IAEA Safety Standards

for protecting people and the environment

Commissioning of Research Reactors

Safety Guide

No. NS-G-4.1

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International Atomic Energy Agency

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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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COMMISSIONING OF RESEARCH REACTORS

SAFETY GUIDE

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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.

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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. It supplements and elaborates upon the safety requirements for the commissioning of research reactors that are established in the IAEA Safety Requirements publication on the Safety of Research Reactors [1]. It also relates to the IAEA Safety Guides on Safety in the Utilization and Modification of Research Reactors [2] and on Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report [3]. These Safety Guides include guidance on the commissioning of reactor modifications and experiments [2] and of the reactor itself [3].

OBJECTIVE

1.2. The objective of this Safety Guide is to provide recommendations on meeting the requirements for the commissioning of research reactors on the basis of international best practices. Specifically, it provides recommendations on fulfilling the requirements established in paras 6.44 and 7.42–7.50 of Ref. [1], and guidance and specific and consequential recommendations relating to the recommendations presented in paras 615–621 of Ref. [2] and paras 228–229 of Ref. [3]. This Safety Guide is intended for use by all organizations involved in commissioning for a research reactor, including the operating organization, the regulatory body and other organizations involved in the research reactor project.

SCOPE

1.3. The recommendations and guidance provided in this Safety Guide are intended to be applicable to most types of research reactor having a limited potential for causing hazard to the public. This Safety Guide describes: the safety objectives of commissioning; the tasks that should be accomplished to meet these objectives; the organization for commissioning that should be in place and the activities needed to perform the tasks; and the process of verification that the objectives have been accomplished.

1.4. In formulating the recommendations in this Safety Guide, the IAEA Safety Guide on Commissioning for Nuclear Power Plants [4] has been consulted. Where appropriate, in consideration of the differences in hazard potential and complexity of systems between nuclear power plants and research reactors, certain provisions of Ref. [4] have been adopted.

1.5. This Safety Guide is primarily intended for use for heterogeneous, thermal spectrum research reactors having a power rating of up to several tens of megawatts. Research reactors of higher power, specialized reactors (e.g. homogeneous reactors, fast spectrum reactors) and reactors having specialized facilities (e.g. hot or cold neutron sources, high pressure and high temperature loops) may require additional guidance. In such cases specific additional commissioning activities may be necessary. These should be agreed upon between the designers, the constructors and the operating organization, and should be satisfactory to the regulatory body. The guidance on commissioning for nuclear power plants [4] may be useful for the commissioning of high power research reactors.

1.6. Low risk research reactors having a power rating of up to several tens of kilowatts and critical assemblies may need a less comprehensive commissioning programme than that outlined here. While all recommendations in this Safety Guide should be considered, some may not be applicable to these low power research reactors. For these reasons, the recommendations in this Safety Guide should be graded[1] for their applicability to a particular research reactor (see Ref. [1], paras 1.11–1.14). Grading may be of assistance in determining the content of the commissioning programme. It should be based on the complexity of the activity and the importance to safety of the systems and equipment concerned.

1.7. Although this Safety Guide is primarily intended for the commissioning of newly designed and constructed reactors, it is also suitable for the recommissioning of a research reactor (e.g. after a period of extended shutdown) and for the commissioning of new experimental devices and reactor modifications. Additional guidance may be useful for certain modifications. In particular, guidance on the commissioning of new digital systems is provided in Refs [5] and [6].

[1] 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 involved.

STRUCTURE

1.8. This Safety Guide consists of eight sections and one appendix. Sections 2 and 3 provide guidance on the management system for commissioning and on the commissioning programme, respectively. Section 3 includes general recommendations and guidance for the commissioning process and, in particular, for the preparation and review of the commissioning programme, which is developed in subsequent sections. Section 4 provides guidance on the organization for commissioning and the management of commissioning, and establishes the responsibilities and functions of the organizations and groups involved, including interfaces between groups and handover activities. Section 5 discusses the general considerations, tests and prerequisites for the different stages of the commissioning programme. Reference to the Appendix is made when discussing the tests and prerequisites for each stage. Section 6 covers preparation of the commissioning procedures and reporting of the results and conclusions of commissioning. Section 7 provides recommendations on keeping the commissioning records and updating the safety documentation to take into account the results of commissioning. Section 8 deals with the commissioning of new experimental devices and reactor modifications. Finally, the Appendix provides a comprehensive list of prerequisites and tests that are usually included in the commissioning programme.

2. MANAGEMENT SYSTEM FOR COMMISSIONING

2.1. A documented management system that integrates safety, health, environmental, security, quality and economic objectives for the research reactor project should be in place. The documentation for the management system should describe the system that controls the development and implementation of all aspects of the reactor project, including the commissioning process. Approval of the management system (or parts thereof) by the regulatory body may be required. The management system should cover four functional categories: management responsibility; resource management; process implementation; and measurement, assessment and improvement. Generally:

— Management responsibility includes providing the means and management support needed to achieve the organization's objectives.

— Resource management includes the measures needed to ensure that resources essential to the implementation of strategy and the achievement of the organization's objectives are identified and made available.
— Process implementation includes the actions and tasks needed to achieve quality.
— Measurement, assessment and improvement provide an indication of the effectiveness of management processes and work performance.

Further requirements for the management system are established in Ref. [1], paras 4.5–4.13, and further guidance is provided in Refs [7–9].

2.2. As part of the integrated management system, a management system for commissioning should be established and put into effect by the operating organization early in the planning for commissioning. The management system should apply to the commissioning of all items, services and processes important to safety and should include the means of establishing controls over commissioning activities to provide confidence that commissioning is performed according to established requirements. In establishing the management system, a graded approach based on the relative importance to safety of each item or process should be used.

2.3. The objective of the management system as applied to commissioning is to ensure that the facility meets the requirements for safety as derived from:

— The regulatory body's requirements;
— Design requirements and assumptions;
— The safety analysis report (SAR);
— The operational limits and conditions (OLCs);
— Administrative requirements of the reactor management[2].

2.4. The management system should support the development, implementation and enhancement of a strong safety culture in all aspects of the commissioning programme.

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

2.5. All work associated with commissioning should be performed in accordance with the management system for commissioning and the guidance in this publication.

MANAGEMENT RESPONSIBILITY

2.6. The management system for commissioning should describe how work is to be managed, performed and assessed. The documentation for the management system should cover the organizational structure, functional responsibilities, levels of authority and interfaces for those managing, performing and assessing the adequacy of work. The management system should also address other management measures, including planning, scheduling, resource allocation and human factors.

2.7. The management system for commissioning should be outlined in a description of the commissioning programme and documented in procedures and work instructions. The procedures should address all applicable requirements specified in the integrated management system established by the operating organization. The work instructions should document both the commissioning activities and the performance and verification of specific commissioning activities. The requirements established under the management system should be communicated to the staff in the commissioning organization.

2.8. Methods of control should be adopted to ensure that procured items and services meet the established requirements and perform as specified. This may involve the development of specifications for items to be procured, the evaluation of suppliers and inspections or tests.

2.9. The commissioning activities should be performed and recorded in accordance with the procedures and instructions documented in the management system.

2.10. Successful implementation of the commissioning programme requires:

— Planning and prioritization of work;
— Addressing all relevant regulatory requirements;
— Addressing the requirements derived from the OLCs;
— Availability of qualified personnel with suitable skills;
— Appropriate instructions and procedures, including those for assessing and correcting non-conforming items;

— Availability of special instruments and equipment;
— A satisfactory working environment, including suitable preparation of the workplace and suitable protection of workers;
— Performing and documenting the required inspections and tests.

2.11. Documents essential to the performance and verification of commissioning activities (e.g. procedures, specifications and drawings) should be controlled. In particular, measures should be established for their preparation, identification, review, validation, approval, issue, distribution, revision and archiving. These control measures should apply to:

— Design documents and any changes and revisions to them;
— Commissioning procedures, instructions and drawings, and any changes and revisions to them;
— Documents on equipment control and maintenance;
— Documentation pertaining to calibration and control of measuring and test equipment;
— Commissioning records and results.

2.12. Methods should be adopted to control non-conformances, corrective actions and changes. Items, services and processes that do not meet the established requirements, including those that require design changes, should be identified and reported to the appropriate level of management, and should be corrected using specified approval channels. To ensure improvement, the causes of such non-conformances should be determined and assessed, and action should be taken to prevent their recurrence.

2.13. Records essential to the performance and verification of commissioning activities should be controlled through a system for their identification, approval, review, filing, retrieval and disposal.

RESOURCE MANAGEMENT

2.14. Equipment and items used for commissioning should be identified and controlled to ensure their proper use.

2.15. The operating organization has the responsibility for commissioning. The reactor manager[3] should participate in the commissioning activities by:

- Having frequent personal contact with the commissioning groups, including the overseeing of work in progress;
- Establishing and implementing a set of performance indicators for commissioning;
- Participating in evaluations of the commissioning process;
- Providing feedback derived from commissioning performance indicators for use in operations.

2.16. The competence requirements for staff performing work should be determined and personnel should be competent to perform their assigned work. Training should be provided when necessary.

2.17. External personnel (e.g. personnel of external suppliers) who perform commissioning activities should be appropriately trained and qualified for the work they are to perform. Experienced and qualified personnel may be allowed to bypass training by proving proficiency. External personnel should perform activities under the same controls and to the same standards as staff. Facility supervisors should review the work of external personnel during preparation for the work and during testing.

2.18. Suppliers should be evaluated and selected on the basis of specified criteria. The management system for commissioning on the site should be extended to include suppliers. The operating organization should confirm that the suppliers, manufacturers and designers have acceptable management systems and should ensure, through audits, that they comply with the integrated management system of the research reactor.

