

IAEA Safety Standards

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Core Management and Fuel Handling for Research Reactors

Safety Guide

No. NS-G-4.3



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International Atomic Energy Agency

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CORE MANAGEMENT AND FUEL HANDLING FOR RESEARCH REACTORS

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CORE MANAGEMENT AND FUEL HANDLING FOR RESEARCH REACTORS

SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2008

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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 within the framework of the research reactor safety programme of the IAEA. It recommends how to meet the safety requirements for core management and fuel handling that are presented in paras 7.65–7.70 of the Safety of Research Reactors [1]. It is related to the Safety Guide on The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors [2], which identifies core management and fuel handling as two of the various important activities to be performed by the operating organization. These activities are related to the prevention of criticality accidents, with reference to Principle 8 of the Fundamental Safety Principles [3]: “Prevention of accidents: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.” This principle states that: “The most harmful consequences arising from facilities and activities have come from the loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or other source of radiation.”

OBJECTIVE

1.2. The purpose of this Safety Guide is to provide recommendations on meeting the safety requirements for core management and fuel handling at research reactors, on the basis of international good practices. This Safety Guide addresses those aspects of core management activities that should be performed in order to allow optimum reactor core operation and reactor utilization for experiments, without compromising the limits imposed by the design safety considerations relating to the fuel assemblies and the reactor as a whole. In this publication, ‘core management’ refers to those activities that are associated with the fuel assemblies, management of core components¹ and

¹ Core components are the elements of a reactor core, other than fuel assemblies, that are used to provide structural support of the core construction, or the tools, devices or other items that are inserted into the reactor core for monitoring, flow control or other technological purposes and are treated as core elements. Core components include experimental devices that may be fixed in the core (e.g. flux trap and test loop components, cold and hot neutron sources, and bulk samples for irradiation). Other experimental devices may be movable (e.g. irradiation baskets, small samples for irradiation).

reactivity control. 'Fuel handling' refers to the movement, storage and control of fresh and irradiated fuel, whether manually or by means of automated systems. This Safety Guide is intended for use by operating organizations, regulatory bodies and other organizations involved in the operation of research reactors.

SCOPE

1.3. The recommendations and guidance provided in this Safety Guide are intended to be applicable to research reactors having a limited hazard potential for the public. The publication describes the safety objectives, the tasks that should be performed to meet these objectives and the activities that should be undertaken to perform these tasks. The recommendations and guidance provided in the Safety Guide on Core Management and Fuel Handling for Nuclear Power Plants [4] have been reviewed and some of the best practices, where appropriate, have been adapted to suit the differences in hazard potential and complexity of systems between nuclear power plants and research reactors.

1.4. Additional guidance that is beyond the scope of this Safety Guide may be necessary for research reactors of higher power levels and specialized reactors (e.g. homogeneous reactors² or fast neutron reactors³). The recommendations and guidance provided for power reactors in Ref. [4] may be more suitable for such reactors (see also para. 1.9 of Ref. [1]).

1.5. Since the primary reason for operating a research reactor is its utilization, other recommendations for core management in this Safety Guide concern the management of in-core and out-of-core experimental devices. The incorporation of newly designed fuel assemblies into an existing core is also considered. This should be useful at those research reactor facilities that are being converted to use low enriched uranium (LEU) instead of high enriched uranium (HEU) [5].

1.6. Guidance on fuel handling covers: receipt of fresh fuel assemblies; storage and handling of fuel assemblies and other core components; inspection

² A homogeneous research reactor uses fuel in the form of a solution of fissile material.

³ In fast neutron research reactors, the fission chain reaction is sustained by fast neutrons.

of fuel assemblies; loading and unloading of fuel assemblies and core components; inspection of irradiated fuel; insertion and removal of other reactor materials, either manually or by means of automated systems; preparation of fuel assemblies for shipment; and loading of a transport container with irradiated fuel.

