

# 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

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.

### *EDITORIAL NOTE*

*An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.*

*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.*

# CONTENTS

1.	INTRODUCTION .....	1
	Background (1.1–1.5) .....	1
	Objective (1.6) .....	3
	Scope (1.7–1.13) .....	3
	Structure (1.14) .....	5
2.	DEVELOPMENT OF OPERATIONAL LIMITS AND CONDITIONS .....	6
	General (2.1–2.15) .....	6
	Attributes of operational limits and conditions (2.16–2.27) .....	10
3.	CONTENT OF THE OPERATIONAL LIMITS AND CONDITIONS DOCUMENT (3.1) .....	12
	Table of contents (3.2) .....	13
	Definitions (3.3) .....	13
	Introduction (3.4) .....	13
	Safety limits (3.5–3.13) .....	13
	Safety system settings (3.14–3.18) .....	15
	Limiting conditions for safe operation (3.19–3.26) .....	16
	Surveillance requirements (3.27–3.32) .....	18
	Administrative requirements (3.33–3.43) .....	19
4.	DEVELOPMENT OF OPERATING PROCEDURES .....	22
	General (4.1–4.5) .....	22
	Roles and responsibilities (4.6–4.20) .....	23
	Categorization and list of operating procedures (4.21–4.22) .....	25
	General considerations for the development of operating procedures (4.23–4.29) .....	26
	Steps in the preparation of a procedure (4.30–4.38) .....	28



5.	FORMAT AND CONTENT OF OPERATING PROCEDURES .....	29
	General (5.1–5.9) .....	29
	Commissioning procedures (5.10–5.22) .....	32
	Operational procedures (5.23–5.27) .....	33
	Maintenance procedures (5.28–5.35) .....	34
	Inspection, calibration and periodic testing procedures (5.36–5.43) .....	35
	Radiation protection procedures (5.44–5.47) .....	36
	Procedures for the authorization of operation, maintenance and utilization (5.48–5.50) .....	37
	Procedures for operator response to anticipated operational occurrences (5.51–5.52) .....	38
	Emergency procedures (5.53–5.56) .....	38
	Physical protection procedures (5.57–5.60) .....	39
	Procedures for the handling of radioactive waste and control of radioactive releases (5.61–5.63) .....	40
	Procedures for extended shutdown (5.64–5.69) .....	40
	Procedures for utilization and for modification of the reactor (5.70–5.79) .....	41
	Administrative procedures (5.80–5.83) .....	43
6.	TRAINING OF PERSONNEL IN THE USE OF PROCEDURES (6.1–6.5) .....	44
7.	COMPLIANCE WITH OPERATIONAL LIMITS AND CONDITIONS AND OPERATING PROCEDURES (7.1–7.4) .....	45
8.	QUALITY ASSURANCE .....	46
	General (8.1–8.4) .....	46
	Specific quality assurance arrangements for operational limits and conditions (8.5–8.6) .....	47
	Quality assurance for operating procedures (8.7–8.8) .....	47
	APPENDIX I: FACTORS TO BE CONSIDERED IN ESTABLISHING LIMITING CONDITIONS FOR SAFE OPERATION.....	49

APPENDIX II: INDICATIVE LIST OF OPERATING PROCEDURES.....	54
REFERENCES .....	59
CONTRIBUTORS TO DRAFTING AND REVIEW .....	61
BODIES FOR THE ENDORSEMENT OF IAEA SAFETY STANDARDS .....	65



# 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.<sup>1</sup> 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.<sup>2</sup>

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<sup>1</sup> 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.

<sup>2</sup> 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;<sup>3</sup>
- (i) Utilization of the reactor (experimental devices, tests, reactor physics experiments);

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<sup>3</sup> 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 document<sup>4</sup> and provides a list of the safety parameters and systems that

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<sup>4</sup> 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).<sup>5</sup>

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<sup>5</sup> 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 committee<sup>6</sup> 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

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<sup>6</sup> 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.<sup>7</sup>

2.14. The operating organization should submit the OLCs to the regulatory body for review, assessment and approval<sup>8</sup>. 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].

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

<sup>8</sup> 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.<sup>9</sup> For many research reactors, this principal physical barrier is the cladding of the fuel elements, whose temperature is maintained below a

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



certain limit by cooling so that the integrity of the cladding is ensured. For some reactors, the principal physical barrier is the primary coolant boundary.

3.6. The safety limits should be established by means of a conservative approach that ensures that all the uncertainties of the safety analyses are taken into account. This implies that the exceeding of a single safety limit does not always lead to unacceptable consequences. Nevertheless, if any safety limit is exceeded, the reactor should be shut down and normal operation should be restored only after an appropriate evaluation has been performed and approval for restarting has been given in accordance with established procedures.

3.7. The fuel temperature may be used to establish a safety limit if there is a provision for measuring it. If the temperature is measured in only one location in the core, the measured temperature should be correlated to the maximum fuel temperature in the core.

3.8. In some research reactors there may be no provision for measuring the fuel temperature. In this case, the safety limit is often expressed in terms of other related parameters that are measured, such as the thermal power level, coolant flow through the core, coolant inlet temperature or outlet temperature, coolant pressure and height of coolant above the core. If the core can be cooled by either forced or natural convection, safety limits should be developed for each mode.

3.9. Selection of the safety limits is of paramount importance and should be given careful consideration. For example, the onset of nucleate boiling, which is often used to establish safety limits, represents an undesirable but not unsafe condition for the reactor. Departure from nucleate boiling and flow instability, however, are conditions that, if approached too closely, would have significance for safety, and these conditions may therefore be used to establish safety limits. For this reason, reactor operation is limited to a power level such that the maximum heat flux in a fuel element is only a fraction of the burnout heat flux. In some instances (e.g. for low power research reactors), the safety limits may be set very conservatively.

3.10. Similarly, the maximum allowable surface temperature for the cladding should be set as a safety limit. This safety limit should be applied to the hottest reactor channel, and it should not be exceeded even during pump failure accompanied by reactor shutdown. It should be noted that some research reactors that are cooled by forced convection utilize downward coolant flow. In the event of pump failure and reactor shutdown, the reactor may be cooled by

natural convection, which involves a reversal of the direction of flow. The safety limit should not be exceeded even in such cases.

3.11. It should be shown in the safety analysis report or other associated document that the safety limits are not violated in any operational state.

3.12. The specification of the safety limit should be clear and precise, and the parameters to which it applies and the objective of the limit should be stated. The basis for the safety limit should provide sufficient information to allow a clear understanding of its safety significance on the part of the operating personnel and the regulatory body.

3.13. Although the integrity of the containment or the means of confinement (if any) is important in limiting the radiological consequences of an accident, a loss of containment or loss of the integrity of the means of confinement does not in itself lead to damage to the fuel cladding. The integrity of the containment or the means of confinement is therefore not included in the safety limits, but it should be included under the limiting conditions for safe operation.

## SAFETY SYSTEM SETTINGS

3.14. For each parameter for which a safety limit is required, and for other important safety related parameters<sup>10</sup>, the safe design of the reactor requires the installation of a system that monitors the parameter and provides a signal that can be utilized in an automatic mode to prevent the value of that parameter from exceeding the safety limit. The set point for this protective action is defined as the safety system setting.

3.15. Some safety system settings are provided to initiate the operation of engineered safety systems to limit the course of anticipated operational occurrences in such a way that either safety limits are not exceeded or the consequences of postulated accidents are mitigated.

3.16. Established safety system settings should ensure the automatic actuation of safety systems within the parameter values assumed in the safety analysis

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<sup>10</sup> For example, a limiting condition for safe operation may be the concentration of radioactive material in the exhaust ventilation, which requires monitoring and action to prevent releases exceeding a set value.

report, despite possible errors that could occur in adjusting the nominal set point. Appropriate alarms should be provided to enable the operating personnel to initiate corrective actions before safety system settings are reached.

3.17. Safety system settings should be established for all operational states of the reactor. In determining a safety system setting, the process uncertainties and measurement uncertainties, the response of instrumentation and uncertainties in calculations should be taken into account (see Ref. [1], para. 7.34).

3.18. The specification of any safety system setting should be clear and precise, and should state the parameters to which it applies and the objective of the specification. The basis for the safety system setting should contain sufficient information to allow a clear understanding of its safety significance on the part of the operating personnel and the regulatory body.

## LIMITING CONDITIONS FOR SAFE OPERATION

3.19. Limiting conditions for safe operation are administratively established constraints on equipment and operational parameters that must be adhered to during the startup, operation, shutting down and shutdown of a research reactor to provide acceptable assurance of safe operation within the reactor licence conditions and within applicable regulations. The limiting conditions for safe operation should be consistent with and, to the extent possible, should be derived from the safety analysis report. Where established, limiting conditions for safe operation should be complied with in all operational states of the reactor (see Ref. [1], para. 7.35). Compliance with limiting conditions for safe operation prevents safety system settings from being reached, addresses other factors that, if not controlled, might give rise to risks to the health and safety of the public, and ensures full capability for performing other necessary safety functions in all operational states and under accident conditions.

