINING

II–2. All reactor operators are required to have knowledge of the reactor areas under their control and supervision and to be trained to assess the effects of their actions on reactor systems. Senior reactor operators and shift supervisors are required to have 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 knowledge required 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: knowledge of nuclear fundamentals and facility specific knowledge. Paragraphs II–10 and II–11 expand this outline by listing individual topics presented under each heading. As already noted, some of these topics may not be relevant to low power research reactors. In addition, since the topics listed in para. II–11 are facility dependent, some of them may not be applicable to some reactors.

DURATION OF TRAINING

II–4. In many training programmes, candidates for the position of reactor operator are required 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 required to work as an authorized reactor operator for a specific period (e.g. one year) at the facility where authorization as shift supervisor is sought. These experience requirements may vary in accordance with national regulations.

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

ASSESSMENT

II–6. To evaluate progress during training, several examinations (e.g. three) are often administered after completion of the specific classroom topics such as:

- — Nuclear and reactor physics and thermohydraulics;
- — Fundamentals of reactor engineering and reactor safety;
- — 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.

CONTINUING TRAINING

II–8. The topics to be covered in a continuing training course and the appropriate duration are highly dependent on the facility and its operating programme. The course materials focus on recent changes made to SSCs, administrative procedures or 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–1. COURSE OUTLINE FOR INITIAL TRAINING

Part A. Knowledge of nuclear fundamentals

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. Statutory bases
   - 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

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

- 2.3.2. Anticipated operational occurrences and incidents
- 2.3.3. Unforeseen event sequences
- 2.4. External events
- 2.5. Radiation protection and monitoring
- 2.6. Environmental monitoring
- 2.7. Facility 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

TABLE II–2. EXAMPLE OF A SCHEDULE FOR TRAINING IN NUCLEAR FUNDAMENTALS FOR 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

TABLE II–3. EXAMPLE OF A FACILITY SPECIFIC ORAL EXAMINATION FOR 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 facility using plans or exploded view placards.

1.2. Three questions taken from the facility knowledge ‘question catalogue’, with emphasis on the subjects of dealing with accidents and procedures relating to radiation protection (using overhead transparencies, when appropriate, prepared beforehand).

2. *Examination by means of practice oriented 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. 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.

TABLE II–3. EXAMPLE OF A FACILITY SPECIFIC ORAL EXAMINATION FOR REACTOR OPERATORS (cont.)

2.2. Demonstration of knowledge of the system and procedures by performing a pre-startup checkout, reactor startup, a power adjustment (from low power to exactly full power) using the basic stepwise procedure, and reactor shutdown.

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

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

	Relevant topics — Theoretical part
Nuclear fundamentals	Facility related reactor physics Thermohydraulic aspects of the reactor Operating procedures Radiation protection aspects of the facility 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
Regulations and organization	General safety rules at the centre; protection against external events Organization, 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

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

Relevant topics — Practical part	
Operational practice	Handling and replacing of fuel elements, neutron absorbers and experiments Use of portable radiation protection 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 — Theoretical part	
Operating procedures, operating manual Service procedures, inspection manual Fault analysis, reportable occurrences	
Special topics — Practical part	
Self-performance or participating 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 NUCLEAR FUNDAMENTALS

II–10. This paragraph provides an expansion of the individual topics which are presented in Table II–1 under Knowledge of nuclear fundamentals. The topics in italics apply to reactor operator, senior reactor operator and shift supervisor training. The remainder apply only to senior reactor operator and shift supervisor training. 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 K γ radiation (energy transfer, secondary radiation, scattered radiation) and neutrons (scattering, capture, fission) with matter;
- *Neutron sources;*
- *Qualitative relation 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 4-factor formula and its extension to the real reactor;*
- *Multiplication factors (k_{eff}, $k\infty$);*
- *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;*
— *Definition of stable period and qualitative treatment of reactor period, or relative rate of flux change;*
— Definitions of 'stationary', 'transient' and 'transitional behaviour';
— *Relation 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 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 resistances in pipes and valves;*
— Flow measurements by orifices;
— O*perating 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 involved in the use of nuclear energy (fission product inventory and uncontrolled reactivity) and risks;*
— *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', 'incorporation', 'inhalation dose', 'ingestion dose' and 'submersion dose', 'dose rate', 'equivalent dose', '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, *film badge, multisphere dosimeter and pocket dosimeter for measurement of doses in the β and n radiation fields* and for the measurement of surface contamination (by α and β radiation and γ spectroscopy);
- *Radiation fields*;
- Unsealed and sealed radioactive materials in the facility and their handling;
- Exposure to natural radiation (sources and intensity);
- *Dose limits for occupationally exposed persons in the monitored facility area and in the restricted access area and during events, and for radiation exposure of the public due to the discharge of radioactive material to air or water;*
- *Lethal doses;*
- Limits for the maximum permissible activity of radioactive material discharged to air or water;
- *The limit on activity of annual 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, loads and measuring 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 (such as the use of time, distance, shielding, protective clothing and respirators) for minimizing radiation exposure 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
- Relation 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. Statutory basis

