

IAEA SAFETY STANDARDS

for protecting people and the environment

**Step 12: Editing of the draft
publication in MTCD and
endorsement of the draft
publication by the CSS**

**Reviewed in NSOC
(Shaw/Asfaw/Nikolaki)**

Commissioning of Research Reactors (Revision of NS-G-4.1)

DS 509A

DRAFT SAFETY GUIDE

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1. INTRODUCTION

BACKGROUND

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

1.2. This Safety Guide provides recommendations on the commissioning of research reactors, both commissioning of reactor modifications and experiments, and commissioning of the reactor itself.

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

- IAEA Safety Standards Series No. DS509B, Maintenance, Periodic Testing and Inspection of Research Reactors [2];
- IAEA Safety Standards Series No. DS509C, Core Management and Fuel Handling for Research Reactors [3];
- IAEA Safety Standards Series No. DS509D, Operational Limits and Conditions and Operating Procedures for Research Reactors [4];
- IAEA Safety Standards Series No. DS509E, The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors [5];
- IAEA Safety Standards Series No. DS509F, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors [6];
- IAEA Safety Standards Series No. SSG-10 (Rev. 1), Ageing Management for Research Reactors [7];
- IAEA Safety Standards Series No. SSG-37 (Rev. 1), Instrumentation and Control Systems and Software Important to Safety for Research Reactors [8].

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

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

1.6. This Safety Guide supersedes IAEA Safety Standards Series No. NS-G-4.1, Commissioning of Research Reactors¹.

¹ INTERNATIONAL ATOMIC ENERGY AGENCY, Commissioning of Research Reactors, IAEA Safety Standards Series No. NS-G-4.1, IAEA, Vienna (2006).

OBJECTIVE

1.7. The objective of this Safety Guide is to provide recommendations on the commissioning of research reactors, to meet the relevant requirements of SSR-3 [1], in particular Requirements 30 and 73.

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

SCOPE

1.9. 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. For research reactors of higher power, specialized reactors (e.g. fast spectrum reactors) and reactors having specialized facilities (e.g. hot or cold neutron sources, high pressure and high temperature loops), additional guidance may be needed. For such research reactors, the recommendations provided in IAEA Safety Standards Series No. SSG-28, Commissioning for Nuclear Power Plants [12] might be more suitable. Homogeneous reactors and accelerator driven systems are out of the scope of this publication.

1.10. Some research reactors, critical assemblies and subcritical assemblies with a low hazard potential might need a less comprehensive commissioning programme. While all recommendations in this Safety Guide are to be considered, some might not be applicable to such research reactors, critical assemblies and subcritical assemblies (see paras 2.15 – 2.17 and Requirement 12 of SSR-3 [1], and IAEA Safety Standards Series No. SSG-22, Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors [13]).

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

1.12. 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.

1.13. Additional guidance may be useful for certain modifications. In particular, recommendations on the commissioning of new digital systems are provided in SSG-37 (Rev. 1) [8].

STRUCTURE

1.14. Sections 2 and 3 provide recommendations on the management system for commissioning and on the commissioning programme, respectively. Section 3 includes general recommendations 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 recommendations 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 describes the general considerations, tests and prerequisites for the different stages of the commissioning programme. Reference to the Appendix is made when describing 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 for a research reactor.

2. APPLICATION OF THE MANAGEMENT SYSTEM TO THE COMMISSIONING OF A RESEARCH REACTOR

2.1. A management system that integrates safety, health, environmental, security, quality, human-and-organizational factor, societal and economic elements for the research reactor project is required to be developed: see Requirement 4 of SSR-3 [1]. The documentation of the management system should describe the system that controls the planning and implementation of all activities at the research reactor, including the development and implementation of the commissioning process. Approval of the management system (or parts thereof) by the regulatory body may be required, see para 4.12 of SSR-3 [1].

2.2. In accordance with paras 4.13–4.20 of SSR-3 [1], the management system is required to cover four functional categories, as follows:

- (a) Management responsibility: includes providing the means and management support needed to achieve the organization's objectives (see para. 2.14 of this Safety Guide).
- (b) 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 (see paras 2.15–2.18 of this Safety Guide).
- (c) Process implementation: includes those actions and tasks needed to achieve the goals of the organization (see paras 2.19–2.24 of this Safety Guide).
- (d) Measurement, assessment and improvement of the management system: includes activities conducted to evaluate the effectiveness of management processes and work performance (see paras 2.25–2.31 of this Safety Guide).

General requirements for the management system are established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [14]. Specific recommendations are provided in

IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installations [15].

2.3. As part of the management system, the arrangements for the management of the commissioning of the research reactor should be established and implemented by the operating organization early in the planning for commissioning. These arrangements 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. This should provide confidence that commissioning is performed in accordance with established codes, standards, specifications, procedures and administrative controls, as required by para. 4.16 of SSR-3 [1].

2.4. In establishing the management system, a graded approach in accordance with the relative importance to safety of each item or process is required to be used: see para. 4.7 of SSR-3 [1].

2.5. The objective of the management system as applied to commissioning should be to ensure that the facility meets the following:

- (a) Regulatory requirements;
- (b) Design requirements and assumptions;
- (c) The safety analysis report (see Requirement 1 of SSR-3 [1]);
- (d) The operational limits and conditions (OLCs) for the research reactor (see Requirement 71 of SSR-3 [1]);
- (e) Administrative requirements associated with the management of the research reactor.

2.6. The management system is required to support the development, implementation and enhancement of a strong safety culture: see paras 1.5(b) and 4.9 of GSR Part 2 [14]. This safety culture should be applied in all aspects of the commissioning programme.

2.7. The management system should describe how commissioning work is to be managed, performed, documented and assessed. The documentation of the management system is required to include the organizational structure, functional responsibilities, levels of authority and interfaces for those managing, performing and assessing the adequacy of work: see para. 4.16 of GSR Part 2 [14]. The management system should also address planning and scheduling of commissioning activities, resource allocation (see Requirement 9 of GSR Part 2 [14] and para. 4.15 of SSR-3 [1]) and human factors.

2.8. The application of the management system to commissioning should be described in the commissioning programme and documented in procedures and instructions. These procedures and instructions should document both the commissioning activities and the performance and verification of specific commissioning activities. The relevant requirements of the management system are required to be communicated to the personnel in the commissioning organization: see para. 4.26 of GSR Part 2 [14].

2.9. Requirement 11 of GSR Part 2 [14] states:

“The organization shall put in place arrangements with vendors, contractors and suppliers

for specifying, monitoring and managing the supply to it of items, products and services that may influence safety.”

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

2.10. Commissioning activities should be performed and recorded in accordance with the procedures and instructions documented in the management system.

2.11. The commissioning programme should include the following:

- (a) Planning and prioritization of work;
- (b) Addressing regulatory requirements;
- (c) Ensuring compliance with the OLCs;
- (d) Ensuring the availability of sufficient qualified personnel with suitable skills;
- (e) Appropriate procedures and instructions, including those for assessing and correcting non-conforming items;
- (f) Ensuring the availability of special instruments and equipment;
- (g) A satisfactory working environment, including suitable preparation of the workplace and suitable protection of workers;
- (h) Performing and documenting the necessary inspections and tests.

2.12. Documents essential to the performance and verification of commissioning activities (e.g. procedures, specifications and drawings) are required to be controlled: Requirement 8 of GSR Part 2 [14]. In particular, measures should be established for the preparation, identification, review, validation, approval, issue, distribution, revision and archiving of such documents. These measures should apply to the following:

- (a) Design documents, and any changes and revisions;
- (b) Commissioning procedures, instructions and drawings, and any changes and revisions;
- (c) Documents on equipment control and maintenance;
- (d) Documentation pertaining to calibration and control of measuring and test equipment;
- (e) Commissioning records and results;
- (f) Other records essential to the performance and verification of commissioning activities.

2.13. Methods should be established to manage non-conformances (see para. 7.48 of SSR-3 [1]), and to implement corrective actions and changes. Items, services and processes that do not meet their

specified performance requirements, including those that necessitate design changes, should be identified and reported to the appropriate level of management, and should be corrected in accordance with the arrangements for approving concessions, corrective actions and preventive actions (see also para. 7.76 of SSR-3 [1]). To ensure improvement, the causes of such non-conformances are required to be evaluated, and action is required to be taken to prevent their recurrence: see para. 6.3 of GSR Part 2 [14].

MANAGEMENT RESPONSIBILITY FOR COMMISSIONING OF A RESEARCH REACTOR

2.14. In accordance with Requirement 2 of SSR-3 [1], the operating organization (licensee) has the prime responsibility for the safety of the research reactor during commissioning. In cases where commissioning activities have been assigned to another organization, the organization performing these activities should be accountable to the operating organization. The reactor management² should participate in the commissioning programme by means of the following:

- (a) Having frequent contact with organizations and groups involved in the commissioning, including overseeing of work in progress;
- (b) Establishing and implementing a set of performance indicators for commissioning;
- (c) Participating in evaluations of the commissioning programme;
- (d) Providing feedback derived from commissioning performance indicators for use in the operation of the research reactor.

