

IAEA Safety Standards

for protecting people and the environment

Commissioning of Research Reactors

Safety Guide

No. NS-G-4.1



IAEA

International Atomic Energy Agency

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COMMISSIONING OF RESEARCH REACTORS

SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2006

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FOREWORD

by Mohamed ElBaradei
Director General

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

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

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

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

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

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was developed under the IAEA programme for safety standards for research reactors, which covers all the important areas of research reactor safety. It supplements and elaborates upon the safety requirements for the commissioning of research reactors that are established in the IAEA Safety Requirements publication on the Safety of Research Reactors [1]. It also relates to the IAEA Safety Guides on Safety in the Utilization and Modification of Research Reactors [2] and on Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report [3]. These Safety Guides include guidance on the commissioning of reactor modifications and experiments [2] and of the reactor itself [3].

OBJECTIVE

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

SCOPE

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

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

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

1.6. Low risk research reactors having a power rating of up to several tens of kilowatts and critical assemblies may need a less comprehensive commissioning programme than that outlined here. While all recommendations in this Safety Guide should be considered, some may not be applicable to these low power research reactors. For these reasons, the recommendations in this Safety Guide should be graded¹ for their applicability to a particular research reactor (see Ref. [1], paras 1.11–1.14). Grading may be of assistance in determining the content of the commissioning programme. It should be based on the complexity of the activity and the importance to safety of the systems and equipment concerned.

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

¹ The recommendations should be graded, for example, by considering — using sound engineering judgement — the safety and operational importance of the topic, and the maturity and complexity of the area involved.

STRUCTURE

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

2. MANAGEMENT SYSTEM FOR COMMISSIONING

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

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

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

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

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

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

- The regulatory body's requirements;
- Design requirements and assumptions;
- The safety analysis report (SAR);
- The operational limits and conditions (OLCs);
- Administrative requirements of the reactor management².

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

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

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

MANAGEMENT RESPONSIBILITY

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

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

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

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

2.10. Successful implementation of the commissioning programme requires:

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

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

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

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

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

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

RESOURCE MANAGEMENT

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

2.15. The operating organization has the responsibility for commissioning. The reactor manager³ should participate in the commissioning activities by:

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

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

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

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

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

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

PROCESS IMPLEMENTATION

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

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

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

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

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

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

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

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

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

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

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

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

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

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

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

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

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

3. COMMISSIONING PROGRAMME

GENERAL OBJECTIVES

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

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

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

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

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

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

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

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

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

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

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

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

FORMAT AND CONTENT

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

- (a) General description;

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

General description

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

Organization and responsibilities

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

Commissioning stages

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

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

Section 5 provides guidance.

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

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

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

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

Commissioning procedures and reports

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

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

Documentation needs

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

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

Management system

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

4. COMMISSIONING ORGANIZATION

ORGANIZATION

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

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

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

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

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

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

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