2.19. The process equipment (hardware and software) necessary for commissioning requirements to be met should be determined, provided and maintained. The work to be carried out should be determined and performed in a safe manner. The process equipment should be suitable for its intended use.

[3] The reactor manager is the member of the reactor management to whom the direct responsibility and authority for the safe operation of the reactor are assigned by the operating organization and whose primary duties comprise the discharge of this responsibility.

PROCESS IMPLEMENTATION

2.20. The activities and interfaces between different groups involved in commissioning should be planned, controlled and managed to ensure effective communication and the clear assignment of responsibility.

2.21. The operating organization should nominate a person having the responsibility and accountability for developing and documenting the commissioning process, monitoring the performance of the process, ensuring that the staff are competent, and evaluating the impact of the process upon safety. This person is usually the reactor manager.

2.22. Commissioning should be carried out in accordance with established engineering codes and standards.

2.23. Inspection, testing, verification and validation activities should be completed before the implementation or operational use of structures, systems and components (SSCs).

2.24. Valid monitoring and measurement should be performed to provide evidence of conformity to requirements and satisfactory performance in service.

2.25. Equipment used for monitoring, data collection, and inspections and tests should be calibrated and documented.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

2.26. Suitable methods should be applied for monitoring the effectiveness of the commissioning programme. The programme should cover the operational conditions expected during the operation and utilization of the reactor, including anticipated experimental programmes.

2.27. Requirements for the preparation of verification, review and audit procedures ([1], para. 7.48) should be taken into account in the commissioning programme.

2.28. An organizational unit should be established with the responsibility to conduct independent assessments of the commissioning programme. This unit

may be the safety committee, as described in paras 7.25 and 7.26 of Ref. [1] and para. 4.18 of this Safety Guide.

2.29. Management self-assessment should be carried out in accordance with Refs [7–9].

2.30. Independent assessment measures, including review and verification, should be established to ensure that commissioning activities are accomplished as specified. These measures may include:

— Review of commissioning procedures;
— Verification of commissioning activities by inspection, witnessing and surveillance;
— Functional testing following maintenance, repair or modification;
— Review and verification of commissioning records, results and reports, including those on the status of commissioning, non-conformance control and corrective actions.

2.31. Qualified personnel should carry out the verification of commissioning activities; they should not be directly responsible for the commissioning activities being verified.

2.32. Audits should be performed to determine the adequacy and effectiveness of, and adherence to, all aspects of the management system during the commissioning programme. The auditors should pay particular attention to the interfaces and transfers of responsibilities that occur between construction, installation, commissioning and operation groups. Further guidance may be found in Section 4 of Ref. [1].

2.33. The operating organization should evaluate the results of the independent assessments and should take any necessary actions to make improvements.

3. COMMISSIONING PROGRAMME

GENERAL OBJECTIVES

3.1. The commissioning programme is established to demonstrate that the requirements and intent of the design as stated in the SAR have been met. The requirements in paras 6.44 and 7.42–7.50 of Ref. [1] establish the basis for all aspects of commissioning.

3.2. Planning for the commissioning programme should begin at the design stage to permit interaction between the designers and the commissioning planners. This will facilitate compliance with the requirement that "The design shall include design features as necessary to facilitate the commissioning process for the reactor" ([1], para. 6.44).

3.3. A commissioning programme is often necessary following reactor modifications or when installing new experimental devices having major safety significance. Guidance for these cases is provided in paras 615–621 of Ref. [2] and Section 8 of this publication.

3.4. After preparation, "The commissioning programme shall be submitted to the safety committee and the regulatory body and shall be subjected to an appropriate review and assessment before being implemented" ([1], para. 7.44).

3.5. Organizational arrangements necessary to achieve the objectives of the commissioning programme should be put in place. They should represent a convenient and practical working scheme that allows the optimum use of available personnel, instruments and methods.

3.6. All anticipated operational modes of the reactor, including the planned core arrangements and experimental set-ups, should be considered in the commissioning programme. The planned core arrangements and the limitations on experiments should be included in the limiting conditions of operation of the OLCs and should be verified in the commissioning process.

3.7. "Experimental devices shall be given adequate consideration during the commissioning of the reactor" ([1], para. 7.43). Some experimental devices may undergo commissioning at the same time as the reactor systems, and, if so, their commissioning should be integrated into the commissioning programme.

3.8. Alternatively, experimental devices may be commissioned after commissioning of the reactor has been completed, provided that they are subject to appropriate specific commissioning procedures before use. Guidance is provided in Section 8 of this publication and in Ref. [2].

3.9. Available information on commissioning and operating experience from other similar reactor facilities should be utilized in developing the commissioning programme.

3.10. The commissioning programme is required to establish "the suitable testing of SSCs on the basis of their importance to safety" ([1], para. 7.42). The Appendix contains guidance on the necessary tests. While this requirement allows for grading in the testing, even SSCs with lesser importance to safety should be tested with the aim of demonstrating functionality and safety. Tests should be arranged in functional groups and in a logical sequence, and should be conducted in accordance with written procedures that consider the fulfilment of prerequisites prior to their implementation. The commissioning programme should therefore be divided into stages.

3.11. Hold-points or witness points for review should be established throughout the commissioning programme to ensure that test results have been evaluated and that all prerequisites for the next stage have been completed, and that the requirements of the operating organization and the regulatory body have been met.

3.12. Procedures for radiation protection, emergencies, security and handling of nuclear material that are needed for commissioning should be established and referenced in the commissioning programme. To the extent possible, the applicability of the procedures to be used during routine operation should be validated.

FORMAT AND CONTENT

3.13. The commissioning programme should be documented in such a way as to enable the objectives and methods of testing to be understood for review and implementation purposes, and to permit management control and coordination. The document describing the commissioning programme should cover the following:

(a) General description;

(b) Organization and responsibilities;
(c) Commissioning stages, with tests and prerequisites, and their scheduling;
(d) Commissioning procedures and reports;
(e) Documentation needs;
(f) A management system that includes verification, review, audit and treatment of non-conformances.

General description

3.14. The general description should give an overall picture of the objectives, requirements, major tests and procedures at each stage, and the results expected.

Organization and responsibilities

3.15. The document describing the commissioning programme should describe the organization responsible for commissioning, including the organizational chart. Functions and responsibilities of the organizations or groups involved and of key individual positions (e.g. the heads of the management group and the commissioning group) should be clearly presented. Section 4 provides guidance.

Commissioning stages

3.16. The document describing the commissioning programme should describe the main stages in the commissioning. These stages may be:

(a) Stage A: tests prior to fuel loading;
(b) Stage B1: fuel loading tests and initial criticality tests; Stage B2: low power tests;
(c) Stage C: power ascension tests and power tests up to rated full power.

Section 5 provides guidance.

3.17. The document describing the commissioning programme should describe the main commissioning tests devised to demonstrate the safe operation within design specifications of all reactor systems and components. This description should include prerequisites for beginning testing, such as system settings (e.g. the alarm level set point) or evidence of completion of previous tests. The interdependence of various systems should be considered in developing the commissioning programme.

3.18. The document describing the commissioning programme should describe the schedule for performing the main tests as stated above. In particular, this schedule should show:

(a) The sequence of tests for individual SSCs;
(b) The time periods scheduled for the detailed development of procedures, reviews, special training of technical staff, conduct of testing, development of documentation and reporting of results if necessary;
(c) Applicable regulatory requirements, such as the witnessing by regulators of tests and inspections;
(d) The plan for evaluation of results and revision of the SAR (if necessary).

3.19. The document describing the commissioning programme should describe simulations of the effects of malfunctions in control and process systems and equipment (e.g. loss of electrical power) that could be expected to occur over the facility's lifetime. These simulations should be included in the commissioning programme only to the extent that they are practicable and will not jeopardize the safety of the reactor.

Commissioning procedures and reports

3.20. The commissioning programme should include stipulations for the preparation, review and approval of commissioning procedures. A list of the procedures to be utilized for the main tests should also be included or should be appropriately referenced. Section 6 provides guidance.

3.21. The commissioning programme should include stipulations for the preparation of summary reports following particular stages or substages where reviews and approvals are required before commencement of the next stages, and for the preparation of the comprehensive commissioning report upon conclusion of the commissioning tests. Section 6 provides guidance.

Documentation needs

3.22. The commissioning programme should include stipulations for the documentation and archiving of commissioning records together with notes on any design changes made or concessions given. Section 7 provides guidance.

3.23. As part of the commissioning programme, the safety documentation, including the SAR and other documentation for the facility, should be revised as necessary on the basis of commissioning results.

Management system

3.24. The management system for commissioning should cover verification, review, audit and treatment of non-conformances. Section 2 provides guidance.

4. COMMISSIONING ORGANIZATION

ORGANIZATION

4.1. A commissioning organization should be established by the operating organization (see Ref. [1], paras 7.3, 7.6, 7.42 and 7.45). The operating organization should specify the following aspects of the commissioning organization:

— Organizational structure;
— Functional responsibilities;
— Levels of authority;
— Approval channels;
— Interfaces between participating groups.

4.2. The principal activities performed during commissioning may be divided into three categories, namely:

(a) Those connected with the final stage of construction and installation of the facility;
(b) Those fulfilling specific needs of commissioning, including safety reviews;
(c) Those connected with the operation of the facility.

Accordingly, activities dealing with construction, commissioning itself and operation will interrelate during the commissioning process. The operating organization should therefore consider these activities appropriately in establishing the commissioning organization.

4.3. The structure of a typical commissioning organization may include:

(a) A management group;
(b) A construction group;

(c) A commissioning group;
(d) An operating group;
(e) Other groups (e.g. a safety committee) as necessary.