RESOURCE MANAGEMENT FOR COMMISSIONING OF A RESEARCH REACTOR

2.15. In accordance with para. 7.28 of SSR-3 [1], the competence requirements for personnel performing commissioning work are required to be determined. Suitable training is required to be provided (see paras 7.28 and 7.29 of SSR-3 [1]) to ensure that personnel are competent to perform their assigned work.

2.16. External personnel (e.g. personnel employed by vendors and suppliers) who perform commissioning activities should be appropriately trained and qualified. Such personnel should be able to demonstrate proficiency or adequate prior qualifications, training and experience. Paragraph 4.15(b) of SSR-3 [1] states:

“The management system shall ensure that...[e]xternal personnel (including suppliers and experimenters) are adequately trained and qualified and perform their activities under the same controls and to the same standards as the reactor personnel”.

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 have been assigned.

Research reactor supervisors should review the work of such personnel, during preparation for the work, during the work, and during testing.

2.17. Vendors and suppliers should be evaluated and selected on the basis of specified criteria. Paragraph 4.15 (a) of SSR-3 [1] states:

“The management system shall ensure that...[s]uppliers, manufacturers and designers of structures, systems and components important to safety have an effective integrated management system in place, with audits to confirm its effectiveness”.

Arrangements should be made with vendors and suppliers to ensure that the regulatory body is provided with any information that it has requested.

2.18. Paragraph 4.15(c) of SSR-3 [1] states:

“The management system shall ensure that...[t]he equipment, tools, materials, hardware and software necessary to conduct the work in a safe manner are identified, provided, checked and verified and maintained”.

The equipment should be suitable for its intended use. Equipment used for monitoring, data collection, and inspections and tests should have a valid calibration certificate and should be appropriately documented.

PROCESS IMPLEMENTATION FOR COMMISSIONING OF A RESEARCH REACTOR

2.19. 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.

2.20. The operating organization should nominate a person to be responsible and accountable for developing and documenting the commissioning programme, monitoring the performance of the programme, ensuring that the operating personnel are competent, and evaluating the impact of the programme on safety. This person is usually the reactor manager (see paras 7.13–7.19 of SSR-3 [1]).

2.21. In accordance with para. 4.16 of SSR-3 [1], commissioning is required to be performed in accordance with established engineering codes, standards, specifications, procedures and administrative controls.

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

2.23. Appropriate monitoring and measurement of SSCs should be performed to provide evidence of conformity to design requirements and satisfactory performance in service.

2.24. Paragraph 4.19, of SSR-3 [1] states that “Suppliers shall be evaluated and selected on the basis of specified criteria”. Such criteria should be developed and documented within the operating

organization's procurement process.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT OF THE MANAGEMENT SYSTEM IN COMMISSIONING OF A RESEARCH REACTOR

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

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

2.26. Suitable methods should be applied for monitoring the effectiveness of the commissioning programme. The methods should take into account the operational conditions expected during the operation and planned utilization of the research reactor.

2.27. Paragraph 7.54 of SSR-3 [1] states:

“The commissioning programme shall include provisions and procedures for audits, reviews and verifications intended to ensure that the programme has been conducted as planned and that its objectives have been fully achieved. Provisions shall also be included for resolving any deviation or deficiency that is discovered during the commissioning tests.”

2.28. An organizational unit should be established to conduct independent assessments of the commissioning programme. This organizational unit may be the reactor safety committee, as described in paras 7.26 and 7.27 of SSR-3 [1] and in para. 4.18 of this Safety Guide. Further requirements on the management of independent assessments and self-assessments are established in GSR Part 2 [14], and further recommendations are provided in GS-G-3.5 [15].

2.29. Independent assessment measures, including review and verification, should be established to ensure that commissioning activities are performed as specified in the appropriate procedures. These measures may include the following:

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

2.30. Qualified personnel should perform the verification of commissioning activities; these personnel should not be directly responsible for the commissioning activities being verified.

2.31. The audits referred to in para. 2.27 should determine the adequacy and effectiveness of, and adherence to, all aspects of the management system during the commissioning programme. In the audits

particular attention should be paid to the interfaces and transfers of responsibilities that occur between the different groups involved in construction, installation, commissioning and operation.

3. COMMISSIONING PROGRAMME FOR RESEARCH REACTORS

GENERAL OBJECTIVES OF THE COMMISSIONING PROGRAMME FOR A RESEARCH REACTOR

3.1. Requirement 30 of SSR-3 [1] states:

“The design for a research reactor facility shall include features as necessary to facilitate the commissioning process for the reactor facility, including experimental facilities. These design features may include provisions to operate with transient cores of different characteristics.”

3.2. Requirement 73 of SSR-3 [1] further states:

“The operating organization for a research reactor facility shall ensure that a commissioning programme for the research reactor is established and implemented.”

3.3. The commissioning programme should demonstrate that the design requirements and intent, as stated in the safety analysis report, have been met.

3.4. To meet Requirement 30 of SSR-3 [1], planning for the commissioning programme should begin at the design stage to permit interaction between the designers and the commissioning planners.

3.5. An additional commissioning programme is often necessary following reactor modifications or when installing new experimental devices having major safety significance. Further recommendations are provided in SSG-24 (Rev. 1) [10] and in Section 8 of this Safety Guide.

3.6. Paragraph 7.49 of SSR-3 [1] states:

“The detailed 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.”

A graded approach should be used by the reactor safety committee and the regulatory body in determining the appropriate level of this review and assessment.

3.7. Organizational arrangements necessary to achieve the objectives of the commissioning programme (see para. 7.51 of SSR-3 [1]) should be established. These arrangements should provide the basis for convenient and practical working arrangements that allow the optimum use of available personnel, instruments and methods. Section 4 of this Safety Guide provides further recommendations.

3.8. In accordance with para. 7.47 of SSR-3 [1], all anticipated operational modes of the research reactor, including the planned core arrangements and experimental set-ups, are required to be considered

in the commissioning programme. The planned core arrangements and the limitations on experiments should be included in the limiting conditions for safe operation during commissioning and should be verified during the commissioning process.

3.9. Paragraph 7.50 of SSR-3 [1] states that “Experimental devices and their potential impact on reactor operations shall be given adequate consideration during the commissioning of the reactor”. Some experimental devices may undergo commissioning at the same time as the reactor systems. The commissioning of such devices should be integrated into the reactor commissioning programme. 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. Further recommendations are provided in Section 8 and in SSG-24 (Rev. 1) [10].

3.10. Information on commissioning and operating experience from other similar facilities should be utilized in developing the commissioning programme (see also para. 6.23 and Requirement 88 of SSR-3 [1]).

3.11. In accordance with para. 7.47 of SSR-3 [1], the commissioning programme is required to include a programme for the testing of SSCs on the basis of their importance to safety. The Appendix contains recommendations on the necessary tests. While this requirement allows for the application of a graded approach to this testing, even SSCs with a lower safety significance 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 include acceptance criteria. Consequently, the commissioning programme is required to be divided into stages, in accordance with para. 7.52 of SSR-3 [1].

3.12. Hold points or witness points for review or inspection 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 design requirements and the requirements of the regulatory body have been met.

3.13. Procedures for radiation protection, for emergency preparedness and response, for nuclear security (including physical security and computer security) and for handling of nuclear material needed for commissioning should be established and referenced in the commissioning programme. The applicability of these procedures for use during routine operation should be validated.

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

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

The commissioning programme should include measures to ensure that commissioning activities on

SSCs important to safety do not compromise the function of the physical protection system, and vice-versa. Measures are required during commissioning to prevent inadvertent or intentional introduction of weaknesses, devices or any threat that could lead to a security breach (including a computer security breach) or radioactive releases: see para. 9.7 of SSR-3 [1].

FORMAT AND CONTENT OF THE DOCUMENTATION DESCRIBING THE COMMISSIONING PROGRAMME FOR A RESEARCH REACTOR

3.15. 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 documentation describing the commissioning programme for a research reactor should cover the following:

- (a) General description of the commissioning programme;
- (b) Organization and responsibilities;
- (c) Commissioning stages, with tests and prerequisites, and their scheduling;
- (d) Commissioning procedures and reports;
- (e) Documentation generated by the commissioning programme;
- (f) The parts of the management system that address the verification, review, audit and treatment of non-conformances (see paras 2.26–2.30).