3.20. The limiting conditions for safe operation should include limits on operating parameters, requirements for minimum operable equipment with systems unavailability rules and the time allowed to attain the safety fallback state in the event that these unavailability rules are not met, and prescribed actions to be taken by the operating personnel in the event of deviations from the established OLCs as well as the time allowed to complete these actions.

3.21. Operability requirements should state for the various modes of normal operation the number of systems or components important to safety that should be either in operating condition or in standby condition. These operability requirements define the minimum safe facility configuration for each mode of normal operation. The actions to be taken in the case that operability requirements cannot be met to the extent intended should be specified, and the time allowed to complete these actions should also be stated.

3.22. Given the higher associated risk during startup of the reactor, the operability requirements for this mode should be more stringent than those set for purposes of operational flexibility in power operation. Systems, structures and components that are required to be operable for startup should be specified.

3.23. For the operability requirements of safety related equipment, the provisions in the design for redundancy, the reliability of the equipment and the period over which equipment may be allowed to be inoperable without an unacceptable increase in risk should be taken into consideration. The basis for determining an unacceptable increase in risk should be clearly documented in the OLCs.

3.24. The objective and applicability of each limiting condition should be stated, its specification should be clear and precise, and its basis should contain sufficient information for it to be fully understood by the operating personnel and easily assessed by the regulatory body.

3.25. The number of limiting conditions for safe operation may be large, even for a low power research reactor. For this reason the limiting conditions should be grouped by topic. An example of one such grouping is as follows:

- (a) Fuel, fuel elements and assemblies;
- (b) Fuel handling and storage of fresh and spent fuel;
- (c) Reactor core configuration;
- (d) Reactivity and reactivity control systems;
- (e) Protection systems and reactor shutdown systems;
- (f) Fuel loading, reactor startup and operation;
- (g) Coolant systems and connected systems;
- (h) Containment systems or means of confinement, including ventilation;
- (i) Operational radiation protection;
- (j) Instrumentation and control systems;
- (k) Experimental devices;

- (l) Electric power supply systems;
- (m) Auxiliary systems and equipment;
- (n) Other limitations.

3.26. A list of selected factors to be considered when establishing limiting conditions for safe operation is provided in Appendix I.

## SURVEILLANCE REQUIREMENTS

3.27. To ensure that safety system settings and limits and conditions for safe operation are observed at all times, the relevant systems and components should be monitored, inspected, checked, calibrated and tested in accordance with an approved surveillance programme.

3.28. It should be an important design requirement for research reactors to allow for appropriate functional testing and inspection of all items important to safety (see para. 6.43 of Ref. [1]). This means that all items subject to safety system settings and limiting conditions for safe operation should undergo some form of surveillance or testing. Surveillance requirements should specify the frequency and scope of tests and the acceptance criteria (see paras 3.18–3.23 of Ref. [6]) to show that the performance requirements associated with the items subject to safety system settings and limiting conditions for safe operation are met.<sup>11</sup> The specification of the surveillance frequency should give average intervals with a minimum frequency that is to be achieved or a maximum interval that is not to be exceeded in order to provide operational flexibility in scheduling the inspection, operability check or calibration.

3.29. The surveillance requirements should be specified in procedures with clear acceptance criteria so that there can be no doubts concerning system operability or component operability. The relationship between these acceptance criteria and the limit or condition being confirmed should be available in written form.

3.30. The surveillance requirements may be presented either by grouping them according to the systems to which they refer or in a mixed way; for example, in

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<sup>11</sup> Surveillance requirements are met by using procedures that are normally part of the maintenance, periodic testing and inspection programme (see Section 5).

groups of requirements for major systems (such as the reactivity control system, the reactor pool or tank and the containment and/or confinement systems) or in groups of requirements covering related activities (e.g. tests before startup, monthly tests, quarterly tests, routeing, monitoring and personal dosimetry).

3.31. Limiting conditions for safe operation concerning the surveillance requirements should also cover activities to detect ageing and other types of deterioration due to corrosion, fatigue and other mechanisms. Such activities will include non-destructive examination of passive systems and of systems explicitly covered by limits and conditions for safe operation. If degraded conditions are found, the effect on the operability of systems should be assessed and acted upon appropriately.

3.32. Some of the OLCs, including surveillance requirements, may not apply during extended periods of shutdown of the reactor. For example, calibration of a power measuring channel may be deferred but should be performed before the next reactor startup. Some additional special surveillance requirements may be necessary during an extended shutdown period, such as during major maintenance or modifications. For these reasons, the surveillance requirements for extended shutdown periods may be specified separately.

## ADMINISTRATIVE REQUIREMENTS

### **General**

3.33. This section of the OLCs document specifies the administrative requirements for the reactor facility.<sup>12</sup> These administrative requirements consist of administrative controls concerning organizational structure and responsibilities, minimum staffing requirements, and required actions following violation of an operational limit or condition.

3.34. A list of safety related procedures could also be included in the OLCs document. These safety related procedures should be reviewed by the safety committee and may be subject to approval by the regulatory body.

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<sup>12</sup> In some Member States, administrative requirements may be part of the quality assurance programme.

## **Organization**

3.35. The organizational structure of the facility should be presented in an organizational chart with a brief description of functions. The chart should show the key personnel of the operating organization who have responsibility for the facility under the terms of the licence, including the reactor manager, shift supervisor and reactor operators.

## **Staffing**

3.36. It should be an important requirement relating to operational safety to determine and specify the minimum staffing requirements of the various disciplines for all operational states of the reactor. These requirements will vary with the complexity and power level of the reactor. The minimum qualifications for key operating personnel should also be specified.

## **Training and retraining**

3.37. The administrative requirements should include a statement that shift supervisors, reactor operators, radiation protection staff, experimenters, maintenance personnel and others who frequent the reactor facility should be properly trained. The staff requiring certification or licensing should be specified. If appropriate, the period of validity of the certification or licence should also be stated.

## **Review**

3.38. The requirement for specified reviews by a safety committee<sup>13</sup> should be stated. The items that should be reviewed by the safety committee may include the following:

- (a) Proposed changes to the OLCs or the facility licence;
- (b) Proposed changes to existing tests, experiments, equipment, systems or procedures, and new tests, experiments, equipment, systems or procedures having safety significance;
- (c) Safety related modifications to the reactor facility;
- (d) Violations of the OLCs, the licence conditions and procedures having safety significance;

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<sup>13</sup> See paras 7.25–7.26 of Ref. [1].

- (e) Events that are required to be reported, or have been reported, to the regulatory body;
- (f) Routine radioactive releases and exposures of personnel and the public;
- (g) Periodic reviews of the operation and safety performance of the facility.

### **Utilization and modifications**

3.39. Administrative requirements for the safe utilization and modification of the facility should be included in the OLCs. Guidance for deciding which experiments or modifications have to be referred to the regulatory body should be included in the administrative requirements. Further guidance on utilization and modification of the facility is provided in Ref. [3].

### **Records and reports**

3.40. An administrative requirement for the preparation and availability of various records and reports should be included in the OLCs.

3.41. The administrative requirements should state that the operating organization should make periodic summary reports to the safety committee and, if required, to the regulatory body on matters relating to the safety of the facility. The content and frequency of reports should be specified.

3.42. Records that are important for the safe operation of the reactor and for demonstrating compliance with the OLCs should be prepared and retained (see Ref. [1], para. 7.83). The records to be maintained by the facility and the time period for which the records are required to be retained should be specified. Typical records to be retained include the following:

- (a) The safety analysis report for the facility and changes to the safety analysis report;
- (b) The facility licence, the licence conditions and the OLCs;
- (c) Required plans such as the emergency plan, the security plan, the quality assurance plan, and the reactor operator and staff training plan;
- (d) Records of releases of effluents to the environment;
- (e) Records of radioactive waste;
- (f) Records important to decommissioning, such as records of spills, as-built drawings and records of modifications to structures;
- (g) Records of radiation exposures;
- (h) Records of significant contamination events;
- (i) Facility drawings;



- (j) Fuel receipt, shipment and inventory records;
- (k) Routine operating data such as log books and recording charts;
- (l) Procedures and changes to procedures;
- (m) Records of events that are required to be reported to the regulatory body;
- (n) Records relating to reactor experiments, such as application forms and collected data;
- (o) Facility radiation records and contamination survey records;
- (p) Records pertaining to the safety committee, such as meeting minutes and review reports;
- (q) Surveillance and maintenance records.