When multiple organizations participate in this structure, the responsibilities of each organization should be clearly established and the interfaces between them should be defined. The regulatory body, while not a part of the organizational structure established for commissioning, will also participate in commissioning through its role in review, assessment and licensing at all stages of the process.

4.4. There are many ways in which these groups can be formed by different organizations. The composition of the groups, in addition to being influenced by the physical size and the design of the facility, may also depend on the availability and experience of personnel performing specialized functions. Whether or not the operating organization decides to contract any of these activities to another organization, responsibility for safety remains with the operating organization.

4.5. In a research reactor facility an overlap of personnel between the various groups is common. In this case, responsibilities should be assigned so that the performance of tests and other functions and their verification are appropriately separated.

4.6. Other representatives may participate in commissioning activities, such as representatives from the designers, the manufacturers and the quality assurance organization. They should collaborate with the groups as appropriate. In particular, the designers and manufacturers should provide adequate and complete information to the groups.

4.7. The commissioning organization and the arrangements made to ensure proper coordination of commissioning activities should be established early enough to allow the identification of all these activities and adequate preparation for them.

4.8. If the operating personnel are not already members of the operating group, the commissioning organization should make provision for the participation of future operating personnel in the commissioning process, so that they become knowledgeable about the facility during commissioning. The operating personnel will gain field experience, and an 'institutional memory' of the facility will be developed. This will also help in achieving a smooth turnover

of the facility to the operating personnel when the commissioning process is completed.

Management group

4.9. The operating organization may choose to be the management group and to manage the commissioning directly. Alternatively, the management group may be appointed by the operating organization and delegated to oversee all commissioning activities, and to control and coordinate the activities of other groups participating in commissioning.

4.10. The role of the management group may be fulfilled by a committee consisting of senior personnel with experience in the disciplines associated with a research reactor. The reactor manager may belong to the management group.

4.11. If a commissioning manager is appointed, his or her authority and responsibility should be defined by the management group.

4.12. The management group should include experts in, as a minimum, reactor physics, radiation protection and nuclear safety.

4.13. The management group should have executive authority for the conduct of all activities associated with the commissioning programme.

4.14. If the reactor manager, who has direct responsibility for reactor safety, disagrees with decisions of the management group, the disagreement should be resolved by the operating organization. The regulatory body may intervene if it believes that safety is being compromised.

Construction group[4]

4.15. The construction group may consist of the designers, suppliers, installers and constructors for the reactor facility. The construction group should ensure that the installation has been completed in accordance with specifications.

[4] The construction group is the group of personnel to whom the operating organization has delegated the responsibility for constructing the reactor facility. These persons may or may not be direct employees of the operating organization that retains the overall responsibility for their actions.

Commissioning group[5]

4.16. The commissioning group should consist of personnel with background and experience relating to the systems and components to be commissioned. The commissioning group should ensure that SSCs are tested to provide assurance that the facility has been constructed according to the design, that operation of individual systems meets design requirements, and that the facility is ready for safe operation.

Operating group[6]

4.17. The operating group should consist of personnel who have responsibility for the operation of the facility. In the context of the commissioning programme, the operating group should ensure that the operation of the facility is in accordance with the assumptions and intents of the commissioning programme. If necessary, qualification of appropriate members of the operating group for authorization from the regulatory body to perform specified tasks (such as reactor operation) during and after fuel loading should be part of the commissioning programme.

Other groups

4.18. "One or more reactor advisory groups or safety committees that are independent of the reactor manager shall be established to advise the operating organization on: (a) relevant aspects of the safety of the reactor and the safety of its utilization and (b) on the safety assessment of design, commissioning and operational issues. One of the committees shall also advise the reactor manager" ([1], para. 4.15). The duties of the safety committee(s) in commissioning should be detailed in the commissioning programme, and should include as a minimum the activities described in para. 4.28 of this Safety

[5] The commissioning group is the group of personnel to whom the operating organization has delegated the responsibility for commissioning. These persons may or may not be direct employees of the operating organization that retains the overall responsibility for their actions.

[6] The operating group is the group of personnel to whom the operating organization has delegated the responsibility for operating the reactor during the commissioning process. The operating group may include employees of other organizations (e.g. the reactor vendor) together with employees of the operating organization. In any case, the operating organization retains the overall responsibility for their actions.

Guide. Other groups, such as groups for quality management, radiation protection and design, may also be formed to participate in commissioning as necessary.

RESPONSIBILITIES

Operating organization

4.19. "The operating organization shall have the overall responsibility for the safety of the research reactor, which shall not be delegated" ([1], para. 7.2). The operating organization should have the overall responsibility for overseeing the satisfactory completion of all commissioning activities and should have the ultimate responsibility for safety during commissioning. The operating organization should also have the responsibility for setting up a commissioning organization and for ensuring that a management system for commissioning is established and put into effect.

4.20. The operating organization may delegate part or all of the activities of planning, establishing and implementing the commissioning programme, but remains responsible for its effectiveness.

4.21. As the holder of the licence, the operating organization should be the only correspondent with the regulatory body on commissioning matters, should maintain close contact with the regulatory body and should provide the regulatory body and the safety committee with the results and analyses of tests directly concerning safety. It should arrange for the required submissions to the regulatory body at the approved stages and should comply with the requirements of the regulatory body. Further, it should receive and disseminate the requirements of and information from the regulatory body.

4.22. If an issue having major safety significance is discovered during commissioning (e.g. in the regulatory body's review and assessment of submissions from the operating organization or as a result of deviations discovered during commissioning), the operating organization should ensure that the issue is subjected to safety analyses and to procedures for design, construction and commissioning that are equivalent to those for the reactor itself (see Ref. [1], para. 7.88). After satisfactory assessment, the operating organization and, if necessary, the regulatory body should approve the resumption of commissioning activities.

4.23. If the operating organization chooses to be the management group and to manage the commissioning directly, it should assume the additional responsibilities stated in para. 4.24 below. Alternatively, the operating organization may choose to appoint a management group with responsibilities and essential tasks as follows.

Management group

4.24. The responsibilities of the management group should include the following:

(a) Ensuring implementation of the management programme;
(b) Reviewing and approving the commissioning programme;
(c) Ensuring that the commissioning procedures are prepared, reviewed and approved by personnel with appropriate technical backgrounds and by appropriate committees;
(d) Defining the authorities and responsibilities of participating groups;
(e) Establishing lines of communication and personnel qualification and training needs, and carrying out reviews of the commissioning programme;
(f) Ensuring the participation of designers in formulating test objectives and acceptance criteria;
(g) Controlling, reviewing and coordinating activities that involve the participation of more than one group;
(h) Monitoring implementation of the commissioning programme;
(i) Resolving any problems between the participating groups;
(j) Ensuring the availability of sufficient properly trained, experienced, qualified and, where required, authorized personnel to carry out the commissioning activities;
(k) Ensuring that appropriate action is taken to correct any deficiencies identified during commissioning;
(l) Preparing the comprehensive commissioning report, with input and support from other involved groups.

Construction group

4.25. The responsibilities of the construction group relevant to the commissioning process should include the following:

(a) Ensuring that the installation of SSCs has been completed in accordance with design requirements and specifications, and that the SSCs are

maintained to prevent deterioration before being turned over to the commissioning group;

(b) Providing, for use as baseline data, as-built documentation of the installation and test certificates highlighting design changes and deviations that have been approved during the construction stage;

(c) Transferring responsibility for the installed systems to the commissioning group using a documented system;

(d) Assisting the management group in formulating test objectives and acceptance criteria, in evaluating test results, in correcting deviations and in revising documentation as necessary.

Commissioning group

4.26. The responsibilities of the commissioning group should include the following:

(a) Planning in advance the commissioning programme with detailed commissioning tests and preparing time schedules and procedures, including sequencing, prerequisites for tests, review points, and human resources and equipment needs;

(b) Ensuring that personnel engaged in commissioning activities are qualified for the level of responsibility and importance to safety of their work;

(c) Providing training as necessary for personnel engaged in commissioning activities;

(d) Interacting with the appropriate groups to establish commissioning test objectives and acceptance criteria;

(e) Establishing a procedure for the systematic recording of facility data for future use and for updating information;

(f) Establishing a procedure for configuration control to control deliberate and unintentional modifications of the facility;

(g) Establishing and implementing procedures to ensure the orderly transfer of responsibility for SSCs from the construction group to the commissioning group, including the identification of special precautions necessary for partly installed or deficient systems;

(h) Carrying out necessary maintenance on items transferred from the custody of the construction group to the commissioning group to prevent deterioration;

(i) Updating the commissioning programme on the basis of experience during commissioning and as a result of design modifications;

(j) Ensuring that the prerequisites for the commissioning tests are satisfied and confirming that the written procedures are adequate and are subjected to a review and approval process;
(k) Ensuring that the commissioning procedures comply with the appropriate rules and regulations, including rules and regulations for radiological protection and safety;
(l) Conducting the commissioning tests, including repeat testing of systems that have been commissioned initially as partially installed;
(m) Reporting to the operating organization any deficiency detected in commissioning in order that corrective actions can be taken;
(n) Ensuring that when design criteria are not met, design changes are requested, reviewed and implemented;
(o) Certifying that the commissioning programme has been satisfactorily completed;
(p) Issuing reports, certificates and completion assurance documentation, and maintaining the required records until transferred;
(q) Transferring responsibility for commissioned SSCs to the operating group using a documented system;
(r) Confirming that the written operating procedures to be used during routine operation are adequate;
(s) Withdrawing or removing procedures and equipment used in commissioning but not appropriate to normal operation;
(t) Ensuring that an opportunity is provided for operating personnel to gain experience by utilizing such personnel for commissioning activities as much as possible;
(u) Ensuring proper housekeeping in the facility during the commissioning activities.