General description of the commissioning programme

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

Organization and responsibilities

3.17. The documentation describing the commissioning programme should describe the organization responsible for commissioning, and should include an organizational chart. The functions and responsibilities of the organizations or groups involved and of key individual positions (e.g. the heads of the management group (see paras 4.10–4.14) and the commissioning group (see para. 4.16)) should be clearly presented. Further recommendations are provided in Section 4.

Commissioning stages, with tests and prerequisites, and their scheduling

3.18. The documentation describing the commissioning programme should describe the main stages in commissioning. As noted in para. 7.52 of SSR-3 [1], these stages are usually arranged in the following sequence:

- Stage A: tests prior to fuel loading;

- Stage B: fuel loading tests, initial criticality tests and low power tests;
- Stage C: power ascension tests and power tests up to rated full power.

Initial criticality tests, low power tests and Stage C tests are not applicable to subcritical assemblies, if adequate subcriticality has been verified. Stage C might not apply to some types of critical assembly that have power levels of zero or of just a few watts. Further recommendations on commissioning stages are provided in Section 5.

3.19. The documentation describing the commissioning programme should describe the main commissioning tests devised to demonstrate the safe operation within design specifications of all the research 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.

3.20. The documentation describing the commissioning programme should describe the schedule for performing the main tests. This schedule should include the following:

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

3.21. The documentation 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 supplies) that could be expected to occur over the lifetime of the research reactor. 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

3.22. The commissioning programme should include provisions for the preparation, review and approval of commissioning procedures, in accordance with para. 7.55 of SSR-3 [1]. A list of the procedures for the commissioning tests should also be included or should be appropriately referenced. Further recommendations are provided in Section 6 of this Safety Guide.

3.23. The commissioning programme should include provisions for the preparation of summary reports following particular stages or substages where reviews and approvals are necessary before commencement of the next stages, and for the preparation of the comprehensive commissioning report

upon conclusion of the commissioning tests. Further recommendations are provided in Section 6.

Documentation generated by the commissioning programme

3.24. The documentation describing the commissioning programme should include provisions for the documentation and archiving of commissioning records (see para. 7.55 of SSR-3 [1]), together with records of any design changes made, or concessions given. Further recommendations are provided in Section 7 of this Safety Guide.

3.25. As part of the commissioning programme, the safety documentation, including the safety analysis report and other documentation for the research reactor, should be revised as necessary on the basis of the results of the commissioning programme.

4. COMMISSIONING ORGANIZATION FOR RESEARCH REACTORS

4.1. A commissioning organization should be established by the operating organization of the research reactor. The operating organization should specify the following aspects of the commissioning organization:

- (a) Organizational structure;
- (b) Responsibilities and lines of communication;
- (c) Levels of authority;
- (d) The approval process;
- (e) Interfaces between participating groups.

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

- Activities connected with the final stage of construction and installation of the facility;
- Activities fulfilling specific needs of commissioning, including safety reviews;
- Activities connected with the operation of the facility.

Activities dealing with construction, commissioning and operation will interrelate during the commissioning process. The operating organization should therefore consider all these activities when establishing the commissioning organization.

4.3. The structure of a typical commissioning organization includes the following:

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

- (c) A commissioning group;
- (d) An operations group;
- (e) Other groups (e.g. the reactor safety committee) as necessary.

The roles of these groups are described in paras 4.10–4.21. 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 review and assessment, inspection and authorization at all stages of the commissioning programme.

4.4. There are many ways in which the groups described in para. 4.3 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. If 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, an overlap of personnel between the various groups is common. In such cases, responsibilities should be assigned so that the performance of tests and other functions and their verification are appropriately separated.

4.6. Other persons may participate in commissioning activities, such as representatives from designers, manufacturers and quality assurance organizations. They should collaborate with the groups described in para. 4.3, as appropriate. In particular, designers and manufacturers should provide the necessary information to enable each group to perform its function.

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 such activities and adequate time for preparation.

4.8. If the operating personnel are not already members of the commissioning 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 research reactor during commissioning. The aim should be for operating personnel to gain practical experience and to develop an ‘institutional memory’ of the facility. This will also help in achieving a smooth handover of the facility to the operating personnel when the commissioning process is completed.

ROLES WITHIN THE COMMISSIONING ORGANIZATION FOR A RESEARCH REACTOR

Operating organization

4.9. The operating organization may choose to be the management group and to manage the

commissioning directly. Alternatively, a separate management group may be appointed by the operating organization and made responsible for overseeing all commissioning activities, and to control and coordinate the activities of other groups participating in commissioning.

Management group

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 expertise in reactor physics, radiation protection and nuclear safety, and should have access to appropriate experts when needed.

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

4.15. The construction group is the group of personnel to whom the operating organization has delegated the responsibility for constructing the research reactor. These persons might or might not be directly employed by the operating organization that retains the overall responsibility for their actions. The construction group may consist of the designers, manufacturers, vendors, suppliers, installers and constructors for the research reactor. The construction group should ensure that the installation has been constructed in accordance with specifications as well as dealing with any deficiencies and modification identified during the commissioning programme.

Commissioning group

4.16. The commissioning group is the group of personnel to whom the operating organization has delegated the responsibility for commissioning. These persons might or might not be directly employed by the operating organization that retains the overall responsibility for their actions. The commissioning group should consist of personnel with a background and experience relevant to the SSCs to be commissioned. The commissioning group should ensure that SSCs are tested to provide assurance that the research reactor has been completed in accordance with the design intent, that operation of individual systems meets design requirements, and that the facility is ready for safe operation.

Operations group

4.17. The operations group is the group of personnel to whom the operating organization has delegated the responsibility for operating the reactor. The operations 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. The operations group should consist of personnel who have responsibility for the operation of the research reactor. In the context of the commissioning programme, the operations group should ensure that the operation of the facility is in accordance with the assumptions and intent of this programme. If necessary, qualification of appropriate members of the operations group in order that they can be authorized by the regulatory body (see para. 7.28 of SSR-3 [1]) to perform specified tasks (such as reactor operation) during and after fuel loading should be part of the commissioning programme.

Reactor safety committee

4.18. Requirement 6 of SSR-3 [1] states:

“A safety committee (or an advisory group) that is independent from the reactor manager shall be established to advise the operating organization on all the safety aspects of the research reactor.”

4.19. Paragraph 4.27 of SSR-3 [1] further states:

“The safety committee (or advisory group) shall advise the operating organization on: (i) the safety assessment of design, commissioning and operational issues; and (ii) relevant aspects of the safety of the research reactor and the safety of its utilization.”

4.20. The duties of the reactor safety committee(s) in commissioning should be described in the commissioning programme, and should include the responsibilities described in para. 4.34 of this Safety Guide.

Other groups

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

4.22. **ROLE OF THE REGULATORY BODY** The role of the regulatory body in the commissioning process for a research reactor is specified by the legal framework and national regulations. The main role of the regulatory body in the commissioning process (including the preparations for commissioning) is the oversight of commissioning activities, including, where appropriate, issuing relevant authorizations, as described in section 3 of SSR-3 [1]. The purpose of this regulatory oversight should be to ensure that the research reactor is constructed in accordance with the design intent and its licensing base and that the operating organization has made the necessary arrangements to progress from construction to operation.

RESPONSIBILITIES WITHIN THE COMMISSIONING ORGANIZATION FOR A

RESEARCH REACTOR

Operating organization

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

4.24. The operating organization has the overall responsibility for overseeing the satisfactory completion of all commissioning activities and has 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 management arrangements for commissioning are established, as described in Section 2.

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

4.26. With regard to the commissioning organization, as the licensee, the operating organization should be the only correspondent with the regulatory body on commissioning matters. Paragraph 7.51 of SSR-3 [1] states:

“Close liaison shall be maintained between the regulatory body and the operating organization throughout the commissioning process. 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.”

4.27. The operating organization should arrange for the required submissions to the regulatory body at the commissioning stage, and should disseminate information from the regulatory body on regulatory requirements to the relevant parts of the commissioning organization.

4.28. If an issue of 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 safety analyses are performed and that procedures for design, construction and commissioning that are equivalent to those for the reactor itself are applied. After satisfactory safety assessment, the resumption of commissioning activities should be subject to approval by the operating organization and, if necessary, the regulatory body.

4.29. 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. 4.30. Alternatively, the operating organization may choose to appoint a separate management group.