#### **Action required in the event of a violation of OLCs**

3.43. Actions that are required to be taken by the operating organization in the event that a safety limit or limiting condition for safe operation is violated or cannot be met should be included in the OLCs.<sup>14</sup>

## **4. DEVELOPMENT OF OPERATING PROCEDURES**

### GENERAL

4.1. All safety related activities should be performed in conformance with documents issued in accordance with approved operating procedures. The availability and correct use of written operating procedures is an important contribution to the safe operation of a research reactor. The IAEA Safety Requirements publication on the Safety of Research Reactors (Ref. [1], para. 7.51) states that “Operating procedures shall be developed for all safety related operations that may be conducted over the entire lifetime of the facility”, and this includes normal operation, anticipated operational occurrences and emergencies.

4.2. The operating procedures for normal operation should be developed to ensure that the research reactor is operated in compliance with the OLCs and should provide instructions for the safe conduct of operation in all modes, such

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<sup>14</sup> See paras 7.39–7.41 of Ref. [1].

as startup, shutdown, power level changes, fuel loading and handling, normal operation and anticipated operational occurrences.

4.3. In this Safety Guide the term ‘operating procedures’ also covers other activities that are conducted by means of written instructions and step by step descriptions of operations, such as commissioning, maintenance, experiments and modifications, activities in emergencies and radiation protection services. Operating procedures are sometimes bound in several volumes called manuals (e.g. operation manual, testing manual, maintenance manual). For low power research reactors, the operating procedures may be collected into a single volume under the general title of operating instructions.

4.4. 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. Among these responsibilities are the performance of the safety analysis as well as the preparation of other safety related documents for review and assessment by the safety committee and approval by the regulatory body, as required. Operating procedures having safety significance are part of such documents.

4.5. Operating procedures should be verified and validated by authorized persons to ensure that they are administratively and technically correct, are easy to understand and to use, and will function as intended. Special attention should be paid to ensuring that operating procedures are compatible with operation in the environment in which they are intended to be used. The operating procedures should be validated in the form in which they will be used.

## ROLES AND RESPONSIBILITIES

### **Operating organization**

4.6. To achieve the objective of safe operation of a reactor, the operating organization should establish administrative controls. These controls will usually be in the form of procedures to be followed by all personnel involved in their implementation.

4.7. The operating organization is responsible for establishing a set of OLCs, including administrative and organizational requirements. These general

operating rules<sup>15</sup> should be supplemented by specific written operating procedures.

4.8. When possible, operating procedures, especially for a new reactor, should be developed in cooperation with the reactor designer, equipment manufacturers and vendors. The assistance of external consultants may also be sought.

### **Operating personnel**

4.9. The operating personnel may initiate and should participate in the process of developing the operating procedures.

4.10. The operating personnel should be knowledgeable about the application of the operating procedures relevant to their tasks in the facility.

4.11. The operating personnel should operate the reactor in accordance with valid operating procedures and should provide feedback to the reactor manager on the application of the procedures.

4.12. Those procedures that are directly related to radiation protection should be reviewed by a radiation protection officer. The radiation protection manager is responsible for the preparation of all the radiation protection procedures for the tasks carried out by radiation protection personnel.

### **Safety committee**

4.13. The safety committee should review and assess the OLCs and the submitted operating procedures, and make recommendations before submission to the regulatory body for approval, as required. The safety committee should establish a process for review of urgently needed new procedures or changes to existing procedures that cannot await a review during a regularly scheduled safety committee meeting. For example, minor modifications to the operating procedures may possibly be made with the approval of the reactor manager followed by a review by the safety committee at its next meeting, provided that the general operating rules are observed.

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<sup>15</sup> These general operating rules are frequently compiled in a document called an operation manual.

## **Reactor manager**

4.14. In addition to those procedures required by the regulatory body (see para. 4.19), the reactor manager should determine the need for operating procedures that may be initiated by the operating personnel or others.

4.15. The reactor manager should ensure the development and implementation of the operating procedures. Alternatively, the reactor manager may appoint a staff member, normally a relevant group leader, to develop procedures.

4.16. The reactor manager is responsible for the approval of all operating procedures, including those reviewed by the safety committee.

4.17. The reactor manager is responsible for the training and retraining of staff in the procedures. The reactor manager should ensure that the latest revision of the procedures is used in the training or retraining.

4.18. The reactor manager should ensure that operational procedures are readily available for reference close to the point where the work is done or operations are carried out. Usually, one full set of operational procedures is kept in the control room and another full set in the reactor supervisor's office. There may be an additional selection of appropriate procedures kept in a location near relevant operations areas that are remote from the control room.

## **Regulatory body**

4.19. The regulatory body should review, assess and approve the OLCs and the submitted operating procedures, as required. The regulatory body may require that some specific procedures be established.

4.20. The operating procedures should be available to the regulatory body for its consideration.

## **CATEGORIZATION AND LIST OF OPERATING PROCEDURES**

4.21. Procedures should be developed for all safety related operations that may be conducted over the entire lifetime of the research reactor. For this reason it is convenient to categorize procedures according to their purpose and content. One such categorization is as follows:

- (a) Commissioning procedures;
- (b) Operational procedures;
- (c) Maintenance procedures;
- (d) Inspection, calibration and periodic testing procedures;
- (e) Radiation protection procedures;
- (f) Procedures for the authorization of operation, maintenance, irradiation or experiments;
- (g) Procedures for operator response to anticipated operational occurrences;
- (h) Emergency procedures;
- (i) Physical protection procedures;
- (j) Procedures for the handling of radioactive waste and control of radioactive releases;
- (k) Decommissioning procedures;
- (l) Procedures for utilization and for modification of the reactor;
- (m) Administrative procedures.

This list is not intended to be comprehensive. Some items may not be appropriate for low power facilities, and the list may be incomplete for high power facilities. Appendix II presents selected operating procedures listed on the basis of this categorization.

4.22. The categorization has been selected for consistency with the topics developed in the IAEA Safety Requirements publication on the Safety of Research Reactors [1]. Categorizations on the basis of other criteria may also be valid. A categorization system may be based on the review and approval route for the procedures; for example, safety related procedures (required and approved by the regulatory body), administrative procedures (reviewed by the operating organization) and other safety related procedures (reviewed by the safety committee and approved by the reactor manager). In other categorizations, only the area of application may be considered.

## GENERAL CONSIDERATIONS FOR THE DEVELOPMENT OF OPERATING PROCEDURES

4.23. Paragraphs 4.24–4.29 present general considerations relating to the different types of procedures presented in para. 4.21. In addition, where possible, a reference is provided to IAEA publications that provide additional information.

4.24. The need for special quality assurance measures should be taken into account when developing procedures for operational activities that have an influence on or that relate to the following:

- (a) Reactivity and criticality;
- (b) Thermal safety;
- (c) Safety of experiments;
- (d) Repair actions;
- (e) Modification of existing systems or components;
- (f) New installations;
- (g) Manipulation of special components and radioactive material;
- (h) Surveillance of equipment;
- (i) Inspection programmes;
- (j) Steps for the approval of different safety related actions (e.g. replacements, repairs, modifications, new installations);
- (k) Accreditation of operating personnel and experimenters.

4.25. To develop a set of procedures for use in operation, a planned and systematic process should be applied. This may be facilitated by using a prescribed format and standard outline of the content to be incorporated.

4.26. Each procedure should be sufficiently detailed for a qualified individual to be able to perform the required activities without direct supervision, but the procedure should not provide a complete description of the facility processes involved.

4.27. The format of the procedures may vary, but the procedures should be developed in accordance with established requirements and recommendations relating to quality assurance.

4.28. Persons with appropriate competence and experience should be designated to prepare and verify procedures.

4.29. Human factors should be taken into account to develop safe, reliable and effective operating procedures. Consideration should be given to the layout, the general design of the facility, staffing requirements and operating experience at the research reactor concerned.

## STEPS IN THE PREPARATION OF A PROCEDURE

4.30. Once the objectives of the procedure have been defined, the first step in the development of an operating procedure is to evaluate the possible methods and staff requirements for fulfilling the objectives of the procedure and to select the methods best suited for achieving the desired goal.

4.31. If it is possible and considered necessary, the methods selected should be simulated by the staff and the relevant technical and administrative personnel who will be performing the task covered by the procedure. A draft procedure should be used for the simulation. The simulation should cover all conceivable technical and human errors that could occur during the performance of the task. The procedures should be finalized on the basis of the results of the simulation.

4.32. If the procedure has significance for radiation protection, it should be reviewed by a radiation protection officer and should be modified as recommended.

4.33. The draft of the procedure may be improved by means of a review by staff members with experience in the subject of the procedure and by those staff members who will use the procedure.

4.34. The reactor manager should be responsible for a review of a draft of the procedure to determine whether the procedure is sufficiently detailed for its intended objectives and is consistent with other relevant procedures. Also, the reactor manager should ensure that implementation of the procedure would not violate any OLCs.