7.1. National regulations and international codes and standards
- Licensing requirements;
- Operating requirements;
- Changes in the facility or in its operation that require regulatory review and approval;
- Access authority of the agents of the regulating body;
- IAEA safety standards;
- IAEA Code of Conduct on the Safety of Research Reactors;
- 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 facility;
- Positions and duties of the radiation protection personnel;
- Radiation protection directives;
- Measures to be taken during and following events to mitigate their consequences;
- Facility instructions, definition 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

II–11. This paragraph provides an expansion of the individual topics which are presented in Table II–1 under Facility specific knowledge. The topics in italics apply to reactor operator training, senior reactor operator training and shift supervisor training. The remainder apply only to senior reactor operator and shift supervisor training. The numbering used reflects the structure in Table II–1.

1. Facility engineering

1.1. Buildings and equipment
— *Safety analysis report for the facility;*
— *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 and 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.*

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; 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 the determination of the operating state; possible modes of operation; effects of system operation on other reactor systems; and initiation of corrective actions in the event of the malfunction of 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 emergency 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 facility computer systems;
- Interface of the computer systems with the balance 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 facility 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 facility status, 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) in accordance with facility requirements;*
- Operation and monitoring of air locks and the facility 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:*
  - *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 measuring 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;*
  - *Various emergency power supply systems and essential power supply bus bars.*

2.3.2. Anticipated operational occurrences and incidents

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

— *Verifying 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, and minimization of effluents released and application of incident related procedures;
- *Abnormal sequences in operation and incidents that have occurred at the facility;*
- *Reactivity related incidents: malfunctions causing reactivity addition; unintentional withdrawal of the highest worth control element or the highest worth effective group or 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 reactor.

2.3.3. Unforeseen event sequences

- Design limits of components and systems important to event sequences and the safety of the facility, such as the reactor tank, heat exchangers, emergency core cooling systems and 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 take 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 measuring instruments for personnel monitoring and radiation protection;
- Personnel monitoring requirements at the point of access to the restricted area;
- Functional modes and *use of the radiation protection measuring 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 effluents from exhaust systems.*

2.6. Environmental monitoring

— Measuring 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; monitoring of the activity of airborne radioactive material discharged via the facility stack.

2.7. Facility 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 by the authorities with regard to shift operation (approved limits on activity levels, reactor protection limits and boundary conditions for operation);
— Measures in the event of violation of approved limits.

3.2. Operating manual

— *Structure, contents and use of the operating manual, including safety specifications, additional plans, drawings and descriptions;*
— Surveillance of safety related systems 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 logbook content;*
— *Scope of duties of persons on shift;*
— *Powers and authorities within a shift;*
— *Powers and authorities of senior management, other managers and radiological protection officers with respect to personnel on shift.*

3.3.2. Alert plans

— *Alarms and alarm equipment at the research reactor facility;*
— *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; radiation protection instructions;*
— Guard instructions and access instructions;
— First aid instructions;
— Fire protection instructions.

CONTRIBUTORS TO DRAFTING AND REVIEW

Abou Yehia, H.	International Atomic Energy Agency
Adams, A.	Nuclear Regulatory Commission, United States of America
Alcala-Ruiz, F.	International Atomic Energy Agency
Aquino, A.G.	Belgian Nuclear Research Centre (SCK–CEN), Belgium
Bastos, J.L.	International Atomic Energy Agency
Boado-Magan, H.J.	International Atomic Energy Agency
Böck, H.	Atominstitut der Österreichischen Universitäten, Austria
Calabrese, C.R.	Comisión Nacional de Energía Atómica (CNEA), Argentina
Chae, H.T.	Korea Atomic Energy Research Institute, Republic of Korea
Deitrich, L.W.	International Atomic Energy Agency
DiMeglio, A.F.	Consultant, United States of America
Egermaier, J.	State Office for Nuclear Safety, Czech Republic
Gurevitz, Y.	Negev Nuclear Research Centre, Israel
Hansen, M.B.	Risø National Laboratory, Denmark
Hossain, M.	Australian Nuclear Science and Technology Organisation (ANSTO), Australia
Isaac, P.	Nuclear Regulatory Commission, United States of America
Ivanov, V.	Research Institute of Atomic Reactors, Russian Federation