Management group

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

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

Construction group

4.31. The responsibilities of the construction group should include the following:

- (a) Ensuring that the installation of SSCs has been completed in accordance with design requirements and specifications, and that SSCs are maintained to prevent deterioration before the responsibility for these SSCs is transferred to the commissioning group;
- (b) Providing documentation of the as-built installation, and test certificates highlighting design changes and deviations that have been approved during the construction stage, for subsequent use as baseline data;
- (c) Transferring responsibility for the installed systems to the commissioning group using a documented system;

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

Commissioning group

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

- (a) Planning the commissioning programme, including detailed commissioning tests, and preparing schedules and procedures, including sequencing of commissioning activities, 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 data on the facility for future use, and a procedure for updating this data;
- (f) Establishing a procedure for configuration control to manage modifications (deliberate and unintentional) 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 any special precautions necessary for partially installed or deficient systems;
- (h) Performing necessary maintenance to prevent deterioration of SSCs for which responsibility has been transferred from the construction group to the commissioning group;
- (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 regulatory requirements, including requirements for protection and safety;
- (l) Conducting the commissioning tests, including repeat testing of systems that were initially commissioned when 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 necessary records until transferred;
- (q) Transferring responsibility for commissioned SSCs to the operations group using a documented system;
- (r) Confirming that the written operating procedures to be used during routine operation are adequate;
- (s) Withdrawing procedures and equipment used in commissioning that are 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 commissioning activities.

Operations group

4.33. The responsibilities of the operations group relevant to commissioning should include the following:

- (a) Participating in 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 operations 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 safety analysis report and OLCs.

Reactor safety committee

4.34. Paragraph 7.49 of SSR-3 [1] states that “The detailed commissioning programme shall be submitted to the safety committee...and shall be subject to appropriate review and assessment before being implemented.”

Other groups

4.35. The responsibilities of any other groups that may be involved in the commissioning process, such

as designers, manufacturers and technical support organizations, should be established by the management group and documented in the management system.

INVOLVEMENT OF REGULATORY BODY

4.36. In accordance with para. 7.49 of SSR3 [1], the detailed commissioning programme is required to be submitted to the regulatory body for review and assessment before being implemented. In its review of the commissioning programme, the regulatory body should verify that its requirements for the review and approval of test results and for witnessing of tests (see para. 3.20(c) of this Safety Guide) have been understood and correctly implemented. The commencement of commissioning should be subject to the approval of the regulatory body following a satisfactory assessment of the commissioning programme. In some cases, this approval may be granted step-by-step during the commissioning process.

4.37. Before authorizing the loading of fuel into the research reactor, the regulatory body needs to have completed the review and assessment of the following:

- (a) The safety analysis report (see paras 3.9–3.11 of SSR-3 [1]);
- (b) The OLCs (see para. 7.33 of SSR-3 [1]), including the specific OLCs for the commissioning of the research reactor;
- (c) The management system (see para. 4.12 of SSR-3 [1]);
- (d) The arrangements for handling fuel;
- (e) The emergency plan and procedures for on-site emergency preparedness and response, and the arrangements for coordination with off-site response organizations, as appropriate (see para. 7.90 of SSR-3 [1]);
- (f) Other documents, as required by the regulatory body.

The regulatory body should also ensure that the requirements for qualification and competence of personnel performing safety related activities (such as reactor operation) have been defined clearly by the operating organization in accordance with para. 7.28 of SSR-3 [1]. In addition, the regulatory body should ensure that appropriate authorizations (for the facility and, where appropriate, for certain operating positions) have been issued before fuel loading commences.

4.38. Before authorizing routine operation of the research reactor, the regulatory body should complete the review and assessment of the results of the commissioning programme and the updated safety analysis report, including the OLCs.

INTERFACES BETWEEN ACTIVITIES OF PARTICIPATING GROUPS IN THE COMMISSIONING OF A RESEARCH REACTOR

4.39. Since many activities are performed in parallel during the commissioning of a research reactor, 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 the effective and efficient implementation of the commissioning programme.

4.40. Appropriate work control processes should be established to coordinate the activities of all groups participating in the commissioning programme.

4.41. In accordance with para. 9.3 of SSR-3 [1], the operating organization is required to establish adequate measures during commissioning to ensure effective communication and coordination among the different groups involved to ensure that safety measures and security measures do not compromise one another.

Interfaces between construction activities and commissioning activities

4.42. The responsibilities of the construction group relevant to the commissioning programme are described in para. 4.31. These responsibilities should be defined before commissioning is commenced to prevent misunderstandings. Particular topics where the construction group and the commissioning group may have interfaces are as follows:

- (a) Special precautions necessary for the commissioning of partially installed systems;
- (b) Return of systems to the construction group 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.
- (e) Handover of the research reactor from construction to commissioning.

Interfaces between commissioning and operating activities

4.43. The following topics should be considered in relation to the interfaces between the commissioning group and the operating group:

- (a) Baseline data derived from commissioning
- (b) The existing radiological conditions;
- (c) Changes in responsibility for safety, including the nomination of responsible persons;
- (d) Conditions for access of personnel;
- (e) Control of temporary procedures;
- (f) Provision of and procedures for radiation monitoring and radiation protection;
- (g) Development of an emergency plan and procedures;
- (h) Retaining commissioning records that might have implications for decommissioning.

HANDOVER OF THE RESEARCH REACTOR FROM COMMISSIONING TO OPERATION

4.44. The operating organization should ensure that an appropriate procedure is established for handover of the research reactor following successful commissioning. Special care should be taken to ensure that responsibilities before and after the handover are clearly defined. Requirement 67 of SSR-3 [1] states that **“The operating organization for a research reactor facility shall have the prime responsibility for safety in the operation of the facility.”**

4.45. A review of the handover of the research reactor should be performed by personnel designated by the operating organization. In performing the review, meetings should be held, and representatives of the organizations involved in the handover process should perform facility walkdowns.

4.46. As part of the handover of the research reactor, documentation should be transferred in acceptance packages and should include the following:

- (a) General correspondence, system records and logbooks;
- (b) Acceptance records from the construction stage;
- (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) Radiation monitoring survey results for full power operation;
- (i) An inventory of spare parts and special tools.

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

EMERGENCY PREPAREDNESS FOR RESEARCH REACTORS

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

4.49. In addition, para. 7.89 of SSR-3 [1] states:

“Appropriate emergency arrangements shall be established from the time that nuclear fuel is first brought to the site, and all emergency arrangements shall be completed before the commencement of fuel loading”.

Non-radiation-related hazards should be considered in the emergency arrangements.

4.50. Requirements for such emergency arrangements are established in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [16].

4.51. All personnel involved in the commissioning programme are required to be trained to respond appropriately to emergencies: see para. 7.91 of SSR-3 [1].

5. COMMISSIONING STAGES FOR RESEARCH REACTORS

5.1. In accordance with para. 7.52 of SSR-3 [1], the commissioning programme is required to be divided into stages (see paras 3.11 and 3.18 of this Safety Guide).

5.2. The group of tests to be performed within each stage should be determined 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. 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. Substages should be utilized during commissioning when necessary. The sequence of tests within each substage should be specified 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 radiation monitoring instruments, should be determined and used.

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

- (a) The prior testing of systems that are needed for testing other systems;
- (b) The interdependence of various systems;
- (c) Keeping certain systems operational during tests, for safety reasons;
- (d) Confirming certain characteristics of the reactor or of systems, for operational or safety reasons;
- (e) Grouping together those tests that should be completed before continuing to the next stage.

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

5.7. Full in situ functional performance tests should be performed for all systems important to safety and for those auxiliary and supporting systems necessary for their operation. If only partial testing is possible, this should not jeopardize demonstrating the functional performance of the system as a whole.

5.8. Before starting the commissioning tests, the following documentation should be prepared, reviewed, made subject to approval and issued in accordance with the management system of the operating organization:

- (a) Commissioning procedures (see Section 6), including related management system requirements;
- (b) Documentation (see Section 7), including design information, preliminary operating manuals, maintenance manuals, OLCs, surveillance and test procedures and emergency procedures;
- (c) Construction documentation (see Section 7), 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 safety analysis report.

STAGES, TESTS AND PREREQUISITES FOR THE COMMISSIONING OF RESEARCH REACTORS

Stage A: Tests prior to fuel loading

5.9. For the equipment scheduled to be commissioned in stage A, initial operational data should be recorded, functional performance should be verified and compatibility of operation with interfacing systems should be confirmed. The pre-operational workplace monitoring programme and environmental monitoring programme should be completed during stage A.

Prerequisites for stage A

5.10. The construction of SSCs should be 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 inspections and tests that are related to the construction of the research reactor. Some of these inspections and tests may have been performed at fabrication plants during the manufacture of 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 proceeding to 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 the custody of the construction group, or that have been subject to maintenance or been modified during or following stage A.

5.13. To meet the requirements established in para. 7.54 of SSR-3 [1], a review should be conducted 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 performed in a safe manner.

The review should confirm that the OLCs are adequate and practical, and should identify any new constraints on operation of the research reactor.

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

5.14. Tests conducted in stage B should 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 all satisfactory. Measures should be taken to ensure that the buildup of radioactive material during this stage is kept to a minimum to facilitate any subsequent corrective actions that might be necessary.