4.35. The reactor manager should forward the final drafts of safety related procedures to the safety committee for review and comment prior to their approval. Procedures having significance for the safety of the reactor should be specified as such and should be subject to approval by the regulatory body, as required.

4.36. The procedure may be released by the reactor manager for a trial period or a period of restricted use and subsequently revised if necessary. Following this validation period, use of the procedure should be subject to final approval by the reactor manager.

4.37. Experience gained in the use of a procedure may indicate a need for its review and updating. Review and updating should, in principle, follow the same steps as those in the preparation of a procedure as outlined here. The reactor manager should specify the process for this review and updating.

4.38. Safety significant revisions of procedures should be treated in accordance with para. 4.35. Other revisions of procedures may be approved directly by the reactor manager.

## **5. FORMAT AND CONTENT OF OPERATING PROCEDURES**

### **GENERAL**

5.1. All operating procedures should have a standard format as specified by the operating organization. They should follow a suitable sequential presentation, should have a clear, concise and logical text, and should cover all relevant issues. The following guidance will facilitate meeting these objectives.

5.2. To ensure consistency in format and content, operating procedures should be prepared in accordance with a general quality assurance procedure or administrative procedure that governs the development, review and control of such documents. Provision should be made in this general procedure or elsewhere for periodic review. There should be a mechanism to verify conveniently that a procedure has been approved (e.g. by means of a signature) and that it is current (e.g. through a list of the latest revision dates).

5.3. Operating procedures should generally direct the step by step performance of all activities except for routine activities that are capable of being performed by qualified personnel without special instructions. More than one procedure may be necessary to accomplish certain tasks. In this case, the order of performance of the procedures should be specified in the procedures themselves.

5.4. There should be a clear differentiation in a procedure between the introduction, guidance and essential steps.



5.5. The following is a typical example of the content to be considered for inclusion in an operating procedure:

- (a) Identification number: A unique number that identifies the procedure as one of a series of operating procedures.
- (b) Revision number and date: The current revision number and date should be included at the head of each page of an operating procedure to ensure that personnel are aware of the revision that is in use (e.g. Revision 3: 16 July 2003).
- (c) Date of expiry: This may be the date of the next revision or it may be indefinite until the withdrawal of the procedure.
- (d) Title: A concise description of the content of the procedure (e.g. reactor startup, control rod calibration).
- (e) Scope and purpose: A statement of the scope and purpose of the procedure.
- (f) Definitions: Definitions of terms used in the procedure that are necessary for understanding and performing the procedure.<sup>16</sup>
- (g) References: References on the basis of which the procedure was developed and that are referred to in the text.
- (h) Responsibilities: Specification of the requirements on and responsibilities of personnel performing the procedure.
- (i) Prerequisites: Specific conditions for the reactor, systems, equipment and personnel required to perform the procedure.
- (j) Additional requirements: Specification and/or description of special tools, support services, radiation protection measures, special safety precautions, possible effects on the reactor during the implementation of the procedure, measures to prevent damage to fuel and equipment, training (education) of personnel, conditions of applicability and preparations relating to the performance of the procedure.
- (k) Instructions: Specific step by step instructions for performing a procedure. The level of detail should be such that qualified personnel can follow the instructions without further directions. Where appropriate, hold points for inspection and verification should be specified. Instructional steps should begin with verbs (i.e. actions such as turn, record, energize, set, note, check, lift, press, test, insert). Caution should be exercised to ensure that the steps in the instructions are complete, and that all required actions have been considered and there are no instruction steps contained in the procedure as prerequisites and special

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<sup>16</sup> In general, use of terminology requiring definitions should be avoided. If this is not possible, a definition needs to be incorporated into the procedure.

requirements that could be overlooked while performing the procedure. Consideration should be given to setting up instructions in the form of checklists on which each step is initialled by operating personnel as it is completed. Where necessary, instructions should be provided for closing activities such as restoring the system to its normal configuration.

- (l) Basis for measurements and calculations: For some procedures that require measurements and calculations, documentation of the basis for the measurements and calculations may be provided to assist operating personnel in understanding the steps performed in the procedure.
- (m) Documentation: While completion of some procedures may be indicated by a simple entry in the reactor logbook, more complicated procedures may be documented by means of appropriate checklists, data tables and reports. Such data sheets should include the name of the person recording the data, the time and the date. The level of detail for documenting a procedure should be commensurate with the relative complexity of the operation and the inherent risks associated with failure to conduct the operation properly.

5.6. Procedures should include arrangements for collecting, tabulating and reporting data and test results. Methods of analysis should be stated and presented in a manner that allows for further verification. Test data should be evaluated against predefined performance parameters and acceptance criteria in which account is taken of the uncertainties assumed in the safety analysis.

5.7. On the basis of the quality assurance requirements, procedures should be prepared for the procurement and acceptance of new components or equipment (e.g. fuel elements, ion exchange resins). The procedures should require a valid calibration certification for test equipment that is used in the procedure.

5.8. Procedures should specify the authority for permitting deviations from the procedure and the circumstances under which deviations are permitted. Such deviations, if permitted, should be made within the bounds of the relevant OLCs.

5.9. In addition to the general recommendations provided here for consideration in developing all procedures, the following sections are intended to provide additional recommendations for the various types of operating procedure.

## COMMISSIONING PROCEDURES

5.10. The content of commissioning procedures for tests of equipment and systems should be defined in accordance with para. 5.5, with special attention paid to the following:

- Summary of purpose, equipment to be tested and relationship to the commissioning programme;
- Prerequisites and initial conditions;
- Precautions, including stopping of the test;
- List of required equipment and instruments;
- List of data to be recorded and checklists;
- Analysis of data and results;
- Acceptance criteria;
- Provisions for corrective actions concerning possible non-conformances;
- Certification of completion of the test.

5.11. Commissioning procedures may be subdivided into those that are derived directly from operating procedures and those that will be required during commissioning only. The latter are sometimes referred to as test procedures.

5.12. A commissioning procedure should be prepared for each commissioning test or activity. The procedure may also be used as a guide for assessing and documenting the results of the test.

5.13. The test procedures should follow the normal facility operating procedures to the extent practicable, to verify these procedures and to provide an opportunity for operating personnel to become familiar with the normal facility operating procedures.

5.14. Certain commissioning activities may simply require generic procedures or lists of instructions.

5.15. Commissioning procedures should include prerequisites, where applicable, for system tests that must be completed prior to performing the step by step instructions established by these procedures, including commissioning of support systems (e.g. operable flow measurement channel prior to testing of the primary coolant system, operable electric power supply prior to commissioning tests of pumps).

5.16. In addition to operational procedures, supporting documentation, including manufacturers' manuals and construction drawings, may be required for commissioning test procedures for some components and systems.

5.17. If necessary, the procedure should include hold points for the notification and involvement of outside agencies, manufacturers and the regulatory body.

5.18. Procedures should state all the necessary changes to the normal operating configuration that are required for testing. However, in this case, configuration checks should be undertaken to ensure that these deviations are made correctly before the start of the tests and that all the components or systems are restored to their normal status after the testing.

5.19. Consideration should be given during the preparation of the procedure to interactions between the reactor and experimental devices.

5.20. Commissioning procedures should be prepared for experimental devices in any case, whether they will undergo commissioning at the same time as the reactor or later.

5.21. The commissioning procedure should contain provisions for dealing with unexpected results of commissioning, deliberate changes to the design, programmes or tests that may become necessary, and incidents that may occur during the commissioning process.

5.22. In practice, many of the commissioning procedures become operational procedures (e.g. procedures for fuel loading, startup, calibration of reactivity control mechanisms and determination of the thermal power level).

## OPERATIONAL PROCEDURES

5.23. The operating organization should ensure that all reactor operation is in accordance with approved operational procedures. These procedures should be prepared for all activities performed by the operating personnel for all operational states of the reactor and, where appropriate, for experiments and for the handling of fuel assemblies or other core and reflector components, including experimental devices.

5.24. Normally, procedures are performed one at a time. If this is not the case, the safety significance of the simultaneous performance of several procedures

should be taken into account in the procedure by specifying special precautions.

5.25. Operating procedures are reviewed periodically and also whenever a change is made in the configuration of the reactor system or components concerned. For operations that are performed infrequently, the existing procedures should be reviewed in any case before use, and revisions should be made as appropriate.

5.26. Operational procedures should specify the actions required in the case of an unexpected event or unexpected results during the performance of the procedure, as necessary.

5.27. Operational procedures should include requirements for work permits, if necessary.

## MAINTENANCE PROCEDURES

5.28. A plan for preventive maintenance should be prepared to assist in the timely completion of those maintenance activities that are required to be completed on a regular (e.g. weekly, monthly, quarterly, semi-annual, annual) basis.<sup>17</sup> Procedures for corrective maintenance activities should be prepared as required.