Operating group

4.27. The responsibilities of the operating group relevant to commissioning should be:

(a) Participating in the commissioning activities and gaining practical training and experience in operation and maintenance of the facility;
(b) Ensuring that the systems to be transferred to the operating group comply with the requirements for design, performance and safety, and accepting responsibility for the transferred systems;
(c) Operating and maintaining the reactor in accordance with approved operating, maintenance and surveillance procedures during the commissioning;

(d) Updating and validating these procedures and other operational documentation, including the SAR and OLCs.

Safety committee(s) and regulatory body

4.28. "The commissioning programme shall be submitted to the safety committee and the regulatory body and shall be subjected to an appropriate review and assessment before being implemented" ([1], para. 7.44). In its review of the commissioning programme, the regulatory body should verify that its requirements for review and approval of results and witnessing of tests (para. 3.18(c) of this Safety Guide) are understood. The commencement of commissioning should be subject to the approval of the regulatory body following a satisfactory assessment of the submitted programme. In some instances the approval for the commissioning process may be granted stepwise. "The results and analyses of tests directly affecting safety shall be made available to the safety committee and the regulatory body for review and approval as appropriate" ([1], para. 7.45).

4.29. Before authorizing the loading of fuel, the regulatory body should complete the review and assessment of:

(a) The SAR;
(b) The OLCs;
(c) The specific OLCs for the commissioning of the facility;
(d) The management system;
(e) The arrangements for handling fuel;
(f) The emergency plan.

Also, the regulatory body should ensure that qualification procedures for the personnel needed to perform specified functions (such as reactor operation) are completed and that appropriate authorizations have been issued before authorizing fuel loading.

4.30. Before licensing and/or authorizing routine operation, the regulatory body should complete the review and assessment of the results of the commissioning programme and the updated SAR, including the OLCs.

Other groups

4.31. The responsibilities of any other groups that may be involved in the commissioning process should be established by the management group.

INTERFACES BETWEEN ACTIVITIES OF PARTICIPATING GROUPS

4.32. Since many activities are performed in parallel during the commissioning of the facility, the interfaces between these activities should be managed by the operating organization (or by the management group on behalf of the operating organization) to ensure the safety of personnel and of the facility and to ensure that the commissioning programme is not hindered.

4.33. Appropriate work control processes should be established to coordinate the activities of all groups involved and to cover the major work activities.

Interfaces between construction and commissioning activities

4.34. The responsibilities of the construction group before commissioning are discussed in para. 4.25 of this Safety Guide. The responsibilities of the construction group during the commissioning process should be well defined before commissioning is commenced to prevent misunderstandings. Particular areas where the construction and commissioning groups may have interfaces are:

(a) Special precautions necessary for the commissioning of partially installed systems;
(b) Return to the construction group of systems for rectification of defects discovered during commissioning tests;
(c) Retesting of equipment following intervention by the construction group;
(d) Certification by the construction group before systems are first energized.

Interfaces between commissioning and operating activities

4.35. The following particular topics should be considered in relation to the interfaces between commissioning and operating activities:

(a) Baseline data derived from commissioning and a statement of the existing radiological conditions;
(b) Changes in responsibility for safety, including the nomination of responsible persons;
(c) Conditions for access of personnel;
(d) Control of temporary procedures;
(e) Provision of and procedures for radiological monitoring and protection;
(f) Development of a plan and procedures for emergencies;

(g) Retaining during commissioning records that may have implications for decommissioning.

HANDOVER OF THE FACILITY

4.36. The operating organization should ensure that an appropriate procedure is in place for handover of the research reactor facility. Special care should be taken to ensure that the responsibilities for personnel, the facility and safety are clearly defined and rest with the appropriate organization at the appropriate time.

4.37. From the time of arrival of nuclear fuel at the site, responsibility for the safety of the facility is required to rest with the operating organization (see Ref. [1], para. 2.8).

4.38. Personnel to conduct a review should be designated by the operating organization receiving the handover package. In performing the review, meetings should be held and representatives of the organizations involved in the handover process should carry out facility walk-downs.

4.39. Documentation should be transferred in system or process packages and should include:

(a) General correspondence, system records and log books;
(b) Acceptance packages from the construction phase;
(c) Results of tests;
(d) As-built diagrams, including electrical, instrumentation, control and flow diagrams;
(e) Records of maintenance and surveillance;
(f) Vendor's manuals;
(g) Records of initial criticality tests, low power tests and power ascension tests;
(h) Radiological survey results for full power operation;
(i) An inventory of spare parts.

A final acceptance document that verifies that all parameters and conditions satisfy the acceptance criteria should be provided to the operating organization.

EMERGENCY PLANNING

4.40. The operating organization should ensure that an emergency plan with implementing procedures is in place and tested before the commencement of fuel loading. Non-nuclear hazards should be considered in the plan.

4.41. All individuals involved in the commissioning programme should be trained to cope with emergencies.

4.42. Requirements for actions to be taken in the event of a nuclear or radiological emergency are established in Ref. [10].

5. COMMISSIONING STAGES

GENERAL

5.1. The commissioning programme should be divided into stages (see paras 3.10 and 3.16). The group of tests to be carried out within each stage should be indicated, together with the point in the sequence of tests at which a review of the test results should be completed before continuing to the next stage.

5.2. On the basis of such a review, the management group should consider whether the commissioning programme should continue to the next stage, and whether the next stage should be modified as a consequence of the test results or because any tests in the stage were not undertaken or were not completed.

5.3. In addition, substages should be utilized during commissioning when necessary. The sequence of tests within each substage should be given in the chronological order in which they will be performed. A detailed list of tests and prerequisites to be considered for inclusion in a commissioning programme is provided in the Appendix.

5.4. At the appropriate commissioning stages, the relevant safety system settings and alarm settings, including those for radiological protection instruments, should be determined and used.

5.5. The sequencing of tests should be determined with account taken of the need for:

(a) Prior testing of systems necessary for testing other systems;
(b) Keeping certain systems operational during tests, for safety reasons;
(c) Confirming certain characteristics of the reactor or of systems, for operational or safety reasons;
(d) Grouping together those tests that should be completed before continuation to the next stage.

5.6. The sequencing of tests should be ordered so that the safety of the facility is not dependent on the performance of the component being tested.

5.7. Full in situ functional performance tests should be carried out for all systems important to safety and for those auxiliary and supporting systems necessary for their operation. Features that permit only partial testing should not jeopardize the functional requirements of the system as a whole.

5.8. Before the commencement of commissioning tests, the following supporting documentation should be prepared, reviewed, approved and issued in accordance with the policies of the operating organization (see Sections 6 and 7):

(a) Commissioning procedures, including related management requirements;
(b) Documentation, including design information, preliminary operating manuals, maintenance manuals, OLCs, surveillance and test procedures and emergency procedures;
(c) Construction documentation, including evidence of pre-construction environmental qualification testing of structures and equipment, construction test reports, construction deficiency lists and any accepted construction non-conformances;
(d) The SAR.

STAGES, TESTS AND PREREQUISITES

Stage A: Tests prior to fuel loading

5.9. In stage A, for the equipment scheduled to be commissioned in this stage, initial operational data should be recorded, functional performance should be verified and compatibility of operation with interfacing systems should be

confirmed. The pre-operational radiological area and environmental monitoring programme should be completed during stage A.

Prerequisites for stage A

5.10. The construction of SSCs should be essentially completed to the extent that outstanding construction items do not affect the validity of test results. Verification that construction conforms to facility drawings should be complete, as should other construction related inspections and tests. Some of these inspections and tests may have been performed at fabrication plants during the manufacture of important components as well as in workshops prior to the installation of components.

Tests for stage A

5.11. The completion of the tests for stage A is necessary before beginning stage B. Details of the tests to be performed in stage A are given in the Appendix.

5.12. Procedures should be established to ensure the adequate retesting of any SSCs that are returned to construction custody, maintained or modified during or following stage A.

5.13. To comply with the conditions of para. 5.11, a review should be carried out following stage A to verify that the test programme has been completed and reported, that any deviations have been identified and corrected, and that the tests to this point have been adequate to demonstrate that fuel loading tests, initial criticality tests and low power tests can be carried out in a safe manner ([1], para. 7.46). The review should confirm that the OLCs are adequate and practical, and any new constraints on operation of the facility should be identified.

Stage B: Fuel loading tests, initial criticality tests and low power tests

5.14. Tests conducted in stage B are intended to confirm that the reactor core, the reactivity control systems, the reactor shutdown and protection systems, other safety systems, reactor physics parameters, the characteristics of the core coolant system and the shielding, as appropriate, are satisfactory. Special care and precautions should be taken in the performance of these tests. Buildup of radioactive material during this stage should be kept to a minimum to facilitate the eventual solution of any problems relating to design and construction.

5.15. As soon as the reactor is made critical, all safety equipment, especially that which could not be tested before startup, should be tested at a low power level. A period of low power operation is advisable for the training of personnel.

5.16. Stage B may be divided into two substages as follows:

(a) B1: Fuel loading tests and initial criticality tests;
(b) B2: Low power tests.

A satisfactory review of results from stage B is necessary before proceeding to stage C.

Prerequisites for substage B1: Fuel loading tests and initial criticality tests

5.17. Radiation protection procedures and emergency procedures should be in place and personnel should be appropriately trained in them to cope with any accident that may occur during the commissioning process.

5.18. Reactor shutdown systems and appropriate startup instrumentation should be fully operable and capable of meeting their design requirements over the full range of operating conditions. There should be documented evidence of this capability that is satisfactory to the regulatory body (in particular, evidence of compliance with the established OLCs for commissioning).