Khamis, I.	Atomic Energy Commission, Syrian Arab Republic
Kraut, A.	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Germany
L'Heureux, R.	Australian Nuclear Science and Technology Organisation (ANSTO), Australia
Litai, D.	International Atomic Energy Agency
Pianarosa, P.	Atomic Energy Control Board, Canada
Schreckenbach, K.	Forschungsreaktor Munich, Germany
Shaat, M.K.	Atomic Energy Authority, Egypt
Shokr, A.M.	International Atomic Energy Agency
Slugen, V.	Slovak University of Technology in Bratislava, Slovakia
Voth, M.H.	International Atomic Energy Agency
Wijtsma, F.J.	Energy Research Centre of the Netherlands (ECN), Netherlands

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Norway: Hornkjøl, S.; *Pakistan*: Rashid, M.; *Paraguay*: More Torres, L.E.; *Philippines*: Kinilitan-Parami, V.; *Portugal*: Buxo da Trindade, R.; *Romania*: Vieru, G.; *Russian Federation*: Ershov, V.N.; *South Africa*: Jutle, K.; *Spain*: Zamora Martin, F.; *Sweden*: Dahlin, G.; *Switzerland*: Knecht, B.; **Thailand*: Wanitsuksombut, W.; *Turkey*: Ertürk, K.; *Ukraine*: Sakalo, V.; *United Kingdom*: Young, C.N.; *United States of America*: Brach, W.E.; Boyle, R.; *European Commission*: Venchiarutti, J.-C.; *International Air Transport Association*: Abouchaar, J.; *IAEA*: Wangler, M.E. (Coordinator); *International Civil Aviation Organization*: Rooney, K.; *International Federation of Air Line Pilots' Associations*: Tisdall, A.; *International Maritime Organization*: Rahim, I.; *International Organization for Standardization*: Malesys, P.; *United Nations Economic Commission for Europe*: Kervella, O.; *Universal Postal Union*: Giroux, P.; *World Nuclear Transport Institute*: Green, L.

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Argentina: Siraky, G.; *Australia*: Williams, G.; *Austria*: Hohenberg, J.; *Belgium*: Baekelandt, L.; *Brazil*: Heilbron, P.; **Bulgaria*: Simeonov, G.; *Canada*: Lojk, R.; *China*: Fan, Z.; *Croatia*: Subasic, D.; *Cuba*: Salgado Mojena, M.; **Cyprus*: Demetriades, P.; **Czech Republic*: Lieteva, P.; *Denmark*: Nielsen, C.; **Egypt*: El-Adham, K.E.A.; *Finland*: Ruokola, E.; *France*: Cailleton, R.; *Hungary*: Czoch, I.; *India*: Raj, K.; *Indonesia*: Yatim, S.; *Iran, Islamic Republic of*: Ettehadian, M.; **Iraq*: Abass, H.; *Israel*: Dody, A.; *Italy*: Dionisi, M.; *Japan*: Ito, Y.; *Korea, Republic of*: Park, W.; **Latvia*: Salmins, A.; *Lithuania*: Paulikas, V.; *Mexico*: Aguirre Gómez, J.; *Morocco*: Soufi, I.; *Netherlands*: Selling, H.; **Norway*: Sorlie, A.; *Pakistan*: Rehman, R.; *Paraguay*: Facetti Fernandez, J.; *Portugal*: Flausino de Paiva, M.; *Romania*: Tuturici, I.; *Russian Federation*: Poluektov, P.P.; *Slovakia*: Konečný, L.; *Slovenia*: Mele, I.; *South Africa*: Pather, T. (Chairperson); *Spain*: Sanz, M.; *Sweden*: Wingefors, S.; *Switzerland*: Zurkinden, A.; *Turkey*: Özdemir, T.; *Ukraine*: Iievlev, S.; *United Kingdom*: Wilson, C.; *United States of America*: Camper, L.; *European Commission*: Hilden, W.; *IAEA*: Hioki, K. (Coordinator); *International Organization for Standardization*: Hutson, G.; *OECD Nuclear Energy Agency*: Riotte, H.; *World Nuclear Association*: Saint-Pierre, S.

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"The IAEA's standards have become a key element of the global safety regime for the beneficial uses of nuclear and radiation related technologies.

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Mohamed ElBaradei
IAEA Director General

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