5.29. In the preparation of maintenance procedures, particular attention should be paid to the effects of the procedure on safety systems and on reactor operation. Some procedures with no impact on reactor safety may be performed during reactor operation; other procedures may require shutdown of the reactor. The maintenance process should not reduce the safety of the reactor, and the OLCs should not be violated.

5.30. A system of work permits should be used for maintenance, including appropriate check-offs, during and after the conduct of the work in accordance with the quality assurance programme. This is to ensure that all work is conducted with the knowledge and permission of the person in operational

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<sup>17</sup> Ageing management activities are generally part of a preventive maintenance programme. Procedures include inspections to evaluate the effects of ageing of equipment and the need for the replacement of equipment.

control of the reactor and that both the safety of the reactor and the safety of the personnel doing the work have been considered. Therefore, maintenance procedures may incorporate the requirement of a work permit as a prerequisite to performing the maintenance.

5.31. Maintenance procedures should specify any changes to the normal reactor operating configuration (e.g. valve line-ups) and should have provisions for the restoration of the normal configuration after maintenance (e.g. procedures for taking mechanical and electrical equipment out of service and for restoring it to service). A generic procedure should therefore be developed or special provisions should be made in individual procedures to achieve configuration control.

5.32. Reference to drawings, manufacturer's manuals to be used and manufacturer's recommendations to be followed should be included in the procedures. It should be ensured that the updated versions of drawings and manuals are used.

5.33. Maintenance procedures should specify that the results of maintenance, testing and inspection should be assessed by properly qualified personnel. Comparison should be made, where appropriate, with the results of previous inspections and tests to determine potential failures and to permit timely corrective action.

5.34. Maintenance procedures should specify that the resumption of normal operation should be permitted only after an authorized person has approved the results of the maintenance.

5.35. Special procedures should be prepared to control contractor maintenance work. These procedures should include prerequisites to the work, requirements for supervision of the contractor, contractor qualification and work coordination.

## INSPECTION, CALIBRATION AND PERIODIC TESTING PROCEDURES

5.36. Periodic testing is performed to fulfil surveillance requirements specified in the OLCs and is intended to ensure compliance with the OLCs. The surveillance programme should be adequately specified to ensure the inclusion of all aspects of the limits or conditions.

5.37. Periodic testing procedures, which include calibration, inspection and operability checks, should be prepared for structures, systems and components that are important for safe operation of the reactor. A plan for scheduling calibrations, inspections and operability checks should be prepared to assist in their completion at the required frequencies.

5.38. The frequency of the surveillance activities should be stated and should be based on:

- Analyses, including insights from probabilistic safety assessment, where available;
- The recommendations of the supplier;
- Experience gained from previous surveillance results;
- Engineering judgement.

5.39. Periodic testing procedures should be consistent with the reactor operating procedures. In addition, when developing periodic testing procedures, the considerations for developing operational and maintenance procedures (see paras 5.23–5.35) should also be taken into account.

5.40. Each periodic testing procedure should provide for a final acceptance (including signature) by a person qualified and authorized to assess the results of the procedure and to verify compliance with the OLCs.

5.41. Periodic testing procedures should have provisions for resolving non-conformances with the OLCs.

5.42. Acceptance criteria (for which consideration has been given to the uncertainties of measurements) should be provided within periodic testing procedures. Providing a range of acceptable values for parameters is therefore generally better than giving single values.

5.43. The procedures may require that instruments used for calibrations be certified in accordance with the requirements of the quality assurance programme.

## RADIATION PROTECTION PROCEDURES

5.44. Radiation protection procedures should be prepared within the framework of the radiation protection programme for the facility.

5.45. Radiation protection procedures should contain instructions for implementing the radiation protection programme, such as instructions for periodic measurements (e.g. for bioassay, contamination surveys, stack effluents, source inventory). The procedures should contain acceptance criteria and should identify the person responsible for reviewing the results. A master radiation protection procedure should be prepared to ensure that all activities are completed at the required frequencies.

5.46. Radiation protection provisions for those personnel operating the reactor, conducting maintenance and periodic testing or performing experiments should be included in each of the relevant procedures and, if necessary, in the work permits for their implementation.

5.47. In developing radiation protection procedures, compliance with the OLCs for reactor operation and with regulatory body requirements should be verified.

#### PROCEDURES FOR THE AUTHORIZATION OF OPERATION, MAINTENANCE AND UTILIZATION

5.48. Procedures for the authorization of operation, maintenance and utilization (conduct of irradiations or performance of experiments) that could affect the safety of the reactor should be prepared, to define the conditions, the levels of responsibility and the means of authorization.

5.49. A procedure for dealing with proposals for experiments should be established. The procedure should require that the proposals include:

- (a) A description of the purpose and intended conduct of the experiment;
- (b) The means of integrating the experimental device with the reactor systems;
- (c) The selection and justification of the criteria employed in the design of the experimental device;
- (d) A safety assessment of the experimental device, including the experiment itself, and of its effects on the safety of the reactor and personnel;
- (e) The requirements for the production and validation of any special documentation for operation and maintenance;
- (f) The requirements for any special training of operating and maintenance personnel and experimenters;
- (g) The requirements for commissioning and functional testing;



- (h) Special requirements for transport, if necessary;
- (i) A decommissioning plan for the experimental device;
- (j) The quality assurance programme used;
- (k) The suggested means of disposal of the radioactive waste generated in the experiments and of the experimental devices after their final use;
- (l) Considerations relating to alarms and interlocks;
- (m) Procedures to ensure adequate means of communication between operators and experimenters.

5.50. Procedures should be prepared for the authorization of irradiations and isotope production. The procedures should include information concerning the means by which new types of irradiation (e.g. irradiation of new materials or of greater quantities of the usual materials) should be authorized.

#### PROCEDURES FOR OPERATOR RESPONSE TO ANTICIPATED OPERATIONAL OCCURRENCES

5.51. Procedures for guiding the response of the operator to anticipated operational occurrences, design basis accidents and, to the extent feasible, beyond design basis accident conditions should be prepared and should be periodically exercised. To improve their execution, the procedures should be reviewed and modified on the basis of operational experience and the performance of the exercises.

5.52. The procedures mentioned in para. 5.49 should be included with the operational procedures for the reactor. On the basis of the safety analysis report, the procedures should contain the duties of the operating organization for all anticipated operational occurrences. The instructions for all operating procedures should be clear and brief, and particularly so for those dealing with anticipated operational occurrences.

#### EMERGENCY PROCEDURES

5.53. Emergency procedures should be prepared, and they should be a component of the emergency plan. Their development should be based on the evaluation and analysis of all aspects of possible emergencies. The procedures should specify the methods and duties of intervention staff and the emergency actions that are necessary to mitigate the possible consequences of the

emergency. They should refer to the emergency facilities and emergency equipment.

5.54. Emergency drills should be periodically conducted. On the basis of experience gained from the performance of the drills, the procedures, including the list of organizations and individuals to be called or informed in the event of an emergency, should be reviewed at specified periods and amended, if necessary, to improve their execution and to ensure that the lessons learned are taken into account.

5.55. In preparing emergency procedures in which the services of off-site organizations such as hospitals, police forces, fire departments and ambulance services are utilized, agreements should be obtained from the organizations concerned. Formal letters of agreement and lists of contact points should be maintained and periodically updated. In addition, emergency procedures including emergency actions to be taken by off-site organizations should include clear and detailed instructions that have been agreed with the off-site organizations.

5.56. Experts should be consulted in preparing emergency procedures (e.g. specialized personnel from fire departments, hospital emergency units, ambulance crews, etc.) [7, 8].

## PHYSICAL PROTECTION PROCEDURES

5.57. Physical protection procedures should be prepared and should be a component of a physical protection plan. The plan should be approved by the competent authorities as specified in the legal framework of the State. The plan and procedures should be kept confidential and should be revealed on a need to know basis only.

5.58. Physical protection procedures should be developed on the basis of the evaluation and analysis of all aspects of security. The instructions for physical protection procedures should be brief but should give sufficient details of the essential steps for coping with security matters.

5.59. If the services of off-site organizations such as police forces and army units are required by physical protection procedures, formal letters of agreement should be obtained and these should be periodically updated.

5.60. Experts should be consulted in preparing security procedures (e.g. security specialists, specialized personnel from the police and army).

## PROCEDURES FOR THE HANDLING OF RADIOACTIVE WASTE AND CONTROL OF RADIOACTIVE RELEASES

5.61. Requirements covering the procedures for handling radioactive waste and for the monitoring and control of radioactive releases are established in Ref. [9]. These procedures may be included as part of the radiation protection procedures or may form an individual group within the operating procedures.

5.62. At some research reactor facilities, the operating personnel and radiation protection staff handle, collect, process, account for, store and dispose of radioactive waste.<sup>18</sup> In this case the procedures for radioactive waste are usually considered to be radiation protection procedures. Further guidance on the predisposal management of radioactive waste is provided in other Safety Guides [10, 11].

