

IAEA Safety Standards

for protecting people and the environment

Operational Limits and Conditions and Operating Procedures for Research Reactors

Safety Guide

No. NS-G-4.4



IAEA

International Atomic Energy Agency

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OPERATIONAL LIMITS AND CONDITIONS AND OPERATING PROCEDURES FOR RESEARCH REACTORS

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OPERATIONAL LIMITS AND CONDITIONS AND OPERATING PROCEDURES 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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The safety standards use the form ‘shall’ in making statements about requirements, responsibilities and obligations. Use of the form ‘should’ denotes recommendations of a desired option.

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was developed under the IAEA work programme for safety standards for research reactors. It supplements and elaborates upon the safety requirements for operational limits and conditions (OLCs) and operating procedures for research reactors that are established in Section 7 (paras 7.29–7.41, 7.51–7.55) of the IAEA publication on the Safety of Research Reactors [1].

1.2. For a research reactor to be operated safely, the provisions made in the final design and any subsequent modifications to the design must be taken into account in specifying the limits on operating parameters and the requirements on the equipment and personnel of the reactor facility. Under the responsibility of the operating organization, these limits on operating parameters and requirements should be developed in the evaluation of the design safety as a set of OLCs.¹ A major contribution to compliance with the OLCs is made by the development and utilization of operating procedures that are consistent with the OLCs. Establishment of OLCs and operating procedures is essential to achieving the objectives of the defence in depth concept.²

¹ The terms ‘safety specifications’ or ‘technical specifications (tech specs) for safe operation’ and ‘general operating rules’ are sometimes used to mean OLCs. These terms are used by operating organizations and regulatory bodies for nuclear reactors. These expressions usually cover safety limits, safety system settings, limiting conditions for safe operation, and surveillance requirements and administrative requirements. In addition, in some Member States the term ‘operating rules’ is used to mean the equivalent of safety limits, safety system settings and limiting conditions for safe operation, and this does not then include surveillance requirements and administrative requirements.

² Defence in depth is a hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of the physical barriers placed between a radiation source or radioactive material and workers, members of the public, or the environment, in operational states and, for some barriers, under accident conditions. The objectives of defence in depth are (a) to compensate for potential human and component failures, (b) to maintain the effectiveness of the barriers by averting damage to the facility and to the barriers themselves, and (c) to protect workers, members of the public and the environment from harm under accident conditions in the event that the barriers are not fully effective.

1.3. The Safety Requirements publication on the Safety of Research Reactors [1] establishes the basic requirements in all the relevant areas associated with the safety of research reactors, including site evaluation, design, operation, decommissioning, regulatory oversight and the management system. This Safety Guide provides recommendations on fulfilling the basic requirements in all relevant areas associated with the safety of research reactors. In making use of this publication and the other Safety Guides that provide recommendations on means of fulfilling the basic requirements established in Ref. [1], the particular characteristics of research reactors should be taken into account. These characteristics include the wide variety of designs, the wide range of power levels, the different modes of operation and purposes of utilization, the particularities of siting and the differences among the operating organizations for research reactors. These characteristics require flexibility in setting objectives and applying the basic requirements when dealing with some specific topics.

1.4. The organizations involved in ensuring the safety of research reactors and the protection of site personnel, the public and the environment have a number of responsibilities that are interrelated. Some of the more important of these are the performance of the safety analysis and the development of the OLCs and safety related documents for review and assessment by the regulatory body. Documented operating procedures having safety significance are part of such documentation. The OLCs are a set of operating rules that normally includes: safety limits and safety system settings on relevant variables and parameters of the reactor; limiting conditions on equipment and operational characteristics of the reactor; surveillance requirements; and administrative requirements. This set should satisfy the basic requirements for the OLCs as established in Ref. [1], paras 7.29–7.41.

1.5. There is an international consensus on the need for the establishment of and compliance with OLCs for the safe operation of nuclear reactors. However, the OLCs are presented in various formats, depending on the structure of the mandatory safety documentation as stipulated in the legal framework established by the State for the operation of research reactors. Thus, some States include the OLCs, together with requirements of other kinds, as an essential part of the reactor licence for operation, while others make reference to a separate document containing the OLCs. In this regard, the structure of the present Safety Guide is oriented to the development of the OLCs as a separate document, which may or may not be attached to the reactor licence and appropriately referenced in the safety analysis report. In the case that the safety analysis report does not include the OLCs, a summary should be

presented in the safety analysis report and reference should be made to the separate document. This summary should be prepared in accordance with the recommendations provided in Ref. [2], paras A.1701–A.1708.