5.19. Startup neutron monitoring instruments should be operable before commencing the approach to criticality. Neutron sources should be utilized in an appropriate geometric arrangement to obtain an adequate neutron count rate for this substage to ensure accurate measurements and adequate control.

5.20. A comprehensive list of prerequisites of substage B1 is given in the Appendix.

Tests for substage B1: Fuel loading tests and initial criticality tests

5.21. Fuel loading, removal of the absorber or addition of the moderator during the approach to criticality necessitates calculations or estimates to predict changes in core reactivity, and periodic measurements of subcritical multiplication to determine subsequent safe increments of reactivity. If the core subcriticality conditions measured during the approach to criticality deviate significantly from predictions made before the operations, further loading of

the core should be delayed until the deviations are analysed, the reasons for the deviations are determined, the implications are understood and appropriate corrective action is taken.

5.22. During this substage, anticipated future core configurations that may be required for the utilization programme should be tested.

Prerequisites for substage B2: Low power tests

5.23. The results of substage B1 should be recorded and reviewed. A satisfactory review of results from substage B1 is necessary before proceeding to substage B2.

Tests for substage B2: Low power tests

5.24. During this substage, significant irradiation of fuel and activation of reactor components should be avoided to facilitate subsequent inspections of the core and reactor components, if these are necessary.

5.25. Low power tests and measurements to be carried out include: reactivity measurements, including measurements of the reactivity worth of reactivity control mechanisms[7]; shutdown system tests; neutron flux mapping measurements; measurements of neutron and gamma radiation fields; tests of the primary coolant system; and confirmation of the response to loss of electric power supply.

5.26. The information obtained from the low power tests should provide assurance that there is no fundamental disagreement between the measured reactor parameters and those of the SAR. Any deviations observed should be investigated and resolved before continuation to the next stage.

5.27. In many instances, tests specific to a particular reactor type are required, and these should be performed, where possible, during this substage.

5.28. A review should be carried out following stage B to verify that the test programme has been completed and reported, that any deviations have been

[7] Reactivity control mechanisms are devices of all kinds for controlling the reactivity, including regulating rods, control rods, shutdown rods or blades, and devices for controlling the moderator level.

identified and corrected, and that the tests to this point have been adequate to demonstrate that power ascension tests and power tests can be carried out in a safe manner. The review should confirm that the OLCs are adequate and practical, and any new constraints on the operation of the facility should be identified. Training plans and operating procedures should be reviewed and modified where necessary to take account of the results of commissioning.

Stage C: Power ascension tests and power tests

5.29. Tests conducted during stage C are intended to confirm where practicable that the reactor can be operated at power in accordance with the OLCs, both for normal operation and during and after anticipated operational occurrences (e.g. power failure or loss of flow of the primary coolant).

5.30. During stage C, baseline data should be established for all safety related parameters that are routinely measured and monitored during operation, including initial system operating parameters and diagnostic data on components having significance for safety. These data will form a basis for the future assessment of degradation or trends in performance.

5.31. Stage C may be divided into two substages as follows:

(a) C1: Power ascension tests;
(b) C2: Power tests.

Prerequisites for stage C

5.32. The following prerequisites should be met before commencing stage C:

(a) Stage B commissioning tests should be completed, and their results should be evaluated and approved.
(b) Regulatory reviews should be carried out and approvals should be obtained as required.
(c) Full reactor systems, including the complete heat removal system, should be functionally proved and ready for full power operation.

Tests for substage C1: Power ascension tests

5.33. Power ascension should be performed in steps, as specified in procedures. At each step a series of tests should be carried out to confirm the design intent and the safety of continuing the power ascension. Data and results obtained in

the tests should be reviewed and any differences between the predicted and observed values should be reconciled before continuation to the next power level (see Ref. [1], paras 7.42 and 7.46).

Tests for substage C2: Power tests

5.34. During substage C2 the following tests should be carried out:

(a) Verification that the radiation dose rates in the facility are as expected and verification of the adequacy of the shielding;
(b) Verification that gaseous, liquid and particulate effluents are at anticipated and acceptable levels;
(c) Verification that reactor parameters and characteristics such as reactivity coefficients and the effects of xenon and other poisons are as anticipated and acceptable.

5.35. Following the demonstration of full power operation, tests and investigations should be carried out to demonstrate or verify various facility parameters associated with utilization or optimization. Within the approved operating envelope, these tests and investigations may include the following:

(a) Determination of contractual acceptance;
(b) Measurement of other effects of experimental equipment that were not previously covered;
(c) Measurement of fuel management parameters;
(d) Final evaluation of radiation measurements for operational, environmental and experimental purposes;
(e) Determination of the neutron flux and gamma field for beam tubes and irradiation facilities.

5.36. A review should be carried out following stage C commissioning to verify that any deviations have been identified and corrected, that the test programme has been adequate to demonstrate that the reactor facility can be operated in a safe manner, and that stage C commissioning has been completed satisfactorily and its results reported (see Ref. [1], paras 7.42, 7.48 and 7.49). The review should confirm that all measured parameters and conditions are within acceptable limits and that the OLCs are adequate. If necessary, any new constraints that may be required on operation of the facility should be specified. Training plans and operating procedures should be reviewed and modified where necessary to take into account the results of commissioning.

6. COMMISSIONING PROCEDURES AND REPORTS

PROCEDURES

6.1. "Procedures shall be prepared, reviewed and approved for each commissioning stage prior to the commencement of tests for that stage" ([1], para. 7.47). Procedures should also be prepared as necessary for other commissioning tasks such as tests. The procedures may also be used as an aid for assessing and documenting the results of tests. The commissioning procedures should include information that specifies:

(a) The objective of the procedure and, where appropriate, gives the reason for introducing the procedure (e.g. for validation of an assumption made in the safety analysis);
(b) All the activities that are necessary to confirm the operational acceptability of the item undergoing testing;
(c) Performance parameters that are to be measured under specified steady state and transient conditions;
(d) The requirements on performance, together with clearly stated acceptance criteria.

6.2. For certain commissioning activities, however, a generic procedure or list of instructions may be sufficient.

6.3. Commissioning procedures for testing equipment and systems should include the following:

(a) The title of the procedure;
(b) A check that the most recent approved version of the procedure is to be used;
(c) A summary of the purpose of the test, the equipment to be tested and the relationship of the test to the rest of the programme;
(d) The relationship of the procedure to other procedures;
(e) Expected results;
(f) Acceptance criteria;
(g) Test methods to be used;
(h) Prerequisites for testing and initial conditions;
(i) Safety provisions required to be in force during the test;
(j) Precautions to be taken, including, if necessary, stopping the test;
(k) Main body: test conditions and step by step instructions;

(l) A list of required calibrated instruments;
(m) Personnel requirements, duties, responsibilities and qualifications;
(n) A list of data to be recorded and checklists to be used;
(o) Analysis of data and results;
(p) Test completion certification;
(q) Reference list.

6.4. The test procedures should follow normal operating procedures for the facility to the extent practical, to check and, if necessary, to amend these procedures and to provide an opportunity for the operating personnel to become familiar with normal operating procedures for the facility.

6.5. Procedures should state any changes from the normal operating configuration that are necessary for testing. In this case, checks and confirmation should be undertaken to ensure that these changes are made correctly before the start of the tests and that the components or systems are restored to their normal status after the testing has been completed.

6.6. Procedures should include arrangements for collecting and tabulating data and test results (test sheets and forms) in accordance with the management system requirements discussed in Section 2. Methods of analysis should be stated and presented in a manner that allows further verification. Test data and results should be evaluated against acceptance criteria that clarify whether the design intent has been met. The uncertainties used in the safety analysis should be taken into account and deviations should be resolved.

REPORTS

6.7. The commissioning group should prepare summary reports following particular stages or substages where reviews and approvals are required and before commencement of subsequent stages or substages. The reports should be submitted to the management group (or the operating organization) and, as necessary, to other participants in the commissioning programme.

6.8. Formal reports for each test should be prepared and should be subject to approval by the commissioning group. The format of commissioning reports may vary, but the reports should include the following information:

(a) Title, authors, identification and distribution;
(b) Summary;

(c) References to appropriate test procedures;
(d) Summary of test methods and objectives;
(e) Summary of conduct of the tests (including dates), limitations, and problems or deficiencies and their resolution;
(f) Summary of data collected, analyses and non-conformances, including related details and conclusions;
(g) Evaluation of results, including statements that acceptance criteria have been met;
(h) Conclusions.

6.9. Stage test reports and a final commissioning report should be prepared by the commissioning group, in addition to individual test reports.

6.10. The management group should review the commissioning reports to ensure that the programme objectives have been achieved. In particular, the management group should ensure that the OLCs have been verified and that assumptions and predictions made in the SAR about the performance of the reactor have been confirmed.

6.11. The comprehensive commissioning report prepared by the management group upon the conclusion of commissioning activities should contain all information, including the collation and evaluation of test results.

6.12. The operating organization, after considering the commissioning reports from the management group, should submit them to the safety committee and the regulatory body. "In particular, the results and analyses of tests directly affecting safety shall be made available to the safety committee and the regulatory body for review and approval as appropriate" ([1], para. 7.45).

7. DOCUMENTATION

7.1. Procedures should be established in accordance with the management programme for commissioning to identify, collect, maintain, review, approve, issue, revise and archive documents.

7.2. Documentation on commissioning that is produced to describe the proposed commissioning activities, to provide results and their evaluation, to

resolve deviations, to permit the transfer of responsibilities for systems between groups, and to ensure that these activities have been correctly performed should be made available to, and should be retained by, the operating organization.