5.63. Procedures for controlling radioactive discharges play an important part in environmental protection and also in gaining public acceptance of the facility. The sensitivity of this matter should be taken into account in the development of these procedures. Further guidance is provided in Ref. [12].

## PROCEDURES FOR EXTENDED SHUTDOWN

5.64. During the extended shutdown period, modifications of the procedures for preventive maintenance and periodic testing may be introduced. Relief from the procedures is possible in those activities that are a function of operating time or energy generation.

5.65. Special procedures should be developed for those inspections that could indicate degradation of mechanical and electrical systems and components.

5.66. Procedures for extended shutdown should be derived from the procedures for normal operation. The effects of giving exemptions for activities

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<sup>18</sup> Further guidance is provided in the IAEA safety standards relating to radioactive waste.

to be conducted during extended shutdown should be carefully investigated, as some activities could cause significant degradation in the systems, which could prevent the recommissioning of the reactor.

5.67. Surveillance procedures to be used during extended shutdown periods for the reactor should be derived from the surveillance procedures for an operating reactor, with exemptions given for certain activities or strengthening of the procedures for others.

5.68. If the operating procedures are modified for the extended shutdown state of the facility, the original version of the operating procedures should be kept for possible future operation of the reactor.

5.69. Procedures should be developed for disconnecting, dismantling and preserving the systems that are to be taken out of operation or temporarily dismantled.

## PROCEDURES FOR UTILIZATION AND FOR MODIFICATION OF THE REACTOR

5.70. Procedures should be prepared for controlling utilization or modification of the reactor<sup>19</sup> having safety significance, to ensure that the design, manufacture, installation, conduct and testing of experiments and modifications are properly executed.

5.71. The utilization and modification of the reactor should be performed in accordance with approved procedures that contain provisions for ensuring that all OLCs are met.

5.72. The following considerations should be addressed in the modification procedure:

- (a) Description and drawings of the proposed modification;
- (b) Justification of the need for the modification;
- (c) Design requirements and criteria;
- (d) Safety assessment supporting the modification, including influences on other systems;

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<sup>19</sup> For further details, see Ref. [3].

- (e) Manufacturing processes;
- (f) Installation processes;
- (g) The commissioning process;
- (h) Review and modification of existing operating procedures and the need for new procedures;
- (i) Updating of documentation (drawings, training materials, etc.);
- (j) Training requirements for reactor operators and support staff (including requalification and relicensing, if necessary);
- (k) Quality assurance requirements;
- (l) Requirements for the optimization of radiation protection;
- (m) Requirements for physical protection;
- (n) Requirements for radioactive waste disposal.

5.73. A procedure should be prepared for the categorization of experiments and modifications on the basis of their safety significance. Generally, three categories for experiments and modifications are utilized: those that fall outside the approved OLCs (major safety significance); those that are within the OLCs (moderate safety significance); and those having no safety significance. An extensive discussion of categorization, safety assessment and approval routes for experiments and modifications is provided in section 3 of Ref. [3].

5.74. In the preparation of procedures for utilization or modification, particular attention should be paid to the consequences for safety systems and for reactor operation. The safety level of the reactor during or as a result of the modification or utilization should not be reduced below the limits set in the OLCs.

5.75. The procedures may include a system of work permits for use for modification or utilization and when performing pre-operational testing, including appropriate checks before and after the conduct of the work in accordance with the quality assurance programme. This is to ensure that all work is conducted with the knowledge and permission of the person in operational control of the reactor, and to ensure the protection and safety of the personnel doing the work as well as the safety of the reactor.

5.76. Procedures for modification and utilization should specify any changes to the normal reactor operating configuration (e.g. valve line-ups) and should include provisions for restoration of the normal configuration.

5.77. Procedures for modification and utilization should include assessment of the results of the modification or utilization by properly qualified persons to verify compliance with the approved design and with the OLCs. The procedures should require comparisons, where appropriate, with the pre-modification conditions to determine possible failures and to permit timely corrective action.

5.78. Modification procedures should ensure that the resumption of normal operation will be permitted only after the person who is responsible for coordinating the modification work has approved the results, including the updating of documentation.

5.79. Special procedures should be prepared to control modification work performed by contractors. These procedures should include requirements for contractors' qualifications and training and for the coordination of work, as well as provisions for surveillance of the contractors. The procedures should list activities of the contractor that are prohibited (e.g. activities causing the generation of dust, use of the reactor power supply).

## ADMINISTRATIVE PROCEDURES

5.80. Administrative procedures should be developed for all operations that are of an administrative nature and that may have an effect on the safety of the reactor (e.g. personnel training and retraining, transport of radioactive material, fuel management and control of visitors).

5.81. Administrative procedures that are consistent with the quality assurance programme should be developed for the generation, collection, and retention and archiving of records and reports.

5.82. Administrative procedures may be used as implementing procedures for the quality assurance programme.

5.83. Administrative procedures should be based on national standards or national regulatory requirements. Where appropriate, as for the transport of radioactive material, the administrative procedures should be in accordance with international standards, agreements or practices.

## **6. TRAINING OF PERSONNEL IN THE USE OF PROCEDURES**

6.1. To ensure that procedures will be properly executed, operating personnel and others should be knowledgeable in the current procedures relating to the tasks for which they are responsible.

6.2. Before a procedure is used, training of operating personnel and others who are intended to implement the procedure should be conducted. Training may take the form of oral or written instructions, demonstrations, drills, training classes or comprehensive training courses and, where applicable, the use of mock-ups.

6.3. Retraining in the use of procedures should be included in the retraining programme for operating personnel and others, and the frequency of the retraining programme should be specified. Retraining should be conducted according to a plan, and special attention should be paid to emergency procedures and infrequently performed procedures. Typical examples of these are:

- Operation of the emergency core cooling systems;
- Operation of the air cleaning system for the containment or the means of confinement;
- Testing of the leaktightness of the reactor building;
- Handling of highly radioactive material under abnormal conditions;
- Fuel shipment;
- Emergency actions such as responses to a fire alarm or evacuation alarm in the reactor building, a personal injury, the release of airborne radioactive material and weather warnings;
- Use of personal protective equipment.

6.4. The operating personnel and others should be required to demonstrate their knowledge and understanding of the operating procedures that they follow in discharging their responsibilities.

6.5. Procedures should be developed for validation of the training, to verify its effectiveness and the qualifications of the staff.

## **7. COMPLIANCE WITH OPERATIONAL LIMITS AND CONDITIONS AND OPERATING PROCEDURES**

7.1. The operating organization has the primary responsibility for ensuring compliance with the OLCs. Relevant controls should be established to discharge this responsibility.<sup>20</sup> The provision of and training in operating procedures consistent with the OLCs is a major contribution to ensuring compliance with the OLCs. Some OLCs may be directly stated in procedures or other documents, and if so this should be clearly indicated in the implementation document.

7.2. To ensure compliance with OLCs, all persons who are responsible for such compliance should always have available a copy of the OLCs currently in force and should be adequately trained in their application. If possible, operational limits should be legibly indicated on instruments and displays to facilitate compliance. Similarly, the current operating procedures should be immediately available to the control room personnel and to others who need to use them or refer to them.

7.3. If an OLC cannot be met or a procedure cannot be followed, this should be reported and the causes should be analysed. This may lead to the modification of an OLC or procedure in accordance with established procedures that allow for changes to be made in a controlled manner and approved as required by the regulatory body. Results of routine or commissioning tests also necessitate analyses and consideration of the need for modifications to the OLCs and/or the operating procedures.

7.4. Records of operation of the research reactor and demonstrations of compliance with the OLCs and operating procedures should be kept and should be stored in accordance with the quality assurance requirements. Reports of non-compliance should be investigated to ensure that corrective action is taken and to help prevent such non-compliance in the future.

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<sup>20</sup> Further guidance is provided in Ref. [6].



## 8. QUALITY ASSURANCE

### GENERAL

8.1. A quality assurance<sup>21</sup> programme based on specific quality standards for the operation and utilization of a research reactor should be established, managed, applied and evaluated for ensuring safety.<sup>22</sup> The senior management should establish, implement and maintain the quality assurance programme, which should cover all processes of the organization, including the operational processes, the interfaces at different operational phases, and the development and implementation of operating procedures. The extent of the quality assurance programme that is required for the operating organization of a particular research reactor will depend on the safety significance of the activities and processes relating to the reactor and on the legal requirements established by the regulatory body. For further guidance on the format and content of the quality assurance programme, see Ref. [13].

8.2. The quality assurance programme should be reviewed and approved at the appropriate levels of management within the operating organization and, where necessary, by the regulatory body.

8.3. The quality assurance programme should provide for independent verification that a component or system is returned to its operational state (including verification that it is not bypassed or disabled) after an inspection, operability check, calibration or any other associated maintenance activity.