5.15. Except for subcritical assemblies, as soon as the reactor is made critical, all safety equipment, especially equipment that 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. Initial criticality tests and low power tests might not apply to subcritical assemblies. Stage B tests of these assemblies might only comprise fuel loading and physics tests. For subcritical assemblies, all safety equipment should be tested after loading the required fuel assemblies, especially equipment that could not be tested before fuel loading.

5.17. A review of results from stage B is necessary before proceeding to stage C. These tests should confirm that the core design, including reactivity characteristics and neutronic performance, and the characteristics of safety systems and radiation protection systems are satisfactory. The information obtained from these tests should provide assurance that there is no significant disagreement between the measured parameters and those of the safety analysis report. Any deviations observed should be investigated and resolved.

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

- B1: Fuel loading tests and initial criticality tests;
- B2: Low power tests.

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

5.19. Procedures for radiation protection (see Requirement 84 of SSR-3 [1]) and procedures for emergency preparedness and response (see Requirement 81 of SSR-3 [1]) should be established and personnel should be appropriately trained in these procedures.

5.20. Reactor shutdown systems and the necessary startup instrumentation should be fully operable and capable of meeting 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).

5.21. Neutron monitoring instruments for reactor startup 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 substage B1 to ensure accurate measurements and adequate control.

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

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

5.23. Fuel loading and removal of the absorber or addition of the moderator during the approach to criticality necessitate 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 (or during the subcriticality verification test for subcritical assemblies) deviate significantly from the predicted conditions, further loading of the core should be paused until the deviations are analysed, the reasons for the deviations are determined, the implications are understood and appropriate corrective actions are taken.

5.24. For subcritical assemblies, adequate subcriticality should be verified (e.g. through $1/M$ calculations, where M is the subcritical neutron multiplication factor).

5.25. During substage B1, anticipated future core configurations that may be needed for the utilization programme should be tested.

Prerequisites for substage B2: Low power tests

5.26. The results of the tests performed in 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

5.27. Paragraphs 5.28–5.32 do not apply to subcritical assemblies (see para. 5.16 on Stage B commissioning tests of subcritical assemblies).

5.28. During substage B2, significant irradiation of fuel and activation of reactor components should be avoided to facilitate any subsequent inspections of the core and reactor components.

5.29. The low power tests and measurements to be conducted include the following:

- (a) Reactivity measurements, including measurements of the reactivity worth of reactivity control mechanisms³;
- (b) Shutdown system tests;
- (c) Neutron flux mapping measurements;
- (d) Measurements of neutron and gamma radiation fields;
- (e) Tests of the primary coolant system;

³ Reactivity control mechanisms are devices for controlling the reactivity, including regulating rods, control rods, shutdown rods or blades, and devices for controlling the moderator level.

(f) Confirmation of the response to loss of the electric power supply.

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

5.31. In many instances, tests specific to a particular reactor type are necessary, and these should be performed, where possible, during substage B2.

5.32. To meet the requirements established in para. 7.54 of SSR-3 [1], a review should be conducted following stage B 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 power ascension tests and power tests can be performed in a safe manner. The review should confirm that the OLCs are adequate and practical, and should identify any new constraints on the operation of the research reactor. 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

5.33. Tests conducted during stage C should, where practicable, confirm 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). Power ascension tests and power tests are not applicable to subcritical assemblies and to some types of critical assembly, which usually have power levels of zero or of just a few watts.

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

Prerequisites for stage C

5.35. 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) The regulatory body should review for approval the results of the stage B tests.
- (c) Full reactor systems, including the complete heat removal system, should be demonstrated to be fully functional and ready for full power operation.

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

- C1: Power ascension tests;

—C2: Power tests.

Tests for substage C1: Power ascension tests

5.37. Power ascension should be performed in steps, as specified in procedures. At each step, a series of tests should be performed to confirm the design intent and the safety of continuing the power ascension. The results obtained in the tests should be reviewed and any differences between the predicted and observed values should be reconciled before continuing to the next power level.

Tests for substage C2: Power tests

5.38. During substage C2 the following tests should be performed:

- (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.

5.39. Following the demonstration of full power operation, tests and investigations should be performed to demonstrate or verify various facility parameters associated with the utilization of the reactor and the optimization of protection and safety. 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 addressed;
- (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.

5.40. To meet the requirements established in para. 7.54 of SSR-3 [1], a review should be conducted 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 research reactor can be operated in a safe manner, and that stage C commissioning has been completed satisfactorily and its results reported. 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 on the operation of the research reactor 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 FOR

RESEARCH REACTORS

COMMISSIONING PROCEDURES FOR RESEARCH REACTORS

6.1. Paragraph 7.53 of SSR-3 [1] states that “Procedures shall be prepared, reviewed and made subject to approval for each commissioning test prior to the commencement of the tests.” Procedures should also be prepared as necessary for other commissioning tasks. The procedures may also be used as an aid for assessing and documenting the results of tests. The commissioning procedures should include the following:

- (a) The objective of the procedure and, where appropriate, 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 performance requirements, together with clearly stated acceptance criteria.

For certain commissioning activities, a generic procedure or list of instructions might be sufficient.

6.2. Commissioning procedures for testing equipment and systems in a research reactor should include the following:

- (a) The title and version number of the procedure;
- (b) A statement that the most recent approved version of the procedure is to be used;
- (c) A summary of the purpose of the test(s), the equipment to be tested and the relationship of the test(s) to the rest of the commissioning programme;
- (d) The relationship of the procedure to other procedures;
- (e) The expected results of the test(s);
- (f) Acceptance criteria;
- (g) Test methods to be used;
- (h) Prerequisites and initial conditions for testing;
- (i) Safety measures that need to be implemented during the test;
- (j) Precautions to be taken, including, if necessary, stopping the test;
- (k) The test conditions and step by step instructions;
- (l) A list of equipment needed to perform the tests (including calibrated monitoring instruments);

- (m) Type and number of personnel needed, and their duties, responsibilities and qualifications;
- (n) Procedure use and adherence;
- (o) A list of data to be recorded and checklists to be used;
- (p) The methods for analysis of test data and results;
- (q) The methods for certification of completed tests;
- (r) A list of references.

6.3. The test procedures should, as far as practicable, follow normal operating procedures for the research reactor, in order to check and, if necessary, to amend these procedures, and to provide an opportunity for the operating personnel to become familiar with the normal operating procedures for the research reactor.

6.4. The commissioning procedures should state any changes from the normal operating configuration that are necessary for testing. In such cases, checks should be undertaken to confirm 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.

6.5. Measures should be taken, where necessary, to prevent disruptive or adverse interactions between the SSCs of the research reactor and the equipment used for commissioning. In particular, care should be taken when connecting test equipment to instrumentation and control systems and when cross connecting fluid systems for commissioning purposes.

6.6. Procedures should include the arrangements for collecting and tabulating data and test results (test sheets and forms) in accordance with the management system. 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.

6.7. Paragraph 7.54 of SSR-3 [1] states that “Provisions shall also be included for resolving any deviation or deficiency that is discovered during the commissioning tests.”

COMMISSIONING REPORTS FOR RESEARCH REACTORS

6.8. The commissioning group should prepare summary reports following each commissioning stage or substage for which reviews and approvals are required and before proceeding with the commissioning programme. The reports should be submitted to the management group (or the operating organization) and, as necessary, to other participants in the commissioning programme.

6.9. 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; however, para. 7.55 of SSR-3 [1] states:

“The reports shall cover the following:

- (a) The purpose of the tests and the expected results;
- (b) The safety provisions required to be in force during the tests;
- (c) Precautions and prerequisites;
- (d) The test procedures;
- (e) The test reports, including a summary of the data collected and their analysis, and evaluation of the results, the identification of deficiencies, if any, and any necessary corrective measures.”

Statements confirming that acceptance criteria have been met as well as conclusions from the tests should also be included.

6.10. Reports of each commissioning stage and a final commissioning report should be prepared by the commissioning group.

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

6.12. A comprehensive commissioning report should be prepared by the management group upon the conclusion of commissioning activities. This report should contain all the necessary information, including the collation and evaluation of test results.

6.13. In addition to the formal commissioning reports, para. 7.51 of SSR-3 [1] states that “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”.

7. COMMISSIONING DOCUMENTATION FOR RESEARCH REACTORS

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

7.2. Paragraph 7.56 of SSR-3 [1] states:

“The results of all commissioning tests, whether conducted by a member of the operating organization or a supplier, shall be made available to the operating organization and shall be maintained for the lifetime of the facility.”

Other documentation on commissioning (e.g. to describe the proposed commissioning activities, to evaluate results, to resolve deviations, to permit the transfer of responsibilities for systems between groups, and to ensure that all these activities have been correctly performed) should also be made available to, and should be retained by, the operating organization.