1.7. The scope of this Safety Guide does not include guidance on transport safety or safety precautions for transport beyond the site or the off-site storage and ultimate disposal of irradiated fuel assemblies and core components.

1.8. Aspects of fuel accounting not directly related to nuclear safety are not considered in the scope of this Safety Guide; thus, safeguards aspects are not included.

1.9. Core management involving the total redesign of the reactor core (e.g. conversion of a conventional core with many fuel assemblies to a compact core with few assemblies) is beyond the scope of this publication and reference should be made to the sections on design in Ref. [1]. Similarly, the design and installation of a new experimental facility that has major safety significance or off-site hazard potential is beyond the scope of this Safety Guide.

1.10. Low risk research reactors having a power rating of up to several tens of kilowatts and critical assemblies may need a less comprehensive core management and fuel handling programme than that outlined here. Low power reactors require infrequent core adjustments to compensate for burnup. They operate with substantial margins to thermal limits, allowing the consideration of a broad envelope of acceptable fuel loading patterns in the initial safety analysis in lieu of core specific calculations. While all recommendations in this Safety Guide should be considered, some may not apply to these low power level reactors. For these reasons, the recommendations provided in this Safety Guide should be graded⁴ for applicability to a particular research reactor (see Ref. [1], paras 1.11–1.14).

1.11. Examples of a graded approach pertaining to reactor modification (e.g. core management) and new experiments are provided in Ref. [6] as follows:

⁴ 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 the complexity of the area involved.

- (a) Paragraphs 305–326 of Ref. [6] discuss a four category system for the treatment of proposed reactor modifications and new experiments and classify them according to their hazard potential into four groups:
 - (i) Changes that could have major safety significance;
 - (ii) Changes that could have a significant effect on safety;
 - (iii) Changes with apparently minor effects on safety;
 - (iv) Changes having no effect on safety.
- (b) Annex I of Ref. [6] discusses a two category system based on the identity of the approving authority (i.e. regulatory body approval or local approval);
- (c) Annex I of Ref. [6] also discusses a multi-category system based on the potential radiological hazard such as:
 - (i) Off-site hazard potential;
 - (ii) On-site hazard potential only;
 - (iii) No hazard potential beyond the reactor hall;
 - (iv) No hazard potential.

Reference [6] describes for each of these categories the level of stringency that should be associated with the design and analysis, construction, commissioning, documentation, review and final approval for modifications and changes.

STRUCTURE

1.12. This Safety Guide consists of ten sections and one annex. Sections 2 and 3 provide recommendations on a management system for core management and fuel handling and on the core management programme respectively. Section 4 identifies the best practices relating to the main aspects of the handling and storage of fresh fuel. Section 5 provides recommendations on refuelling activities. Section 6 provides recommendations on aspects of the handling, storage and inspection of irradiated fuel. Section 7 deals with the handling and storage of core components, in particular, those that have been irradiated. Section 8 provides general recommendations on the preparatory arrangements for the dispatch of fuel assemblies from the site. Section 9 provides recommendations on administrative and organizational arrangements for core management, and Section 10 on general aspects of documentation.

1.13. The annex presents a brief discussion of the reasons why core management is necessary in some research reactors.

2. MANAGEMENT SYSTEM FOR CORE MANAGEMENT AND FUEL HANDLING

GENERAL

2.1. A documented management system that integrates safety, health, environmental, security, quality and economic objectives for the research reactor project should be put in place. The management system documentation should describe the system that controls the development and implementation of all aspects of the research reactor project, including core management and fuel handling. The management system (or parts thereof) should be submitted to the regulatory body for approval as required, in accordance with national regulations. The management system should include four functional categories: management responsibility; resource management; process implementation; and measurement, assessment and improvement. In general:

- (a) Management responsibility includes providing the means and support needed to achieve the organization's objectives;
- (b) Resource management includes measures to ensure that the resources essential to the implementation of strategy and the achievement of the organization's objectives are identified and made available;
- (c) Process implementation includes those actions and tasks needed to achieve quality;
- (d) Measurement, assessment and improvement provide an indication of the effectiveness of management processes and work performance.