8.4. The management should ensure that an approved quality assurance programme is documented and distributed to staff for implementation of its requirements and should ensure its effective implementation.

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<sup>21</sup> The IAEA has revised the requirements and guidance in the subject area of quality assurance for new safety standards on management systems for the safety of nuclear facilities and activities involving the use of ionizing radiation [13, 14]. Aspects of managing a nuclear facility, including the safety, health, environmental and quality requirements, are to be integrated into one coherent management system.

<sup>22</sup> See Ref. [1], paras 4.5–4.9.

## SPECIFIC QUALITY ASSURANCE ARRANGEMENTS FOR OPERATIONAL LIMITS AND CONDITIONS

8.5. To provide assurance that the selection, development, implementation and modification of the OLCs have been correctly conceived, the overall quality assurance programme for operation of the reactor should specify the system for controlling the establishment of the OLCs and the management responsibilities for this process. This process should also be applied to the development of any additional operating rules and other technical requirements referred to in the OLCs. This quality assurance programme refers to other documents that define the processes in detail.

8.6. The items to be audited and the maximum interval between audits should be stated and may include, for example:

- Facility operations for conformance with the OLCs and the facility licence;
- The response by the operating organization to violations of the OLCs;
- The implementation of licensing procedures;
- Events that should be reported to the regulatory body;
- The facility emergency plan and procedures;
- The training programme for reactor operators;
- The updating of documents.

For requirements and guidance on auditing, see Refs [13, 14], and also Safety Guide No. 50-C/SG-Q: Q5.<sup>23</sup>

## QUALITY ASSURANCE FOR OPERATING PROCEDURES

8.7. The quality assurance programme should specify the system for the development, implementation and modification of operating procedures to ensure that they have been correctly conceived and implemented.

For requirements and guidance, see Refs [13, 14] and Safety Guides No 50-C/SG-Q: Q3, Q13 (see footnote 23).

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<sup>23</sup> INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for Safety in Nuclear Power Plants and other Nuclear Installations: Code and Safety Guides Q1–Q14, Safety Series No. 50-C/SG-Q, IAEA, Vienna (1996).

8.8. The quality assurance programme should specify the means of detecting and correcting non-conformances in the operating procedures. This may be done by means of periodic review and auditing by the operating organization.

## **Appendix I**

### **FACTORS TO BE CONSIDERED IN ESTABLISHING LIMITING CONDITIONS FOR SAFE OPERATION**

I.1. The following list of operational parameters and equipment should be considered in establishing limiting conditions for safe operation of research reactors. These limiting conditions for safe operation may be operational constraints or administrative limitations imposed on each of the listed items. The user should look at the entire list and select the appropriate items in accordance with the type of reactor and the conditions of operation. The grouping of items by systems or activities of a common nature has been made only for convenience. However, the presentation of limiting conditions for safe operation by groups in the OLCs document provides for a logical arrangement and gives clarity to the document.

#### **I.2. FUEL AND FUEL ELEMENTS AND ASSEMBLIES**

- (a) Uranium enrichment;
- (b) Uranium content;
- (c) Materials used;
- (d) Geometry;
- (e) Burnup limits;
- (f) Fuel failure criteria (e.g. maximum allowed activity of the cooling water);
- (g) Inspection and testing of fresh fuel and in-service elements and assemblies.

#### **I.3. FUEL HANDLING AND STORAGE OF FRESH AND SPENT FUEL**

- (a) Storage of fresh fuel;
- (b) Storage of spent fuel;
- (c) Storage of failed fuel;
- (d) Capability to unload and store core components;
- (e) Requirements for fuel movements (e.g. staffing, tools, measurements);
- (f) Requirements for preparation of fuel for off-site shipment.

#### I.4. REACTOR CORE CONFIGURATION

- (a) Permissible internal or peripheral cavities;
- (b) Maximum and minimum number of fuel elements;
- (c) Conditions of reflection (e.g. type of reflector and configuration);
- (d) Number of control elements, including fuel followers;
- (e) Mixed cores (e.g. cores containing fuel of different enrichments);
- (f) Permissible configurations;
- (g) Requirements for determining new configurations;
- (h) Reactor power;
- (i) Average and peak fuel element power;
- (j) Maximum allowed fuel temperature and cladding temperature;
- (k) Departure from nucleate boiling ratio or flow instability.

#### I.5. REACTIVITY AND REACTIVITY CONTROL SYSTEMS

- (a) Maximum excess reactivity;
- (b) Minimum shutdown margin during operation and during fuel movement;
- (c) Reactivity worth of the reactivity control mechanisms (e.g. regulating, shim, safety, pulse rods or blades);
- (d) Reactivity addition rates by means of reactivity control mechanisms, experiments and fuel elements;
- (e) Total reactivity worth of all experiments;
- (f) Maximum reactivity worth of specific types of experiment (e.g. experiments fixed or not fixed to the reactor structure);
- (g) Reactivity worth of backup shutdown system (if any);
- (h) Reactivity balance (e.g. pattern of withdrawal levels of the reactivity control mechanisms, fuel burnup distribution in the core);
- (i) Type and number of control rods (including material, configuration).

#### I.6. PROTECTION SYSTEMS AND REACTOR SHUTDOWN SYSTEMS

- (a) Type and minimum number of neutronic measuring equipment items necessary to scram the reactor in each mode of operation;
- (b) Type and minimum number of other measuring equipment items (temperature, flow, radiation level, etc.) necessary to scram the reactor;
- (c) Alarm and scram limits for the aforementioned equipment;
- (d) Interlocks and trips;
- (e) Bypassing channels;
- (f) Other safety instrumentation;
- (g) Reactor shutdown delay time (e.g. rod drop time).

## I.7. REACTOR STARTUP AND OPERATION

- (a) Minimum operability requirements of structures, systems and components;
- (b) Completion and review of checklists;
- (c) Visual inspections of reactor core, beam tube shutters and shielding;
- (d) Additional conditions for startup following a trip.

## I.8. COOLANT SYSTEMS AND CONNECTED SYSTEMS

- (a) Coolant chemistry (content of solids and dissolved gases, pH and conductivity);
- (b) Temperature, pressure (in lines, across filters, etc.) and flow;
- (c) System configuration for different modes of operation (e.g. how many and which pumps should be operable, which main valves should be open or closed, etc.);
- (d) Changeover conditions to and from the natural convection mode of cooling, if applicable;
- (e) Coolant or moderator level;
- (f) Emergency core cooling;
- (g) Leak detection and loss of coolant alarm limits;
- (h) Radionuclide content in the coolant;
- (i) Content of fission products in the coolant;
- (j) Coolant availability;
- (k) Ultimate heat sink;
- (l) Moderator chemistry (e.g. required properties and characteristics).

## I.9. CONTAINMENT SYSTEMS OR MEANS OF CONFINEMENT, INCLUDING VENTILATION

- (a) Temperature, humidity and air flow in different areas of the reactor;
- (b) Pressure drop across filters;
- (c) Containment pressure relative to the atmosphere (normal and under emergency conditions);
- (d) Isolation of the containment or the means of confinement and starting of emergency ventilation;
- (e) Operations that require containment or confinement;
- (f) Configuration and minimum equipment for ventilation;
- (g) Leak rate from the containment or the means of confinement;
- (h) Hazardous materials inside the containment or the means of confinement;
- (i) Efficiencies of filters and iodine traps.

## I.10. OPERATIONAL RADIATION PROTECTION

- (a) Type (gaseous, particulate, gamma, neutron, etc.) and location of radiation monitoring instruments;
- (b) Alarm setting for monitoring instruments for radiation (including monitoring instruments for initiating scrams, if any);
- (c) Limits on the concentration of radionuclides or other limits on the liquid or gaseous effluents that may be released in a given time period, such as maximum annual releases (site limits may apply where more than one facility is located at the same site);
- (d) Dose control values for operation, such as annual dose limits;
- (e) Operating limits for surface contamination;
- (f) Dose targets (individual and collective);
- (g) Criteria for respiratory protection and special protective clothing;
- (h) Criteria for bioassay or whole body counting;
- (i) Storage capacity for liquid and solid waste.

## I.11. INSTRUMENTATION AND CONTROL SYSTEMS

- (a) Type and minimum number of items of measuring equipment associated with safety systems;
- (b) Startup instrumentation;
- (c) Display monitors;
- (d) Data acquisition systems;
- (e) Requirements for the calibration of instrumentation and its periodic control, including updating of the related documentation.

## I.12. EXPERIMENTAL DEVICES

- (a) Suitability of materials for use in the ambient conditions, for encapsulation of irradiation samples, with fissile materials, etc.;
- (b) Explosive materials;
- (c) Interlocking requirements for experiments.

## I.13. ELECTRIC POWER SUPPLY SYSTEMS

- (a) Emergency power supplies for all operational states (e.g. configuration of distributors and list of equipment connected to a distributor, startup and operation of diesel generators, batteries for the uninterruptible power supply system, etc.);
- (b) Testing of emergency power supplies.