7.3. The commissioning documentation should include the following:

- (a) The elements of the management system relevant to commissioning.
- (b) The commissioning programme.
- (c) The comprehensive commissioning report.
- (d) Working files and related documents, including the following:
 - (i) Checklists and logs;
 - (ii) Certificates and approvals;
 - (iii) Reports on significant events;
 - (iv) Reports of deviations and their resolution;
 - (v) Reports of changes implemented;
 - (vi) Walk downs and handover documentation from construction and commissioning (see para 4.46).
- (e) Management records.
- (f) Supporting documents, including design reports, as-built engineering drawings, the safety analysis report, operating procedures, OLCs, maintenance procedures and vendor specifications and data.

RECORD KEEPING FOR COMMISSIONING OF RESEARCH REACTORS

7.4. Two categories of records — permanent records and temporary records — should be established within the commissioning programme for a research reactor.

7.5. Permanent records are required to be maintained for the lifetime of the research reactor: see para. 7.56 of SSR-3 [1]. Permanent records are those records that meet one or more of the following criteria:

- (a) They demonstrate a capability for safe operation of the research reactor;
- (b) They demonstrate the cause of an accident or the malfunction of an item;
- (c) They provide baseline data for subsequent use in periodic inspections;
- (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 that the records are kept permanently.

7.6. Temporary records are those records that are necessary only to demonstrate the completion of activities in accordance with the commissioning stages. They need not be maintained after the completion of the activities, once such activities have been reviewed and are considered completed.

UPDATING THE SAFETY ANALYSIS REPORT FOR A RESEARCH REACTOR

7.7. A summary of the commissioning programme and its results should be incorporated into the research reactor's safety analysis report before the authorization of routine operation by the regulatory body. Further recommendations are provided in SSG-20 (Rev. 1) [9].

8. COMMISSIONING OF NEW EXPERIMENTAL DEVICES, EXPERIMENTS AND MODIFICATIONS

8.1. Proposals for experimental devices⁴ to be installed after completion of the research reactor commissioning programme, new experiments not considered during the commissioning programme, and/or modifications to the research reactor are required to be reviewed: see Requirement 83 of SSR-3 [1]. Recommendations on this subject are provided in SSG-24 (Rev. 1) [10].

8.2. All new experimental devices, experiments and modifications are required to be subject to an adequate commissioning programme to demonstrate functionality and safety prior to being placed in service: see paras 7.47 and 7.50 of SSR-3 [1].

8.3. In accordance with para. 7.101 of SSR-3 [1], new experimental devices, experiments and modifications having major safety significance (see section 3 of SSG-24 (Rev. 1) [10]) are required to be subject to commissioning procedures that are equivalent to those for the reactor itself, and the recommendations of this Safety Guide apply fully.

8.4. New experimental devices, experiments and modifications not having major safety significance should be commissioned in accordance with the recommendations provided in SSG-24 (Rev. 1) [10]. Such devices, experiments or modifications 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.

8.5. The basis for final approval of the experimental device, experiment or modification 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 review by the reactor safety committee, approval by the reactor manager, and, if appropriate, submitted to the regulatory body for review and approval.

⁴ 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.

8.6. Following the commissioning of new experimental devices, experiments and modifications, the system documentation, drawings, safety analysis report and operating procedures should be updated to reflect the new status.

EXTENSION OF THE COMMISSIONING PERIOD FOR NEW EXPERIMENTAL DEVICES, EXPERIMENTS AND MODIFICATIONS TO A RESEARCH REACTOR

8.7. For some new experimental devices, experiments and 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. SSG-24 (Rev. 1) [10] provides further recommendations on this post-implementation stage.

DRAFT

APPENDIX

PREREQUISITES AND TESTS FOR EACH COMMISSIONING STAGE OF A RESEARCH REACTOR

A.1. The number of commissioning tests and the order in which they are performed generally depends on the type of research reactor and the specific commissioning programme. Recommendations on commissioning tests for power reactors are provided in SSG-28 [12]; 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 research reactor. In accordance with Requirement 12 of SSR-3 [1], a graded approach to testing needs to 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 (see also para. 2.17 of SSR-3 [1]). Notwithstanding this, testing should be sufficiently comprehensive to establish the proper behaviour of the research 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 safety analysis report are not usually conducted.

A.3. In establishing the commissioning tests, the design and safety documentation should be used. The designers and the construction group should participate in establishing the test objectives and acceptance criteria. Normally, designers, vendors or suppliers 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, vendor or supplier, to fulfil the objectives of the commissioning programme. 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 paras 3.18–3.21 and Section 5 of this Safety Guide. In general, when conducting testing, emphasis should be placed on safety systems and engineered safety features that are relied on for the following:

- (a) Fulfilling the main safety functions described in Requirement 7 of SSR-3 [1] (i.e. control of reactivity, removal of heat from the reactor and from the fuel storage, confinement of radioactive material, shielding against radiation and control of planned radioactive releases, as well as limitation of accidental radioactive releases);
- (b) Conformance with OLCs.

A.5. The commissioning programme should also include verification tests covering all other systems necessary for the intended operation of the research reactor, in particular, the installed 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 (see SSG-37 [8]).

A.6. During commissioning substage B1 (see paras 5.19–5.25), the reactor core is loaded with fissionable material and becomes critical. The tests conducted during this substage should cover the typical core configurations that may be necessary during operation 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.

PREREQUISITES AND TESTS FOR COMMISSIONING STAGE A OF A RESEARCH REACTOR

Prerequisites for commissioning stage A

A.8. Before the testing of any SSC in stage A, the following points should be considered:

- (a) Implementation of the management system with regard to the commissioning programme.
- (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 as follows:
 - 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 commissioning 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 the further implementation of the commissioning programme. In some cases, repeating tests that have already been conducted (e.g. in workshops, or during fabrication and construction) might 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. The tests conducted during commissioning stage A should demonstrate the operability of systems and, where appropriate, should verify redundancy. The following are examples of tests and verifications that should be conducted during stage A:

- (a) Auxiliary systems⁵:
 - (i) Demonstration of the operability and, where appropriate, the electrical independence of systems;
 - (ii) Verification that communication and alarm devices are loud enough to be heard in the appropriate parts of the facility, but also that alarms are not too loud to interfere with communications.
- (b) Electrical systems:
 - (i) Ensuring that all electrical systems are checked and energized;
 - (ii) Adjusting voltage and frequency, testing the starting load and full load, and verifying electrical independence;
 - (iii) 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;
 - (iv) Checking operation under simulated accident conditions and full loss of off-site power;
 - (v) Checking operation of emergency power initiating devices and the performance of emergency power systems;
 - (vi) Battery discharge tests and verification of the capability of battery chargers, transfer devices and inverters.

⁵ 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.

- (c) Reactor structures:
 - (i) Checking dimensions, alignments, supports, position and fit of flow directing devices, dummy fuel assemblies, reflector elements and other relevant items.
- (d) Instrumentation and control systems⁶:
 - (i) Testing the operation of functions for normal operation, including regulation, control, monitoring, logging and operation of computer systems (hardware and software);
 - (ii) Testing the performance of the protection system, announcements and alarms for anticipated operational occurrences and for remote monitoring and shutdown.
- (e) Reactivity control, reactor shutdown and protection systems:
 - (i) Checking dimensions, supports, fit and clearances for reactivity control mechanisms;
 - (ii) Demonstration of normal operation and scram, including verification of the response of computer programmes and drive mechanisms, and verification of the performance of sequencing, inhibits, interlocks, alarms, control room indications, rod position instrumentation, run-in timing and drop times;
 - (iii) Verification of the proper operation of safety system logic and of trip and alarm settings, the response time of measurement channels, and the implementation of satisfactory provisions for redundancy, electrical independence and equipment qualification;
 - (iv) Verification of the proper response to failure modes and loss of electrical power supplies.
- (f) Reactor vessel (or tank) and internals:
 - (i) Checking for secure installation of removable internals and, where appropriate, retainers such as seal wires, lock nuts or tack welds;
 - (ii) Checking that the beam tube ports are aligned, and plugs are fitted and sealed, and verification of leak tests;
 - (iii) Verification of cleaning, fill and leak tests for the pool and/or tank;
 - (iv) Checking of recirculation, filtration, evaporation rate, purification and make-up systems, and the level and leakage indication.
- (g) Reactor primary and secondary coolant systems⁷:

⁶ Typical systems include the reactivity control systems, monitoring systems, indication systems, communication and alarm systems, startup instrumentation, safety and protection systems and computer systems.

⁷ Typical systems and components include pumps, valves, piping, heat exchangers, cooling towers and instrumentation.