OBJECTIVE

1.6. The purpose of this Safety Guide is to provide recommendations on all important aspects of developing, formulating and presenting the OLCs and the operating procedures for research reactors. In particular, detailed recommendations are provided on the development, content and implementation of OLCs and operating procedures for the operation of research reactors as well as for experiments (see Ref. [3], para. 303). This Safety Guide is directed at both operating organizations and regulatory bodies.

SCOPE

1.7. This Safety Guide covers the concept of OLCs, their content as it applies to research reactors, and the responsibilities of the operating organization in respect of their establishment, modification and documentation, and with regard to compliance with them. The operating procedures necessary to facilitate full compliance with the OLCs and to ensure their observance are also within the scope of this Safety Guide.

1.8. The recommendations provided in this Safety Guide are intended to be applicable to most types of research reactor having power levels of up to a few tens of megawatts. Research reactors of higher power levels and specialized reactors (e.g. homogeneous reactors, fast reactors) may require the provision of additional guidance that is beyond the scope of this Safety Guide. Some flexibility in the application of the recommendations provided in this Safety Guide is warranted on the basis of the specific characteristics of research reactors (see para. 1.11) or the relevant regulations of States. Because of the differences in the approaches to the preparation of OLCs and operating procedures in different States, the level of detail required in the application of the guidelines should be agreed upon by the operating organization and the regulatory body to develop a set of OLCs acceptable to the regulatory body.

1.9. Research reactors are used for various purposes, including research, training, radioisotope production, neutron therapy, neutron radiography and

material tests, and therefore they have differing design features and operational regimes. Design and operating characteristics may vary significantly, since experimental devices may affect the performance of reactors. In addition, the need for greater flexibility in the use of research reactors may require an approach to achieving or managing safety different from that for nuclear power plants.

1.10. Low risk research reactors having a power rating of up to tens of kilowatts and critical assemblies may need less comprehensive OLCs and operating procedures than those outlined here. While all recommendations in this Safety Guide should be considered, some may not apply to these low risk reactors. For these reasons, the recommendations and guidance provided in this Safety Guide should be graded for applicability to a particular research reactor (see Ref. [1], paras 1.11–1.14).

1.11. The factors to be considered in deciding whether certain recommendations provided here may be waived in applying a graded approach to the application of safety requirements include (but are not limited to):

- (a) Reactor power levels;
- (b) The radiological source term;
- (c) The amount and enrichment of fissile and fissionable material;
- (d) Spent fuel elements, high pressure systems, heating systems, fuel accumulators, and other systems and components that may affect the safety of the reactor;
- (e) The type of fuel element;
- (f) The type and mass of moderator, reflector and coolant;
- (g) The amount of reactivity that can be introduced and its rate of introduction, reactivity control, and inherent and engineered safety features;
- (h) The quality of the containment or the means of confinement;³
- (i) Utilization of the reactor (experimental devices, tests, reactor physics experiments);

³ The means of confinement is a barrier surrounding the main parts of a reactor containing radioactive material that is designed to prevent or mitigate the uncontrolled release of radioactive material to the environment in operating states or in design basis accidents. If the design is also able to fulfil this function under overpressure conditions after an accident, it is often called a containment.

- (j) The presence of personnel in the installation during the operation of the reactor;
- (k) The type of operation of the facility (e.g. whether permanent or only for short experiments);
- (l) Siting of the reactor;
- (m) Proximity of the reactor to population groups.

1.12. The OLCs represent an envelope of parameters. Compliance with the OLCs will protect the reactor, and will protect the staff, the general public and the environment from undue radiation exposure. In addition, establishing the OLCs forms an important part of meeting the requirements for the issuing by the regulatory body of the authorization to operate the facility. Therefore the requirement to develop the OLCs and to operate the facility in accordance with them should not be waived. However, the number of OLCs may vary depending on the factors listed in para. 1.11.

1.13. The development and use of operating procedures make a major contribution to the safe operation of the reactor. The operating procedures facilitate full compliance with the OLCs, and therefore the preparation and use of operating procedures should not be waived in any case. Since the operating procedures are required to be consistent with the OLCs, the number and the complexity of the procedures may vary depending on the factors listed in para. 1.11.