#### I.14. AUXILIARY SYSTEMS AND EQUIPMENT

- (a) Fire protection systems;
- (b) Communication systems;
- (c) Cranes (e.g. limitation of manipulation and loading);
- (d) Emergency lighting systems.

#### I.15. OTHER LIMITATIONS

- (a) Other design features;
- (b) Site features;
- (c) Administrative controls.



## **Appendix II**

### **INDICATIVE LIST OF OPERATING PROCEDURES**

#### **II.1. COMMISSIONING PROCEDURES**

- (a) Cleaning procedures for the cooling and ventilation systems;
- (b) Commissioning and acceptance tests for mechanical, electrical and instrumentation systems and components;
- (c) Tests prior to fuel loading;
- (d) Fuel handling;
- (e) Fuel loading, initial criticality tests and low power tests;
- (f) Control rod calibration;
- (g) Calibration of reactor safety channels and other neutron detection channels;
- (h) Determination of shutdown margin and core excess reactivity;
- (i) Power ascension tests and power tests;
- (j) Determination of thermal power level;
- (k) Reactor emergency procedures;
- (l) Radiation protection procedures;
- (m) Procedures for removal of foreign material;
- (n) Verification of biological shielding;
- (o) Handling of non-conformances.

#### **II.2. OPERATIONAL PROCEDURES**

- (a) Reactor startup, operation, power level changes and shutdown;
- (b) Determination of core reactivity to meet the OLCs (e.g. shutdown margin and excess reactivity, set point calculations, etc.);
- (c) Determination of thermal power level;
- (d) Routine loading, unloading, handling and movement of fuel elements, fuel assemblies and other core components and reflector components;
- (e) Special fuel handling (e.g. handling of failed fuel, preparation for and shipment of spent fuel);
- (f) Reactivity determination, loading, unloading, irradiation, handling and safety evaluation for experimental devices;
- (g) Performance of routine checks on reactor operation, the status of systems and the condition of the facility;
- (h) Operation of the mechanical and electrical support systems and equipment of the reactor;

- (i) Shift turnover entries and entries in the reactor logbooks;
- (j) Acceptance testing of new fuel elements;
- (k) Ion exchange replacement or regeneration;
- (l) Operation of hoisting devices.

### II.3. MAINTENANCE PROCEDURES

- (a) Equipment replacement and repair;
- (b) Preventive maintenance of reactor equipment and reactor support system equipment;
- (c) Repair or replacement of reactivity control mechanisms;
- (d) Cleaning of the heat exchanger and tube plugging;
- (e) Replacement of seals;
- (f) Replacement of filters;
- (g) Routine maintenance on the overhead crane;
- (h) Routine maintenance on the auxiliary power supply;
- (i) In-service inspection;
- (j) Inventories of spare parts.

### II.4. INSPECTION, CALIBRATION AND PERIODIC TESTING PROCEDURES

- (a) Inspection and dimensional checking of fuel and preparation of the fuel inventory;
- (b) Inspection and calibration of the reactivity control mechanism;
- (c) Release and drop time measurements for safety rods and control rods;
- (d) Calibration of reactor measuring channels and protection channels;
- (e) Calibration and testing of fixed and portable radiation monitors, airborne radiation monitors and personal monitors;
- (f) Calibration and testing of process systems (e.g. for temperature, flow, emergency power and ventilation);
- (g) Performance check for emergency core cooling systems;
- (h) Efficiency and flow rate measurements for the emergency ventilation system;
- (i) Flow rate measurements for the operational ventilation system;
- (j) In situ periodic testing of built-in filters in the ventilation system;
- (k) Measurements in the primary cooling system;
- (l) In-service inspection of the reactor vessel, pool liner and core components;
- (m) Performance checks for the secondary cooling system;
- (n) Measurement of the leaktightness of the building;

- (o) Testing of pneumatic tube systems;
- (p) Testing of the emergency power supply system;
- (q) Checking of the fire protection system.

## II.5. RADIATION PROTECTION PROCEDURES

- (a) Radiation surveys and air sampling;
- (b) Control of the contamination of surfaces, personnel and equipment, including the use of decontamination facilities;
- (c) Administrative measures for controlling access to or residence time in radiation areas;
- (d) Control of occupational radiation exposure, such as procedures for monitoring external and internal exposures of the operating personnel, temporary personnel and visitors;
- (e) Issue, selection, use and maintenance of protective equipment;
- (f) Monitoring of radioactive material and the packaging and shipment of radioactive material;
- (g) Analysis of the reactor coolant;
- (h) Inventory, handling and leak testing of stored sealed radioactive sources;
- (i) Control and periodic review of operations to ensure that radiation exposures are as low as reasonably achievable.

## II.6. PROCEDURES FOR THE AUTHORIZATION OF OPERATION, MAINTENANCE, IRRADIATION OR EXPERIMENTS

- (a) Authorization for operation;
- (b) Authorization for maintenance (work permit);
- (c) Authorization for modification;
- (d) Authorization for experiments;
- (e) Permit for irradiation;
- (f) Procedures for isotope production.

## II.7. PROCEDURES FOR OPERATOR RESPONSE TO ANTICIPATED OPERATIONAL OCCURRENCES

- (a) Operator response to alarms, loss of electric power supplies, instrument failures, pipe leakage, etc.;
- (b) Operator response to failures of experiments;
- (c) Response to abnormal radioactive releases;
- (d) Response to spread of contamination.

## II.8. EMERGENCY PROCEDURES

- (a) High airborne radiation levels or area radiation levels;
- (b) Fire, internal flooding;
- (c) Tornado, hurricane, typhoon, flood or other weather related emergency;
- (d) Earthquake;
- (e) Injury of personnel, with and without radioactive contamination;
- (f) Credible reactor accident (e.g. loss of primary coolant, abnormal release of radioactive material, rapid insertion of positive reactivity, significant fuel failure);
- (g) Aircraft crash, sabotage or attempted sabotage.

## II.9. PHYSICAL PROTECTION PROCEDURES

- (a) Surveillance and alarm system tests for fuel storage areas;
- (b) Surveillance and alarm system tests for facility access points;
- (c) Required patrols and inspections during reactor operation and when the reactor is shut down;
- (d) Control of access to the facility (e.g. identification badges, door locks, closed circuit television monitoring systems, electronic card keys);
- (e) Preventing and/or coping with an unauthorized intruder;
- (f) Coping with an attack;
- (g) Coping with a civil disturbance.

## II.10. PROCEDURES FOR THE HANDLING OF RADIOACTIVE WASTE AND CONTROL OF RADIOACTIVE RELEASES

- (a) Monitoring, handling, storage and disposal of solid radioactive waste;
- (b) Collection, monitoring, processing and disposal of liquid radioactive waste;
- (c) Control of monitoring for gaseous and particulate airborne radioactive releases.

## II.11. PROCEDURES FOR EXTENDED SHUTDOWN

- (a) Disconnecting and dismantling of systems that have to be taken out of service;
- (b) Protecting systems or components against deterioration;
- (c) Preventing undesired use of systems or components that have been taken out of service (e.g. electric power supply, isolation valves).

## II.12. DECOMMISSIONING PROCEDURES

- (a) Handling of spent fuel;
- (b) Dismantling and handling of activated and radioactively contaminated components, and handling of radioactive waste;
- (c) Radiation protection during and after decommissioning.

## II.13. PROCEDURES FOR UTILIZATION AND FOR MODIFICATION OF THE REACTOR

- (a) Proposals for experiments or modifications;
- (b) Determination of the safety significance of an experiment or a modification, for purposes of review and approval;
- (c) Review and approval of a new or modified experiment or modification;
- (d) Conduct of an experiment, including commissioning and decommissioning;
- (e) Conduct of a modification, including commissioning of modified systems and updating of the facility documentation.

## II.14. ADMINISTRATIVE PROCEDURES

- (a) Control and accountability of nuclear material;
- (b) Reporting of the fuel inventory;
- (c) Shipment of spent fuel;
- (d) Testing and certification of packages used for the shipment of radioactive material;
- (e) Qualification, training and retraining of personnel;
- (f) Generation, collection and retention of records;
- (g) Isolation and tagging of equipment;
- (h) Instructions to personnel concerning possible health effects of radiation exposure, legal requirements, etc.;
- (i) Instructions for internal communications;
- (j) Requirement for on-call personnel;
- (k) Quality assurance;
- (l) Purchase of safety related components.

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*“The IAEA’s standards have become a key element of the global safety regime for the beneficial uses of nuclear and radiation related technologies.*

*“IAEA safety standards are being applied in nuclear power generation as well as in medicine, industry, agriculture, research and education to ensure the proper protection of people and the environment.”*

**Mohamed ElBaradei  
IAEA Director General**

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