- (i) Checking clearances and mechanical supports, and verification of leak tests;
 - (ii) System and component tests, including calibration of flow and pressure measuring instruments, simultaneous operation of auxiliary systems, tests required by applicable codes and standards, and pressure boundary tests;
 - (iii) Verifying correct operation at design flow and pressure, and testing (where possible) for excessive vibration and recording baseline data;
 - (iv) Checking the provisions for cooling by natural convection.
- (h) Moderator systems:
- (i) Checking and testing of system and components;
 - (ii) Verification of moderator systems flow and functional performance, using dummy reflector elements for loading, withdrawing and locking elements in core locations;
 - (iii) Verification of the operation of the water (heavy water) purification and recombination system.
- (i) Emergency core cooling systems⁸:
- (i) Testing the performance of the system in all expected operating modes (under the normal power supply and the emergency power supply), and the proper operation of initiating devices, logic and set points.
- (j) Reactor building containment⁹:
- (i) Checking the normal operation of the containment and the heating and/or ventilation systems;
 - (ii) Checking isolation (operation, initiation and logic), leak tests (full system and components), verification of redundancy and electrical independence, and of compliance with requirements for equipment qualification, and with integrity requirements under accident conditions;
 - (iii) When taking credit for containment, a leak rate test;
 - (iv) When taking credit for exhaust filtration, verification of filter efficiency;
 - (v) Measurement of exhaust rate and differential pressure across building walls.

⁸ Typical systems include emergency water supply, make-up, injection or core spray, piping, supports and associated components.

⁹ 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.

- (k) Fuel storage and handling¹⁰:
 - (i) Functional tests of all equipment, leak tests where necessary, and checking on-site equipment and training of personnel using a dummy fuel assembly.
- (l) Radiation protection systems and waste disposal systems¹¹:
 - (i) Functional tests of all equipment, response tests and calibrations;
 - (ii) Leak tests of liquid waste disposal systems.
- (m) Reactor component handling systems:
 - (i) Load tests and functional tests of handling equipment and cranes.
- (n) Experiments and experimental devices¹²:
 - (i) Verification of installation and removal of devices, fit tests and, where possible, verification of the proper operation of equipment;
 - (ii) Leak tests.

PREREQUISITES AND TESTS FOR COMMISSIONING STAGE B OF A RESEARCH REACTOR

Prerequisites for commissioning stage B

A.11. In addition to the completion of the stage A tests and verifications, administrative measures and precautions should be implemented as additional prerequisites for commissioning stage B¹³. These should include the following:

- (a) Access control, in particular for access to the research reactor control room. Guidance on access control for nuclear security purposes is provided in the IAEA Nuclear Security Series [17–19];
- (b) Establishment of 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;

¹⁰ Typical systems include cranes, shielded transfer flasks, bridges, handling tools, hot cells, storage facilities, alarms, ventilation systems, and security and safeguards related equipment.

¹¹ Typical systems include process, effluent and other installed radiation monitors, portable radiation survey instruments, laboratory equipment for analysis, and systems and components to process, store, release or control the release of waste.

¹² Typical facilities for experiments include pool or reflector irradiation facilities, pneumatic capsule systems, loops and thermal columns, and associated instrumentation and control systems.

¹³ In some States, a certificate is required by the regulatory body upon completion of prerequisites for stage B, and permission to proceed might be required from the regulatory body.

- (d) Evaluation and approval of the results of the test referred to in para. A.10
- (e) Preparation of detailed procedures for commissioning substage B1.

A.12. At a minimum, the following documentation should be available before the start of commissioning stage B1:

- (a) The management system, updated as necessary following commissioning stage A.
- (b) Completed reviews of the results of the commissioning tests in stage A (see para. A.10).
- (c) An updated safety analysis report, as required by the regulatory body. Special attention should be given to non-conformances, deficiencies and modifications discovered during stage A, and their resolution.
- (d) Revisions of OLCs on the basis of the results of tests in commissioning stage A, with justification for these revisions.
- (e) Reviewed and approved operating procedures for the establishment of initial criticality. These operating procedures should include the following:
 - (i) Objectives of the substage B1 tests, and the expected results.
 - (ii) OLCs for the startup instrumentation and other measuring channels.
 - (iii) Checklists and verification procedures for the startup instrumentation.
 - (iv) The core geometry, including source and detector positions and the fuel loading plan in accordance with previous analyses.
 - (v) 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. These criteria may include hold points in the fuel loading process to allow re-evaluations.
 - (vi) Procedures for measurements of subcritical multiplication, and, for subcritical assemblies, the procedure for measuring the subcriticality margin.
 - (vii) Organization and responsibilities for personnel participating in substage B1.
- (f) Logbooks to sequentially record all relevant operating actions and the location, status and transfers of fresh fuel assemblies;
- (g) Checklists and work permits;
- (h) Maintenance records, updated to take into account the results of testing and maintenance activities already performed.

A.13. Radiation protection procedures should be established for the commissioning programme and should be subject to approval by the operating organization. A radiation protection programme for the

research reactor should be implemented as soon as radioactive materials, including neutron sources and fuel assemblies, are introduced at the facility. This programme should include consideration of the following:

- (a) Potential release of radioactive material to the environment during the commissioning process;
- (b) Occupational exposure of persons participating in the commissioning programme;
- (c) Arrangements for emergency preparedness and response;
- (d) Radiation protection equipment relating to the commissioning process, including installed monitoring system, portable monitors and contamination monitors;
- (e) Inventory and transfer of radioactive sources;
- (f) Training in radiation protection.

Recommendations on the content of a radiation protection programme are provided in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [20].

A.14. Emergency procedures for the commissioning programme should be established and made subject to approval by the operating organization and, if required, by the regulatory body. These procedures should address the following:

- (a) Potential non-radiation-related risks associated with the commissioning programme;
- (b) The management of on-site emergencies and cooperation with appropriate authorities for potential off-site emergencies during the commissioning process, if these are considered in the safety analysis;
- (c) Training of personnel in emergency procedures;
- (d) Provision of drills and exercises.

Tests for commissioning substage B1: Fuel loading and approach to criticality

A.15. The following are examples of tests and verifications that should be conducted during substage B1 (it is assumed 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). Some of these tests (e.g. those marked with *) might not be applicable to subcritical assemblies:

- (a) Protection and reactivity control systems:
 - (i) Testing of control functions, alarms, rod withdrawal and/or insertion speeds, sequences and indications;
 - (ii) Checking of safety system trip settings, logic, operation and manual scram;
 - (iii) Checking for friction problems in the movement or positioning of reactivity control

- mechanisms and guides;
- (iv) *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:
- (i) *Flow tests for vibration during primary coolant flow, tests for differential pressures across the core and major components, loss of flow and piping leakage;
 - (ii) Water quality tests;
 - (iii) Checking of friction or sticking problems when positioning solid moderator elements.
- (c) Neutron flux measuring equipment and alarms:
- (i) Final test of alarm and trip settings and actions, using the neutron source.
- (d) Fuel loading:
- (i) Satisfactory performance of fuel loading, in accordance with written procedures (i.e. performing a criticality experiment, except in the case of a subcritical assembly);
 - (ii) Independent verification that fuel assemblies and reactivity control mechanisms have been properly placed in their correct positions, in accordance with an approved plan;
 - (iii) Monitoring of the neutron count rates during fuel additions and during the movement of the reactivity control mechanisms for each of the planned individual fuel loads or subcritical cores;
 - (iv) Establishment of criteria for reducing the incremental fuel additions because of the proximity of criticality.
- (e) Subcritical reactivity measurements:
- (i) Satisfactorily increasing the core reactivity, step by step;
 - (ii) Verification 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 or, in the case of subcritical assemblies, the subcriticality margin;
 - (iii) Estimation of the critical mass and reduction of the fuel loading increment as criticality is approached;
 - (iv) Preliminary estimates of the reactivity worth of the reactivity control mechanisms by means of subcritical multiplication measurements.
- (f) Reactor close to criticality:
- (i) Ensuring that adequate precautions are taken 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);

(ii) If necessary, making subcritical measurements at regular intervals during the movement of reactivity control mechanisms;

(iii) For a subcritical assembly, confirmation of the specified subcriticality margin.

(g) *Reactor critical (not applicable to subcritical assemblies):

(i) Satisfactory withdrawal of the neutron source, if possible, and readjustment of the position of the reactivity control mechanisms to maintain criticality;

(ii) Satisfactory raising of the power to bring the neutron count rate into a responsive range on the instrumentation for subsequent measurements;

(iii) Where possible, measurements of reactivity coefficients and the reactivity worth of reactivity control mechanisms (safety, compensating or regulating devices);

(iv) Scramming the reactor and estimating the reactivity worth of all the reactivity control devices, if possible.

A.16. . The following are examples of additional tests and verifications that should be conducted, as applicable, for subcritical assemblies in substage B1:

(a) Control and shutdown system:

(i) Verification of the sensitivity and ranges of neutron instrumentation for indications, alarms, control and protection functions.