STRUCTURE

1.14. This Safety Guide consists of eight sections and two appendices. Section 2 describes the relationship between the OLCs and the fundamental safety objective of protecting people and the environment from harmful effects of ionizing radiation, and discusses: the concept of OLCs; the need for OLCs; their development; the roles and responsibilities of the operating organization and the regulatory body in their preparation and review; and the presentation of each operational limit or condition. Section 3 discusses the content of the OLCs document⁴ and provides a list of the safety parameters and systems that

⁴ OLCs are a set of rules setting forth parameter limits, and the functional capability and performance levels of equipment and personnel approved by the regulatory body for safe operation of an authorized facility. The document that contains the OLCs as a whole is referred to as the ‘OLCs document’.

should be covered by the OLCs, including surveillance requirements for these parameters. This section also provides guidance on administrative requirements that should be covered by the OLCs. Section 4 covers the development of operating procedures. It describes the functions and responsibilities of the operating organization, operating personnel, the safety committee, the reactor manager and the regulatory body in developing and implementing procedures, and discusses general considerations regarding their categorization and other issues. Section 5 provides guidance on the format and content of procedures of various types to achieve consistency and completeness in developing the operating procedures. In addition, it describes specific topics to be addressed in procedures of each category. Section 6 provides guidance on the training of personnel in the use of procedures. Section 7 provides guidance on how to ensure compliance with OLCs and operating procedures, including the need to retain records of such compliance. Section 8 provides guidance on quality assurance pertaining to the OLCs and on the quality assurance practices applied to the development and implementation of the operating procedures. Appendix I provides a list of selected factors that should generally be considered in establishing the limiting conditions for safe operation and the surveillance requirements. Appendix II provides a list of typical procedures for the categories identified in Section 5.

2. DEVELOPMENT OF OPERATIONAL LIMITS AND CONDITIONS

GENERAL

2.1. To prevent situations from arising that might lead to accident conditions and to mitigate the consequences of accident conditions if they do arise, “A set of OLCs important to reactor safety, including safety limits, safety system settings, limiting conditions for safe operation, requirements for inspection, periodic testing and maintenance and administrative requirements, shall be established and submitted to the regulatory body for review and assessment” (Ref. [1], para. 7.29).⁵

⁵ See also para. 510 of the IAEA Safety Fundamentals publication on The Safety of Nuclear Installations, Safety Series No. 110, IAEA, Vienna (1993).

2.2. Thus the OLCs form an envelope or boundary for reactor parameter values and system conditions, within which the operation of the reactor has been demonstrated in the safety analysis report to be safe, and the site personnel, the public and the environment are adequately protected against radiation hazards. Thus the OLCs contribute to the prevention of accidents and to mitigation of the consequences of accidents if they do occur.

2.3. The OLCs are required to be developed to ensure that the reactor facilities are operated in accordance with the design assumptions and intent. In order to achieve this requirement, the safety analysis report should be developed so as to identify clearly the OLCs that must be met.

2.4. The OLCs should be submitted for the review and approval of the regulatory body as an important part of the licensing process, on the basis of which the operating organization is authorized to operate the facility.

2.5. The important function of the OLCs in the operation of the research reactor requires that they be adequately selected, clearly established and appropriately substantiated by means of a written statement of the reasons for their adoption. When reviewed and approved by the regulatory body, the OLCs represent an accepted basis for the operation of the reactor facility.

2.6. The technical aspects of the OLCs cover the limitations to be observed, as well as the operational requirement that structures, systems and components important to the safety of the research reactor be able to perform their intended functions as assumed in the safety analysis report. Safe operation depends on operating personnel as well as on equipment; OLCs should therefore also cover actions to be taken and limitations to be observed by operating personnel.

2.7. Regarding the functions of operating personnel, the OLCs include those principal requirements for surveillance and corrective or complementary actions that are necessary to supplement the functioning of equipment involved in maintaining the established OLCs. Some OLCs may involve combinations of automatic functions and actions by operating personnel.

2.8. The OLCs at research reactor facilities should include the following items:

- (a) Safety limits (see paras 3.5–3.13);
- (b) Safety system settings (see paras 3.14–3.18);

- (c) Limiting conditions for safe operation (see paras 3.19–3.26);
- (d) Surveillance requirements (see paras 3.27–3.32);
- (e) Administrative requirements (see paras 3.33–3.43).

Each OLC should be supported by a clear statement of its objective, applicability, specification and justification, as appropriate. These items should be included in the documentation on OLCs to increase the facility personnel's consciousness of their application and observance.

2.9. The development of the OLCs is based on the reactor design, on the safety analysis and on the information in the safety analysis report concerning the conduct of operations. The style and the format of the OLCs should be appropriate for their main purpose (see para. 2.1), and the following aims should also be taken into account:

- (a) To facilitate verification that operation is in compliance with the approved OLCs;
- (b) To facilitate understanding and awareness by the operating personnel of the application of and need for compliance with the OLCs.