7.3. The commissioning documentation should cover or include the following:

(a) The management system for commissioning.
(b) The commissioning programme.
(c) A comprehensive commissioning report.
(d) Working files and related documents, including:
  — Checklists and logs;
  — Certificates and approvals;
  — Reports on significant events;
  — Reporting of deviations and their resolution;
  — Reporting of changes implemented.
(e) Management records and other records.
(f) Supporting documents, including: design reports, as-built engineering drawings, the SAR, operating procedures, OLCs, maintenance procedures and vendor specifications and data.

RECORD KEEPING

7.4. Two categories of records should be established: permanent and temporary.

7.5. Permanent records should be maintained for the lifetime of the facility. Permanent records are those records that meet one or more of the following criteria:

(a) They demonstrate a capability for safe operation.
(b) They demonstrate the cause of an accident or the malfunction of an item.
(c) They provide baseline data for periodic inspection.
(d) They are necessary for the maintenance, modification or replacement of an item.
(e) They will facilitate decommissioning.
(f) The regulatory body or other relevant organizations require them.

Specifications, procedures and results should be retained permanently as part of the facility's historical record.

7.6. Temporary records are those records that are necessary only to demonstrate the completion of activities in accordance with requirements. They need not be maintained after the completion of the activities has been reviewed and the activities are considered completed.

UPDATING THE SAFETY ANALYSIS REPORT

7.7. A summary of the commissioning programme and its results should be incorporated into the facility's SAR before the issuing of an operating licence for routine operation. For further guidance see Section A.1502 of Ref. [3].

8. COMMISSIONING OF NEW EXPERIMENTAL DEVICES AND MODIFICATIONS

GENERAL

8.1. Proposals for experimental devices[8] installed after completion of the reactor commissioning programme, new experiments not considered during the commissioning programme, and/or modifications to the reactor and the facility should be reviewed in accordance with paras 7.85–7.92 of Ref. [1] and the guidance in Ref. [2].

8.2. All new experimental devices, experiments and modifications should undergo commissioning to demonstrate functionality and safety. New experimental devices, experiments and modifications having major safety significance[9] should be subject to procedures for commissioning equivalent to those for the reactor itself ([1], para. 7.88), and the recommendations of this Safety Guide should be followed in full. New experimental devices, experiments and modifications not having major safety significance should be commissioned in accordance with the guidance given in paras 615–621 of Ref. [2].

[8] An experimental device is a device installed in or around a reactor to utilize the neutron flux and ionizing radiation from the reactor for research, development, isotope production or any other purpose.

[9] See para. 310 of Ref. [2].

8.3. New experimental devices, experiments or modifications not having major safety significance should be brought into service with appropriate regard to the verification of safety by means of a commissioning programme involving checks, measurements and evaluations prior to and during implementation.

8.4. To be considered adequate, a commissioning programme for those activities not having major safety significance should satisfy the objectives stated in para. 618 of Ref. [2].

8.5. The basis for final approval of the modification or experiment should be the successful completion of the commissioning. A commissioning report should be produced in which the results of the commissioning are presented and assessed. The report should be subject to approval by the reactor manager, the reactor safety committee and, if appropriate, the regulatory body.

8.6. Following the commissioning of new experimental devices and reactor modifications, the system documentation, drawings, SAR and operating procedures should be updated to reflect the new status. Further guidance on this topic is provided in paras 703–705 of Ref. [2].

EXTENSION OF COMMISSIONING PERIOD

8.7. For some new experiments and reactor modifications, a certain period of operation may be necessary before sufficient information on their effects on the operation, reliability and safety of the reactor can be obtained and evaluated. Paragraphs 701–706 of Ref. [2] provide further guidance on this post-implementation stage.

Appendix

PREREQUISITES AND TESTS FOR EACH STAGE OF COMMISSIONING

GENERAL

A.1. The number of tests and the order of their performance generally depend on the type of reactor and the circumstances of the facility project. Specific tests used for commissioning a power reactor are discussed in Ref. [4]. These tests should be evaluated for their applicability to the commissioning of research reactors.

A.2. The commissioning programme usually includes tests for all SSCs of the facility. For this purpose a graded approach to testing should be adopted, the extent and type of tests to be performed being determined on the basis of the importance to safety of each item and the overall hazard potential of the research reactor. Notwithstanding this, testing should be sufficiently comprehensive to establish the proper behaviour of the reactor in all modes analysed in the design, including, to the extent possible, anticipated operational occurrences. However, tests falling outside the range of assumptions used in the SAR are not usually conducted.

A.3. In establishing the commissioning tests, the design and safety documentation should be used. The design and construction groups should participate in the setting of the test objectives, requirements and acceptance criteria. Normally the designer or supplier will establish a minimum number of tests for contractual warranty purposes. These tests should be supplemented by additional tests, which should be discussed with the designer or supplier, to fulfil the objectives of the commissioning process and those of the operating organization. However, the set of tests should be agreed by all the organizations involved in commissioning and should be acceptable to the regulatory body.

A.4. The performance of tests should be scheduled in accordance with the recommendations in this Safety Guide. In general, when conducting testing, emphasis should be placed on safety systems and engineered safety features that are relied on for:

(a) Establishing conformance with the OLCs;

(b) Executing the safety functions of shutdown, heat removal, containment of radioactive material and mitigation of the consequences of any accidents at the facility.

A.5. The commissioning programme should also include verification tests covering all other systems necessary for the intended operation of the facility, in particular the area radiation monitoring system, the fire protection system and the communication system. Adequate consideration should be given to testing the experimental devices and their auxiliary equipment that will be commissioned together with the reactor. If computerized systems are used in performing tests, these systems should be validated.

A.6. During substage B1, the reactor core is loaded with fissionable material and becomes critical. The tests conducted during this substage cover the typical core configurations that may be necessary during the operational stage of the reactor. The measurement of reactor parameters in each of these core configurations should be made in a core of the minimum excess reactivity necessary for the measurement. The results of the tests should then be compared with the conclusions of the safety analysis and the neutronic calculations performed before beginning the commissioning process.

A.7. The items in this appendix should be included, as appropriate, in the procedures for testing fuel loading and the approach to criticality.

STAGE A

Prerequisites for stage A

A.8. Before the initial testing of any structure, system or component, the following points should be considered:

(a) Implementation of the management system for commissioning.
(b) Completion and documentation of the construction of equipment to be tested during stage A (e.g. records and certificates of installation and calibration, as well as operating and maintenance procedures or manuals for the equipment to be tested).
(c) Performance of preliminary tests and inspections to provide assurance that the equipment is ready for testing (e.g. verification that construction conforms to facility drawings; checks and verifications of records and status of equipment after installation; checks of continuity and separation

of wiring, interlocks and protective devices; initial operation and calibration of instruments; adjustment and setting of controllers and limit switches; tagging for handover purposes).

(d) Confirmation that test equipment is operable and calibrated.

(e) Performance of functional tests of individual components or subsystems, for example:
- Tanks, valves, pumps and pipes;
- Motors and generators;
- Fans and ventilation ducts;
- Instruments and controls.

(f) Completion of the writing and review of detailed procedures for stage A tests.

Tests for stage A

A.9. The primary prerequisite for testing the performance of fuel loading and the approach to criticality is the completion of stage A tests. The testing of systems (e.g. electrical systems, instrumentation systems, ventilation systems, water purification systems, water cleanup systems and water service systems) should be sequenced to ensure the availability of those systems that are necessary for implementation of the commissioning programme. In some cases, the repetition of workshop, fabrication and construction tests that have already been conducted may not be necessary provided that the test methods, results and documentation meet the requirements of the commissioning programme. However, these tests should be verified.

A.10. Representative stage A systems that should be tested are listed in the following, together with suggested tests. These tests should demonstrate the operability of the system concerned and, where appropriate, should verify redundancy.

(a) Auxiliary systems

Typical systems include systems for service water, instrument and service air, compressed gas, heating and normal ventilation, water purification, water cleanup, fire protection, and communications and alarms. Typical tests include:
- Demonstration of operability and, where appropriate, electrical independence of systems;
- Verification that communication and alarm devices are loud enough to be heard in the appropriate parts of the facility but that alarms are not so loud that they may interfere with communications.

(b) *Electrical systems*

Typical tests include:

— Ensuring that all electrical systems are checked and energized, adjusting voltage and frequency, testing starting load and full load, and verifying electrical independence;
— Checking the functioning of interlocks, instrumentation and control systems, emergency devices and lighting, indicating and alarm devices, protection devices, relays, circuit logic, transformers and breakers;
— Checking operation under simulated accident conditions and full loss of off-site power;
— Checking operation of emergency power initiating devices and the performance of emergency power systems;
— Battery discharge tests and verification of the capability of battery chargers, transfer devices and inverters.

(c) *Reactor structures*

Typical tests include:

— Checking dimensions, alignments, supports, position and fit of flow directing devices, dummy fuel assemblies, reflector elements and other relevant items.

(d) *Instrumentation and control systems*

Typical systems include the reactivity control systems, monitoring systems, indication systems, communication and alarm systems, startup instrumentation, safety and protection systems and computer systems. Typical tests include:

— Testing operation of functions for normal operation: regulation, control, monitoring, logging and operation of computer systems (hardware and software);
— Testing performance of the protection system, annunciation and alarms for anticipated operational occurrences and for remote monitoring and shutdown.

(e) *Reactivity control, reactor shutdown and protection systems*

Typical tests include:

— Checking dimensions, supports, and fit and clearances for reactivity control mechanisms;
— Demonstration of normal operation and scram; verification of response of computer programmes, drive mechanisms, sequencing, inhibits, interlocks, alarms, control room indication, rod position instrumentation, run-in timing and drop times;
— Verification of proper operation of safety system logic, trip and alarm settings, response time of measurement channels, redundancy tests, electrical independence and qualification requirements;

— Testing of proper operation in failure modes and with loss of electrical power.