(b) Flux mapping measurements:

(i) Global measurements in core and the reflector, noting the effects of absorbers and different fuel types and/or enrichment;

(ii) Establishment of neutron flux distributions, radial and axial power peaking factors, and critical power ratio;

(iii) Local neutron flux mapping near fuel and near absorbers;

(iv) 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.

(c) Initial measurements of neutron and gamma radiation levels:

(i) Radiation surveys and verification of responses of radiation monitors.

(d) Electrical systems:

(i) Confirmation of correct responses to loss of electrical power supplies.

Tests for commissioning substage B2: Low power tests (not applicable to subcritical assemblies)

A.17. The following are examples of tests and verifications that should be performed during substage B2:

- (a) Reactivity measurements:
 - (i) Establishment and verification of excess reactivity and the reactor shutdown margin;
 - (ii) Determination of the reactivity worth of regulating, compensating and safety reactivity control devices and other absorbers;
 - (iii) Determination of reactivity coefficients (initial isothermal temperature coefficients of coolant, moderator and reflector coefficients, and void coefficients);
 - (iv) 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:
 - (i) Verification of the sensitivity and ranges of neutron instrumentation for indications, alarms, control and protection functions;
 - (ii) Verification of operation of reactivity control functions such as reactivity insertion and/or removal sequencing, automatic power control, interlocks and computers;
 - (iii) Verification of protection functions such as trip set points, alarms, timings and shutdown.
- (c) Flux mapping measurements:
 - (i) Global measurements in the core and the reflector, noting the effects of absorbers and different fuel types and/or enrichment;
 - (ii) Determination of neutron flux distributions, radial and axial power peaking factors, and critical power ratio;
 - (iii) Local neutron flux mapping near fuel and near absorbers;
 - (iv) 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) Measurements of neutron and gamma radiation levels:
 - (i) Radiation surveys and verification of responses of radiation monitors.
- (e) Primary coolant system:
 - (i) Determination of in-core coolant flow distribution (if necessary), leakage, vibration, pressure drop and the effect of experimental devices and facilities;

- (ii) Verification of response to trips and loss of flow tests.
- (f) Electrical systems:
 - (i) Confirmation of correct responses to loss of electrical power supplies;
 - (ii) If possible, checking that full loading has no undesirable effects on the performance of instrumentation and control systems.

PREREQUISITES AND TESTS FOR COMMISSIONING STAGE C OF A RESEARCH REACTOR

Prerequisites for commissioning stage C (not applicable to subcritical assemblies)

A.18. The following activities should be performed before starting stage C:

- (a) The stage B commissioning tests should be completed, and the results should be evaluated and approved.
- (b) The reviews of the stage B commissioning tests should be completed.
- (c) Detailed operating and commissioning procedures for stage C should be prepared.

Tests for commissioning stage C (not applicable to subcritical assemblies)

A.19. During stage C, the reactor power should be raised in steps until full power is reached. Hold points should be established at each step. The approval of the regulatory body might be required before proceeding. Tests and adjustments should be performed at each step, as necessary. Of particular interest will be the performance of the research reactor protection and control systems, the results of radiation surveys to confirm the provision of adequate shielding, the validation of analytical models used for design and safety analysis, and the response of the reactor to anticipated operational occurrences, including transients.

A.20. Testing should be sufficiently comprehensive to establish that the research reactor 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.21. The following are examples of tests and verifications that should be performed at relevant power levels during stage C:

- (a) Reactivity measurements:
 - (i) Measurement of temperature, power coefficients and xenon poisoning.
- (b) Shutdown tests:

- (i) 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.

 - (i) Calibration of the power measuring channels;
 - (ii) Calibration of safety system measurement channels and readjustment of the safety system settings accordingly;
 - (iii) Evaluation of perturbations, asymmetry and flux tilts.
- (d) Instrumentation and control systems:
 - (i) Checking the performance of control systems, reactivity insertion and/or removal sequencing and interlocks;
 - (ii) Checking the operation of other process control systems;
 - (iii) Calibration and verification of instrumentation for flow, pressure, temperature and power;
 - (iv) Checking of control computers and the automatic reactor control system, validation of process variable inputs and performance outputs, and checking the effects of failures;
 - (v) Determination of xenon override characteristics during power reduction and shutdown.
- (e) Coolant and moderator systems:
 - (i) Verification of bulk flow rate, channel and/or core flow, pressure drops, leakage and detection, vibration;
 - (ii) Chemical analysis of the coolant, and checking for radioactive contamination and of alarms for chemical and radiochemical control of the coolant;
 - (iii) Natural circulation tests and checking of the performance of systems for decay heat removal;
 - (iv) Checks of the performance of secondary and tertiary heat removal systems including chemical and biological analysis where necessary;
 - (v) 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);
 - (vi) Verification of the reactor response to failures of the coolant system, including failures of pumps and valves.
- (f) Evaluation of steady state core performance:

- (i) Verification of reactor power measurements;
 - (ii) Verification of fuel and coolant temperatures and core thermohydraulic 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;
 - (iii) Verification that core limits are not exceeded for permitted modes and/or patterns of reactivity control devices.
- (g) Measurements of neutron and gamma radiation levels:
- (i) Verification of the results of gamma and neutron radiation surveys and of the effectiveness of shielding;
 - (ii) Review of access control;
 - (iii) Verification of responses and calibration of installed and portable radiation monitors.
- (h) Radioactive effluent system and waste monitoring system:
- (i) Verification of calibration of the effluent monitoring system and the waste monitoring system;
 - (ii) Checks of operability of other systems for processing, storage and release of gaseous and liquid waste.
- (i) Reactor building:
- (i) Confirmation of the performance of ventilation systems and air-conditioning systems (minimum permitted equipment availability at full power), and verification of the performance of the confinement and/or cleanup emergency systems, if not previously demonstrated.
- (j) Other auxiliary systems:
- (i) Verification of the 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;
 - (ii) Confirmation of load carrying capability of equipment at full power;
 - (iii) If applicable, verification of shutdown and monitoring capability remote from the control room;
 - (iv) Confirmation of satisfactory performance following loss of electrical power supplies at full power operation.
- (k) Experiments and experimental devices:

The following tests, measurements or verifications 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.

- (i) Measurement of neutron flux, spectra and gradients for experiments;
 - (ii) Measurement of the reactivity effect of experimental devices (insertion, removal, failure, void);
 - (iii) Tests of effects of experimental devices on flux distributions and on the response of control and safety instrumentation;
 - (iv) Tests of the operation of instrumentation and control systems for experimental devices and auxiliary systems (e.g. emergency power system, cooling system);
 - (v) Tests of safety devices associated with experimental devices (alarms, shutdown systems, power setback systems) and any containment features;
 - (vi) Functional tests of equipment for experimental devices (radioisotope production, heat supply, loop or rig tests, cold source devices, irradiators, beam tubes);
 - (vii) Tests simulating failure of equipment (e.g. loss of loop cooling).
- (l) Preparation for routine operation:

Before commencing routine operation, the following should be confirmed:

- (i) The testing of major reactor experimental devices has been completed, baseline data have been obtained, demonstrations of operability have been performed, and any necessary modifications or adjustments have been made.
- (ii) Operational documentation, including operating procedures and OLCs, has been revised where necessary.
- (iii) Commissioning reports have been completed, the safety analysis report has been revised to include the significant results, and an application has been made to the regulatory body for an authorization for operation (including utilization and modification) of the research reactor, in accordance with para. 3.4 of SSR-3 [1].

CONTINUATION OF TESTS FOLLOWING STAGE C

A.22. Typical tests and activities that should be completed as research reactor operations proceed are as follows:

- (a) Accumulation of baseline data;
- (b) Further tests, adjustments, modifications and optimization of parameters to prepare the research reactor for routine operation;
- (c) Periodic re-evaluation of reactivity values (e.g. shutdown margin, worth of reactivity control

mechanisms);

- (d) Confirmation of predictions of fuel management and burnup estimates;
- (e) Confirmation of adequacy of handling, storage and transport of spent fuel;
- (f) Determination of the effect of irradiation on core components and materials (e.g. creep);
- (g) Development and confirmation of methods and procedures for experiments and utilization facilities;
- (h) Confirmation of adequacy of radiation protection measures, including verification of remote monitoring instrumentation connected to the emergency centre;
- (i) Establishment of baseline environmental monitoring data;
- (j) Verification of unique operational modes (e.g. remote operation, pulsed modes);
- (k) Verification of contractual requirements (e.g. production objectives, long term operation, supply of local heat);
- (l) Verification of methods and equipment for utilization (e.g. for the production, handling, processing, storage and transport of radioisotopes);
- (m) Long term tests of prototypical features and equipment.

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