2.10. The operating organization is required to be responsible for the preparation of the OLCs and for their submission to the regulatory body, as one of the requirements for the granting of a licence (see paras 3.11(f) and 7.29 of Ref. [1]). The operating organization should consult the designer in preparing the OLCs and should ensure that the operating personnel know the OLCs and adhere to them. In addition, the proposed OLCs should be reviewed by the safety committee⁶ before their submission to the regulatory body. When specific restrictions are placed on operation by the regulatory body, the operating organization should ensure that the approved OLCs are revised appropriately.

2.11. The operating organization should prepare OLCs for each stage of reactor operation that may require a regulatory licence. For example, the commissioning stage of the reactor usually requires specific OLCs, which may be revised after completion of this stage. Similarly, operation of the reactor under special conditions, such as the conduct of a particular experiment or the undertaking of a reactor modification, may require special OLCs. Other reasons for a change in the OLCs may be an observed inadequacy of present

⁶ See Ref. [1], para. 4.15.

parameter values or requirements, experience gained during reactor operation, technological progress, and extended shutdown or decommissioning. The OLCs are therefore normally reviewed and changed as necessary over the reactor's lifetime.

2.12. In line with its overall responsibility, the operating organization is responsible for conducting a periodic review of the OLCs, in association with a review of the safety analysis report, so as to make revisions on the basis of operating experience. Accordingly, the operating organization is also responsible for the timely submission of any additions or changes to the existing OLCs to the regulatory body for review and approval.

2.13. In accordance with para. 2.10, the operating organization is responsible for ensuring compliance with the approved OLCs. To assist in discharging this responsibility, safety limits, safety system settings and surveillance requirements are required to be established in the OLCs (see Ref. [1], para. 7.29). In this context, the operating organization is responsible for keeping adequate records to facilitate audits and inspections to verify that the operation of the facility is in compliance with the OLCs. In addition, the operating organization is responsible for establishing procedures to be followed in the event of a violation of a safety limit or limiting condition.⁷

2.14. The operating organization should submit the OLCs to the regulatory body for review, assessment and approval⁸. The objective is to verify that each OLC is well founded, provides an adequate safety margin in relation to accidents analysed in the safety analysis report and complies with the applicable regulations.

2.15. The regulatory body should conduct regulatory inspections of the operating organization, reactor management and operations of the reactor facility to verify compliance with the approved OLCs. Further guidance on regulatory inspections is provided in Ref. [4].

⁷ See paras 7.39–7.41 of Ref. [1], and paras 7.3 and 7.4 of this Safety Guide.

⁸ Approval is not required in some Member States.

ATTRIBUTES OF OPERATIONAL LIMITS AND CONDITIONS

2.16. The presentation adopted for the OLCs may vary from State to State depending on national regulations and practices and on the particular reactor. It may range from a short list of limits and limiting conditions to a set of detailed specifications together with the objective, applicability statement and basis (see para. 2.8) for each of the specifications. The facility personnel should be made fully aware of the importance of OLCs and compliance with them. The latter format, consisting of a brief description of the objective, applicability, specification and basis for each of the safety limits, safety system settings and limiting conditions for safe operation, should be given consideration as a good practice. The presentation may also include a statement describing actions to be taken, with the allowed completion time, in the event of deviations from the established OLCs (see para. 3.20) or in the case of violation of an operational limit or condition (see para. 3.43).

2.17. The presentation adopted for the OLCs may also be used in an appropriate manner for surveillance requirements (see paras 3.27–3.32) and administrative requirements. The surveillance requirements may be included in the section of the document on the limiting conditions for safe operation or may be specified in a separate section of the OLCs document. The surveillance requirements should include the requirements for inspection, operability checks and calibrations, as applicable, and should clearly establish the frequency and scope of the tests required to verify that the performance levels for safe operation as set in the OLCs are met.

2.18. Clear presentation and avoidance of ambiguity are important factors in reliability in the use of OLCs, and advice on human factors should be sought at an early stage in the development of the documentation in which the OLCs will be presented to the operating personnel. The meaning of terms should be explained to help prevent misinterpretation.

2.19. Whenever modifications to the OLCs become necessary, the approach outlined in para. 2.18 should be followed. All modifications to the facility should be reviewed to determine whether they necessitate modifications to the OLCs. Any modification to the OLCs should be subject to review by the safety committee and to assessment and approval by the regulatory body, as required [3].