(*f*) *Reactor vessel/tank and internals*

Typical tests include:

— Checking for secure installation of removable internals and, where appropriate, retainers such as seal wires, lock nuts or tack welds;
— Checking that the beam tube ports are aligned and plugs are fitted and sealed, and verification of leak tests;
— Verification of cleaning, fill and leak tests for pool and/or tank;
— Checking of recirculation, filtration, evaporation rate, purification and make-up systems, and the level and leakage indication.

(*g*) *Reactor primary and secondary coolant systems*

Typical systems and components include pumps, valves, piping, heat exchangers, cooling towers and instrumentation. Typical tests include:

— Checking clearances and mechanical supports and verification of leak tests;
— System and component tests, including calibration of flow and pressure measuring instruments, simultaneous operation of auxiliary systems, tests required by codes and standards, and pressure boundary tests;
— Operation at design flow and pressure, testing, where possible, for excessive vibration and recording baseline data;
— Checking the provisions for natural convection cooling.

(*h*) *Moderator systems*

Typical tests include:

— Checking and testing of system and components.

(*i*) *Emergency core cooling systems*

Typical systems include emergency water supply, make-up, injection or core spray, piping, supports and associated components. Typical tests include:

— Testing performance in all expected operating modes (under normal and emergency power supply), and proper operation of initiating devices, logic and set points.

(*j*) *Reactor building containment*

Typical systems include pool seals, containment penetrations, airlocks, isolation valves, emergency ventilation systems, recirculation systems, make-up systems, exhaust systems, filtering systems, air purification systems, and instrumentation and control systems. Typical tests include:

— Checking normal operation and heating and/or ventilation requirements;

— Checking isolation (operation, initiation and logic) and leak tests (full system and components), and verification of redundancy and electrical independence, and of fulfilment of qualification requirements and integrity requirements under accident conditions;
— When taking credit for containment, a leak rate test;
— When taking credit for exhaust filtration, verification of filter efficiency;
— Measurement of exhaust rate and differential pressure across building walls.

(k) Fuel storage and handling

Typical systems include cranes, shielded transfer flasks, bridges, handling tools, hot cells, storage facilities, alarms, ventilation systems, and security and safeguards related equipment. Typical tests include:

— Functional tests of all equipment, leak tests where required, and on-site equipment checking and training using a dummy fuel assembly.

(l) Radiation protection systems and waste disposal

Typical systems include process, effluent and area radiation monitors, radiation survey instruments, laboratory equipment for analysis, and systems and components to process, store, release or control the release of waste. Typical tests include:

— Functional tests of all equipment, response tests and calibrations;
— Leak tests of liquid waste disposal systems.

(m) Reactor component handling systems

Typical tests include:

— Load tests and functional tests of handling equipment and cranes.

(n) Experiments and experimental devices

Typical facilities for experiments include pool or reflector irradiation facilities, pneumatic capsule systems, loops and thermal columns, and associated instrumentation and control systems. Typical tests include:

— Verification of installation and removal, fit tests, and the proper operation of equipment, where possible at this stage;
— Leak tests.

STAGE B

Prerequisites for stage B[10]

A.11. In addition to the completion of the above tests and verifications, administrative measures and precautions should be in place as additional prerequisites. These should include:

(a) Security measures and access control, in particular of access to the reactor control room;
(b) Establishment of clear responsibilities of personnel in emergencies and criteria for the evacuation of buildings;
(c) Establishment of precautions for fuel handling to prevent damage or inadvertent criticality and to distinguish between differences in fuel types, enrichment levels and poison elements;
(d) Evaluation and approval of the test results referenced in para. A.4;
(e) Preparation of detailed procedures for substage B1;
(f) Other recommendations as indicated in the following paragraphs.

A.12. The following list presents minimum recommendations relating to the updating and availability of safety documentation:

(a) The current management system for commissioning.
(b) Completed review documentation concerning the items in para. A.10 as applicable.
(c) An updated SAR as required by the regulatory body. In particular, special attention should be given to items of non-conformance, deficiencies and modifications discovered during stage A and their resolution.
(d) Revisions of OLCs on the basis of stage A results, with justification.
(e) Operating procedures for the initial criticality should be prepared, reviewed and approved. The operating procedures should include:
   — Objectives and expected results as calculated;
   — OLCs for the startup instrumentation and other measuring channels;
   — Checklists and verification procedures for the startup instrumentation;

[10] In some Member States, a certificate is required by the regulatory body upon completion of prerequisites for stage B, and permission from the regulatory body to proceed may be required.

— The core geometry, including source and detector positions and the fuel loading plan in accordance with previous analysis;
— Fuel loading procedures, and administrative criteria and measures regarding results derived from the subcritical multiplication measurements, and estimated reactivity worth for the reactivity control mechanisms in subcritical cores; criteria may include hold points in the fuel loading process for re-evaluations;
— Procedures for measurements of subcritical multiplication;
— Organization and responsibilities for personnel participating in substage B1;
— Log books for the operation and for the fuel should be available to record sequentially all relevant operating actions and the location, status and transfers relating to the fresh fuel assemblies; adequate checklists and work permits should be available;
— Maintenance records should be updated in accordance with the results of testing and maintenance activities already performed.

A.13. The radiation protection programme for the facility should be implemented as soon as radioactive materials, including neutron sources and fuel assemblies, are introduced at the facility. The programme should include consideration of:

(a) Potential release of radioactive material to the environment during the commissioning process;
(b) Radiation doses to persons participating in the commissioning process;
(c) On-site radiological emergencies;
(d) Radiation protection equipment relating to the commissioning process, including area monitors and portable monitors;
(e) Inventory and transfer of radioactive sources;
(f) Training in radiation protection.

Radiation protection procedures should be established for the commissioning programme and should be approved by the operating organization.

A.14. Emergency procedures for the commissioning programme should be established and approved by the operating organization and, if required, by the regulatory body. These procedures should cover:

(a) Potential conventional risks associated with the commissioning process;
(b) Preparation for the management of on-site radiological emergencies and cooperation with appropriate authorities for potential off-site

emergencies caused by the research reactor during the commissioning process, if these are considered in the safety analysis;

(c) Provision of adequate training of personnel in emergency procedures.

Tests for substage B1: Fuel loading and approach to criticality

A.15. The tests and verifications listed in the following are illustrative of the types conducted during substage B1. (In the tests and verifications it is supposed that the approach to criticality is through progressive addition of fuel. For an approach to criticality through actions on the moderator, reflector or neutron absorbers, different steps and verifications may be appropriate.)

(a) Protection and reactivity control systems

— Testing of control functions, alarms, rod withdrawal and/or insertion speeds, sequences and indication;
— Checking of safety system trip settings, logic, operation and manual scram;
— Checking for friction problems in the movement or positioning of reactivity control mechanisms and guides;
— Performance of rod drop time measurements (with and without primary coolant flow) and verification of the operation of shock absorbers.

(b) Moderator and primary coolant system

— Flow tests for vibration during primary coolant flow, differential pressures across the core and major components, loss of flow and piping leakage;
— Water quality tests;
— Checking of friction or sticking problems when positioning solid moderator elements.

(c) Final test of neutron flux measuring equipment and alarms

— Checking of alarm and trip settings and actions with the neutron source.

(d) Fuel loading

— Performance of fuel loading in accordance with written procedures (performing a criticality experiment);
— Independent verification that fuel assemblies and reactivity control mechanisms have been properly placed in their correct positions according to an approved plan;
— Monitoring of the neutron count rates during fuel additions and during the movement of the reactivity control mechanisms for each of the individual fuel loads or subcritical cores planned;
— Establishment of criteria for reducing the incremental fuel additions because of the proximity of criticality.

(e) Subcritical reactivity measurements

— Increasing the core reactivity, step by step;
— Ensuring that the neutron flux is continuously monitored, that the reciprocal count rate is plotted against fuel loading, and that results are evaluated to predict criticality;
— Estimation of the critical mass and reduction of the fuel loading increment as criticality is approached;
— Preliminary estimates of the reactivity worth of the reactivity control mechanisms by means of subcritical multiplication measurements.

(f) Reactor close to criticality

— Taking precautions when moving the reactivity control mechanisms (e.g. reducing the amount of reactivity in each movement and waiting longer for the neutron count rate to stabilize);
— If necessary, making subcritical measurements at regular intervals during the movement of reactivity control mechanisms.

(g) Reactor critical

— Withdrawal of the neutron source, if possible, and readjustment of the position of the reactivity control mechanisms;
— Raising of the power sufficiently to bring the neutron count rate into a responsive range on the instrumentation for subsequent measurements;
— Performance of possible measurements of reactivity coefficients, and measurements of reactivity worth of reactivity control mechanisms (safety, compensating or regulating devices);
— Scramming the reactor and estimation of the reactivity worth of all the reactivity control devices, if possible.

Tests for substage B2: Low power tests

A.16. The following are examples of activities that should be carried out during substage B2:

(a) Reactivity measurements

— Establishment and verification of excess reactivity and reactor shutdown margin;
— Calibration of reactivity worth of regulating, compensating and safety reactivity control devices and other absorbers;
— Determination of reactivity coefficients (initial isothermal temperature coefficients of coolant, moderator and reflector coefficients, and void coefficients);

— Determination of the reactivity worth of in-core and reflector experimental devices such as loops, rigs, capsules and irradiation sites that have been installed.

(b) Control and shutdown system tests

— Verification of sensitivity and ranges of neutron instrumentation for indication, alarm, control and protection functions;
— Verification of operation of reactivity control functions such as reactivity insertion and/or removal sequencing, automatic power control, interlocks and computers;
— Verification of protection functions such as trip set points, alarms, timings and shutdown.