Requirements and recommendations and guidance on the management system are provided in Ref. [1], paras 4.5–4.13, and Refs [7, 8].

2.2. As a part of the management system, a management system for core management and fuel handling should be established and put into effect by the operating organization early in the research reactor project. The system should be applied to all items and processes important to safety and should include the means of establishing controls over core management and fuel handling activities to provide confidence that they are performed in accordance with established requirements. The roles and responsibilities of personnel involved in core management and fuel handling should be defined in the management system (see also Section 9 of this Safety Guide). In establishing the system, a graded approach based on the relative importance to safety of each item or process (e.g. core configuration, critical experiments) should be adopted.

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

- (a) The requirements of the regulatory body;
- (b) The design requirements and assumptions made in the design;
- (c) The safety analysis report (SAR);
- (d) The operational limits and conditions (OLCs) (see Ref. [9]);
- (e) The administrative requirements for reactor management.

The management system should support the development and enhancement of a strong safety culture in all aspects of the core management and fuel handling programmes.

2.4. The management system for core management on the site should include procurement activities and should be extended to include suppliers. The operating organization should ensure that the manufacturers and designers have acceptable management systems and should ensure through audits that they comply with the integrated management system of the research reactor operating organization.

MANAGEMENT RESPONSIBILITY

2.5. The core arrangements and core components, including experimental devices, should be determined during the design stage of the reactor. However, it may become necessary to change the core and core components during the operational lifetime of the reactor because of the need to change fuel or because of changing experimental requirements (see the annex). This may lead to a corresponding change in the handling requirements for fuel and core components. In such cases, pertinent information from designers, manufacturers and other operating organizations should be used.

2.6. Successful implementation of the core management programme requires the following:

- (a) Planning and prioritization of work;
- (b) Availability of qualified personnel with suitable skills;
- (c) Availability of appropriate computational methods and tools;
- (d) Availability of approved procedures;
- (e) Addressing all applicable regulatory requirements;
- (f) Addressing the requirements of the OLCs;

- (g) Availability and operability of special tools and equipment;
- (h) A satisfactory working environment;
- (i) Implementation and execution of the required inspections and tests.

2.7. The operating organization has the responsibility to prepare and issue procedures and specifications for the procurement, inspection, loading, utilization, unloading, storage, movement and testing of fuel and core components. Documents such as the core management programme, procedures, specifications and drawings should be prepared, reviewed, updated, approved, issued, validated as required, and archived.

2.8. There should be a designated person responsible and accountable for core management and fuel handling, including: developing and documenting the 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. In any case, the reactor manager should participate in the core management and fuel handling activities by means of:

- (a) Frequent personal contact with core management and fuel handling staff, including the oversight of work in progress;
- (b) Establishing and implementing a set of safety performance indicators;
- (c) Participating in evaluations of the core management and fuel handling process;
- (d) Providing feedback derived from performance indicators for operations.

2.9. Records essential to the performance and verification of core management and fuel handling activities should be controlled using a system that includes their identification, approval, review, filing, retrieval and disposal.

RESOURCE MANAGEMENT

2.10. The competence requirements for staff performing the work should be specified and it should be ensured that the personnel deployed are competent to perform their assigned work.

2.11. Personnel whose roles are not dedicated to the research reactor facility and personnel of external suppliers who perform core management or fuel handling activities should be appropriately trained and qualified for the work they are expected to perform. Experienced and qualified personnel may be allowed to bypass training after obtaining an appropriate proof of their

proficiency. However, they should in any case be instructed on the work to be done at the reactor and they should be aware of the structure of the reactor core. External personnel would perform activities under the same controls and to the same standards as reactor personnel. Supervisors should review the work of external personnel during preparation for the work and during testing and acceptance testing.