2.20. Whenever it is necessary to modify the OLCs on a temporary basis, for example, to perform tests or experiments, particular care should be taken to

ensure that the effects of the change are analysed. The modified state, although temporary, necessitates at least the same level of approval as a permanent modification. Any reasonable alternative approach, if available, should be preferred to the temporary modification of an OLC.

2.21. Periodic reviews should be undertaken to ensure that the OLCs remain applicable for their intended purpose, and, where necessary, the OLCs should be modified in the light of operating experience and technological developments. This periodic review, in association with a review of the safety analysis report, should be carried out even if the facility has not been modified.

2.22. Consideration may be given to the application of probabilistic safety assessment in the optimization of OLCs. Probabilistic assessment methods together with operating experience may be used in the justification and modification of OLCs.

Objective of the specification of OLCs

2.23. The OLCs should be meaningful to the responsible operating personnel. The objective of the specification of the OLCs should be clearly stated, and the OLCs should be specified in terms of measurable or directly identifiable values of parameters. This is important because the objective may not be evident from the specification itself. For example, if the objective of a particular operational limit or condition is stated as to ensure the integrity of the fuel cladding, a temperature may be specified. However, if there is no instrument for measuring the cladding temperature, it may be necessary to specify a reactor power level, coolant flow rate through the core, coolant inlet temperature and height of water above the fuel. It is not self-evident from these four specifications that the final objective is to ensure the integrity of the cladding. The relationship of a limiting parameter with other measurable parameters should be indicated by means of tables or diagrams, as appropriate. The limit or condition should be stated in such a way that it is clear whether a violation has or has not occurred in any situation.

Applicability of the specification of OLCs

2.24. The applicability of an operating limit or condition is specified in a statement that indicates the operational state (e.g. startup, normal operation, refuelling), the variables, the components, the systems and the administrative requirements to which the specification applies. Such a statement of applicability should be included to ensure a clear and proper understanding of

the scope of the specifications; for example, the specific cooling modes (natural, forced, etc.) in which a given limit is applicable may be specified.

Statement of the specification of OLCs

2.25. The specification of the OLCs provides a statement of the value of a particular parameter or the values of a group of parameters, either as a single value or as a range of possible values. The specification may concern a structure, a system, a component, an operation, or a surveillance requirement or administrative requirement. The specification should be stated in a clear and concise manner and should not conflict with other specifications. Specifications may be derived from the design, from the safety analysis report and from experience.

Bases for the specification of OLCs

2.26. Reasons should be given for the selection of the specification. These reasons should be based on the safety analysis report, on the reactor design or on aspects relating to the conduct of operations. These reasons or bases may be simple but conservative statements made on the basis of operational experience or experimental results. Reference to the relevant sections of the safety analysis report with a brief summary should be included in the bases.

2.27. The bases should show that the specification is conservatively selected for normal operation. Appropriate consideration should be given to factors such as calibration errors, measurement accuracy and system response times or operator response times.

3. CONTENT OF THE OPERATIONAL LIMITS AND CONDITIONS DOCUMENT

3.1. Just as the format of the OLCs may differ between States, so may the content and the order of presentation. However, all items relevant to safe operation should be included in the OLCs. The content and presentation of the OLCs document may be arranged in the following manner: table of contents; definitions; introduction; safety limits; safety system settings; limiting

conditions for safe operation; surveillance requirements; administrative requirements.

TABLE OF CONTENTS

3.2. The table of contents should provide sufficient detail to allow for easy reference to a specific operational limit or condition.

DEFINITIONS

3.3. Definitions of specific terms used in the OLCs document should be given. In addition, the definitions of terms particular to the research reactor should be provided. (See the definitions in the IAEA Safety Glossary [5].)

INTRODUCTION

3.4. The introduction should contain general information about the research reactor operating organization and the authorship of the OLCs document, including its historical development, if necessary. It should also include a statement of any restrictions placed on the OLCs. An example is: “These OLCs are applicable during the commissioning stage of the reactor only”. Finally, there should be a statement that all operations of the reactor should be in accordance with the OLCs.

SAFETY LIMITS

3.5. Safety limits are limits on process variables within which the operation of the research reactor facility has been shown to be safe. Safety limits are necessary to protect the integrity of the principal physical barrier that guards against uncontrolled radioactive releases in all operational states and design basis accidents.⁹ For many research reactors, this principal physical barrier is the cladding of the fuel elements, whose temperature is maintained below a

⁹ Those safety limits that might be exceeded in the event of a design basis accident should be justified on the basis of careful analyses.