(c) Flux mapping measurements

— Global measurements in core and reflector, with the noting of effects of absorbers and different fuel types and/or enrichment;
— Establishment of neutron flux distributions, radial and axial power peaking factors, and critical power ratio;
— Local neutron flux mapping near fuel and absorbers;
— Calibration of neutron flux measurement channels and determination of the effect of experimental devices and reactivity control mechanisms on the sensors that cause reactor trips.

(d) Initial measurements and/or tests on neutron and gamma radiation fields

— Radiation surveys and verification of responses of radiation monitors.

(e) Primary coolant system tests

— Determination of in-core coolant flow distribution (if required), leakage, vibration, pressure drop and the effect of experimental devices and facilities;
— Verification of response to trips and loss of flow tests.

(f) Electrical systems

— Confirmation of correct responses to loss of electric power supplies.
— If possible, checking that full loading has no undesirable effects on the performance of instrumentation and control systems.

STAGE C

Prerequisites for stage C

A.17. The following activities should be carried out before starting stage C:

— Stage B commissioning tests should be completed and results should be evaluated and approved.

— Required reviews should be completed.
— Detailed operating and commissioning procedures should be prepared.

Tests for stage C

A.18. During stage C, the reactor power is raised in steps until full power is reached. Hold points are established at each step. Regulatory approval may be required to proceed. Tests and adjustments are performed at each step, as necessary. Of particular interest will be the performance of reactor protection and control systems, radiation surveys including shielding, validation of analytical models used for design and safety analysis, and the response of the reactor to anticipated operational occurrences, including transients.

A.19. Testing should be sufficiently comprehensive to establish that the facility can be operated safely, without placing the reactor in operating modes or conditions that fall outside the range of assumptions used in the safety analysis. Consideration should be given to testing at the extremes of system operating modes, and testing under simulated conditions of minimum availability of equipment if the facility is intended to be operated in these modes.

A.20. Tests that should be performed at relevant power levels include those listed below:

(a) *Reactivity measurements*
Measurement of temperature and power coefficients and of xenon poisoning.

(b) *Shutdown tests*
Scram tests to verify trips, including timing following simulated transients.

(c) *Channel calibrations*
Some of the following calibrations may have been initiated in stage B. However, they should be completed before reaching full power.
— Calibration of the power measuring channels;
— Calibration of safety system measurement channels and readjustment of the safety system settings accordingly;
— Evaluation of perturbations, asymmetry and flux tilts.

(d) *Validation of the instrumentation and control systems*
— Checking of performance of control systems, reactivity insertion and/or removal sequencing and interlocks;
— Checking of operation of other process control systems;

- Calibration and verification of instrumentation for flow, pressure, temperature, power, etc.;
- Checking of control computers: automatic reactor control system, validation of process variable inputs and performance outputs, effects of failures;
- Determination of xenon override characteristics on power reduction and shutdown.

(e) Verification of the operation of coolant and moderator systems

- Verification of bulk flow rate, channel and/or core flow, pressure drops, leakage and detection, vibration;
- Chemical analysis of the coolant and checking for radioactive contamination and of alarms for chemical and radiochemical control of the coolant;
- Natural circulation tests and checking of the performance of systems for decay heat removal;
- Checks of the performance of secondary and tertiary heat removal systems;
- Checks of the performance of auxiliary systems (coolant and/or moderator make-up systems, purification and/or cleanup systems, failed fuel detection systems, auxiliary cooling systems, moderator and/or reflector cooling systems);
- Verification of the reactor response to failures of the coolant system: pumps and valves.

(f) Evaluation of steady state core performance

- Verification of reactor power measurements;
- Verification of fuel and coolant temperatures and core thermal-hydraulic properties where practical by considering surface heat flux, linear heat rate and departure from nucleate boiling ratio, and by assessment of the critical heat flux;
- Verification that core limits are not exceeded for permitted modes and/or patterns of reactivity control devices.

(*g*) *Radiation measurements and tests*

- Verification of gamma and neutron radiation surveys and of the effectiveness of shielding, review of access control;
- Verification of responses and calibration of area radiation monitors.

(h) Radioactive effluent and waste system tests

- Verification of calibration of effluent and waste monitoring systems;
- Checks of operability of systems for processing, storage and release of gaseous and liquid waste.

(i) *Reactor building tests*
- Confirmation of performance of ventilation systems and air-conditioning systems (minimum permitted equipment availability at full power), and verification of performance of confinement and/or cleanup emergency systems, if not previously demonstrated.

(j) *Other auxiliary system tests*
- Verification of performance margins of auxiliary systems necessary for the operation of safety systems and engineered safety features or to maintain operating environments at minimum equipment design capability.

(k) *Confirmation of load carrying capability of equipment at full power.*

(l) *Verification of shutdown and monitoring capability remote from the control room, if required.*

(m) *Confirmation of proper performance following loss of electrical power at full power operation.*

(n) *Experiments and experimental devices*

The following are tests, measurements or verifications that should be performed either during stage C or during the commissioning of an individual experimental device. Some tests may necessitate critical experiments or the use of mock-ups.
- Measurement of neutron flux, spectra and gradients for experiments;
- Measurement of reactivity effect of experimental devices (insertion, removal, failure, void);
- Tests of effects of experimental devices on flux distributions and on the response of control and safety instrumentation;
- Tests of operation of instrumentation and control systems for experimental devices and auxiliary systems (e.g. emergency power system, cooling system);
- Tests of safety devices associated with experimental devices (alarms, shutdown systems, power setback systems) and any containment features;
- Functional tests of equipment for experimental devices (radioisotope production, heat supply, loop or rig tests, cold source devices, irradiators, beam tubes);
- Tests simulating failure of equipment (e.g. loss of loop cooling).

(o) *Preparation for routine operation*

Before commencing routine operation, the following items should be confirmed:
- Testing has been completed for major reactor experimental devices, baseline data have been obtained, demonstrations have been performed, and any necessary modifications or adjustments have been made.

— Operational documentation, such as operating procedures and OLCs, has been revised where necessary.
— Commissioning reports have been completed, the SAR has been revised to include the significant results, and an application has been made for a routine operating licence.

(p) Typical tests and activities that should be completed as operations proceed are the following:

— Collection of baseline data, tests, adjustments, modifications and parameter optimization to prepare the facility for routine operation;
— Re-evaluation of reactivity values over time (shutdown margin, worth of reactivity control mechanisms, etc.);
— Confirmation of predictions of fuel management and burnup estimates;
— Confirmation of adequacy of handling, storage and shipment of spent fuel;
— Determination of the effect of irradiation on core components and materials (e.g. creep);
— Development and confirmation of methods and procedures for experiments and utilization facilities;
— Confirmation of adequacy of radiation protection measures, including verification of remote monitoring instrumentation connected to the emergency centre;
— Establishment of baseline environmental monitoring data;
— Verification of unique operational modes (remote operation, pulsed modes, etc.);
— Verification of contractual requirements (e.g. production objectives, long term operation, supply of local heat);
— Verification of methods and equipment for utilization (e.g. for the production, handling, processing, storage and shipment of radioisotopes);
— Long term tests of prototypical features and equipment.

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GLOSSARY

anticipated operational occurrence[1]. An operational process deviating from normal operation which is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions.

audit. A documented activity performed to determine by investigation, examination and evaluation of objective evidence the adequacy of, and adherence to, established procedures, instructions, specifications, codes, standards, administrative or operational programmes and other applicable documents, and the effectiveness of their implementation.

commissioning[2]. The process by means of which systems and components of facilities and activities, having been constructed, are made operational and verified to be in accordance with the design and to have met the required performance criteria.

construction. The process of manufacturing and assembling the components of a facility, the carrying out of civil works, the installation of components and equipment and the performance of associated tests.

normal operation. Operation within specified operational limits and conditions.

operating organization. An organization applying for authorization or authorized to operate an authorized facility and responsible for its safety.

operational limits and conditions. A set of rules setting forth parameter limits, the functional capability and the performance levels of equipment and

[1] Examples of anticipated operational occurrences are loss of normal electrical power or malfunction of individual components

[2] The terms siting (site evaluation), design, construction, commissioning, operation and decommissioning are used to delineate major stages in the lifetime of a research reactor (see Ref. [1], para 3.4). Several stages may coexist, as, for example, construction and commissioning, when the actual activities do not interfere with each other.

personnel approved by the regulatory body for safe operation of an authorized facility.

operational states. States defined under normal operation and anticipated operational occurrences.

research reactor[3]. A nuclear reactor used mainly for the generation and utilization of neutron flux and ionizing radiation for research and certain other purposes.

(nuclear) safety. The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards.

safety analysis report. A document provided by the applicant to the regulatory body in support of an application for authorization, containing information concerning the nuclear facility, its design, the safety analysis and provisions to minimize the risk to the operating personnel, the public and the environment.

safety committee. A group of experts from the operating organization convened to advise on the safety of operation of an authorized facility.

safety limits. Limits on operational parameters within which an authorized facility has been shown to be safe. Safety limits are operational limits and conditions beyond those for normal operation.

safety system[4]. A system important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to

[3] For the purposes of this Safety Guide, the term research reactor also includes associated experimental facilities and critical assemblies.

[4] Safety systems can be of the active or passive type. Active systems or components are those that will initiate their assigned functions upon receiving an input signal from the protection system or manually. Passive systems or components are those that do not need an input signal to initiate their assigned functions. There is a recognized degree of passivity for safety systems that allows for a definition (not universally recognized) of three categories. The highest category is the one in which all the components needed for safety are passive.

limit the consequences of anticipated operational occurrences and design basis accidents.

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