2.12. The hardware and software based process equipment that is necessary for work to be carried out in a safe manner and for meeting requirements should be identified, provided and maintained. Equipment and items used for core management and fuel handling⁵ should be identified and controlled to ensure their proper use. Equipment used for monitoring, data collection and inspections and tests should be qualified for the operating environmental conditions and should be calibrated as necessary.

PROCESS IMPLEMENTATION

2.13. Core design and experiment design should be carried out in accordance with established engineering codes and standards.

2.14. The core management and fuel handling activities should be performed and recorded in accordance with approved procedures and instructions.

2.15. The activities and the interfaces between different groups involved in core management and fuel handling should be planned, controlled and managed to ensure effective communication and the clear assignment of responsibility.

2.16. Inspection, testing, verification and validation activities should be completed before the implementation or operational use of a new core design or experiment design or a new handling technique.

2.17. Valid monitoring and measurement should be established to provide evidence of compliance with requirements and satisfactory in-service inspection.

⁵ Fuel handling is discussed in Sections 4–6 of this Safety Guide.

2.18. Suppliers should be evaluated and selected on the basis of specified criteria.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

2.19. Suitable methods should be applied for monitoring the effectiveness of the core management and fuel handling programme. To be effective, the programme should comply not only with the recommendations of this Safety Guide, but also with the requirements of the experimental programme.

2.20. An organizational unit should be established with the responsibility to conduct independent assessments of the core management and fuel handling programme. This unit is usually the safety committee as described in para. 7.25 of Ref. [1].

2.21. The operating organization should evaluate the results of the independent assessments and should take necessary actions to implement recommendations and suggestions for improvement.

3. CORE MANAGEMENT

GENERAL

3.1. The primary objective of core management is to ensure the safe, reliable and optimum use of the nuclear fuel in the reactor, while remaining within the limits imposed by the design of the fuel assembly and the design of the reactor, on the basis of the safety analysis contained in the SAR and the OLCs derived from the safety analysis. The secondary objective is to meet the requirements of the utilization programme (e.g. the need for neutron flux for experiments) while keeping within the OLCs.

3.2. While the details of core management will depend on the reactor type and the organization of the facility, in all cases the core management programme should meet the following objectives:

- (a) To provide the means to perform core management functions effectively throughout the fuel cycle so as to ensure that core parameters remain within the OLCs. Core management functions include: core design (specification of fuel assembly loading and shuffle patterns to provide optimum fuel burnup and desired fluxes); experiment design and installation; fuel assembly procurement; reactivity determinations; and core performance monitoring;
- (b) To determine core operating strategies that permit maximum operating flexibility for reactor utilization and optimum fuel utilization while remaining within the OLCs;
- (c) To ensure that only fuel assemblies and experimental devices of approved design are used.

3.3. The specific safety requirement relating to core management (see para. 7.65 of Ref. [1]) that is addressed in this Safety Guide covers the following:

- (a) Validated methods and codes should be used to determine appropriate positions in the core for locating the fuel, reflector, safety devices (control rods⁶, valves for dumping the moderator and/or reflector, burnable absorbers, etc.), experimental devices, irradiation facilities and moderators;
- (b) The integrity of the fuel assembly should be ensured at all times during the utilization of the reactor core by maintaining relevant core configuration parameters in accordance with the design intent and assumptions as specified in the OLCs for the reactor;
- (c) The reactor core should be monitored to ensure that reactor operation is conducted at all times in accordance with the design intent and assumptions as specified in the OLCs for the reactor; the effects and safety implications of the irradiation of core material, core components and experimental and irradiation facilities should be assessed;
- (d) The integrity of the cladding of the fuel assembly should be continuously monitored (not necessarily monitored ‘online’ in the reactor but commonly monitored indirectly by monitoring the fission product activity in the primary coolant and off-gas systems), and in the event of detection

⁶ Some research reactors have other forms of reactivity control devices (e.g. plates). In this Safety Guide, the term ‘control rod’ is generally used for all forms of the research reactor’s reactivity control devices.