IAEA Safety Standards

for protecting people and the environment

# Safety in the Utilization and Modification of Research Reactors

Specific Safety Guide

No. SSG-24

IAEA
International Atomic Energy Agency

# IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

## IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available at the IAEA Internet site

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The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at PO Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

## RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** comprises informational publications to encourage and assist research on, and the development and practical application of, nuclear energy for peaceful purposes. It includes reports and guides on the status of and advances in technology, and on experience, good practices and practical examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

# SAFETY IN THE UTILIZATION AND MODIFICATION OF RESEARCH REACTORS

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA SAFETY STANDARDS SERIES No. SSG-24

# SAFETY IN THE UTILIZATION AND MODIFICATION OF RESEARCH REACTORS

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
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# FOREWORD

## by Yukiya Amano
## Director General

The IAEA's Statute authorizes the Agency to "establish or adopt… standards of safety for protection of health and minimization of danger to life and property" — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For 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 regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

# THE IAEA SAFETY STANDARDS

## BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

## THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish

fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

**Safety Fundamentals**

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

**Safety Requirements**

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered 'overarching' requirements, are expressed as 'shall' statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

**Safety Guides**

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety

[1] See also publications issued in the IAEA Nuclear Security Series.

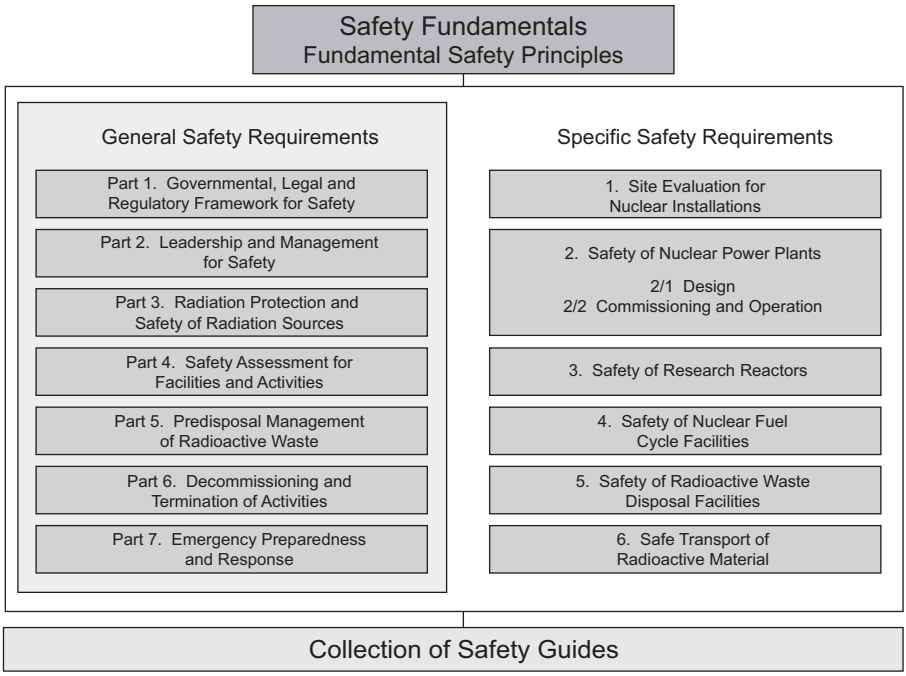


*FIG. 1. The long term structure of the IAEA Safety Standards Series.*

Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as 'should' statements.

## APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

## DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and four safety standards committees, for nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the

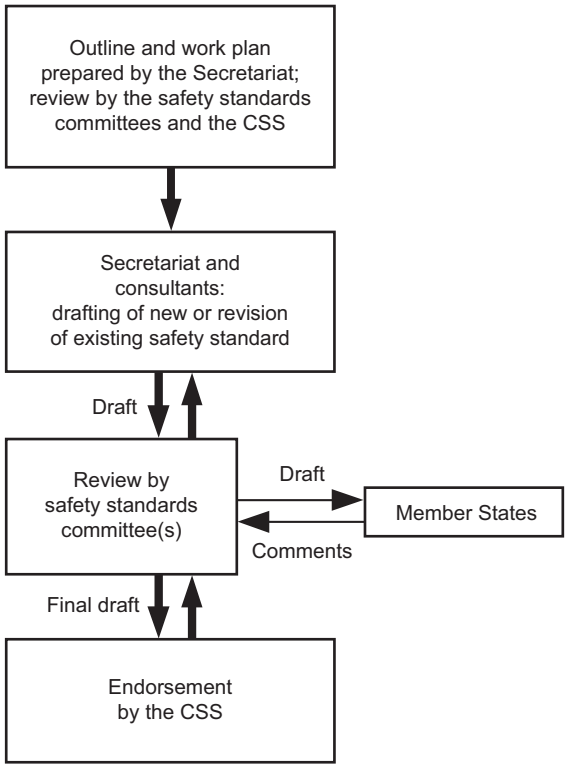


*FIG. 2. The process for developing a new safety standard or revising an existing standard.*

safety standards, policies and strategies, and corresponding functions and responsibilities.

## INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

## INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see http://www-ns.iaea.org/standards/safety-glossary.htm). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

# CONTENTS

# 1. INTRODUCTION

## BACKGROUND

1.1. This Safety Guide was developed under the IAEA programme for safety standards, which covers all of the important areas of research reactor safety. The Fundamental Safety Principles publication [1] establishes principles for ensuring the protection of workers, the public and the environment. This Safety Guide directly addresses four of these principles, i.e. responsibility for safety, optimization of protection, limitation of radiation risks to individuals and prevention of accidents[1]. In addition, this Safety Guide provides recommendations on meeting the requirements established in the IAEA Safety Requirements publication on the Safety of Research Reactors [2], for ensuring adequate safety at all stages of the lifetime of a research reactor. In particular, recommendations are provided on which analyses, verifications and evaluations should be performed to fulfil the safety requirements for the operating organization that are established in paras 2.15, 2.18–2.20, 3.6–3.12 and 4.14 of Ref. [2].

1.2. This publication supersedes Safety Series No. 35-G2[2]. The main changes and adaptations relate to consistency with Ref. [2], the other recently published Safety Guides for research reactors and other relevant safety standards. The feedback from the application of Safety Series No. 35-G2 is also incorporated into the present publication.

1.3. Owing to the particular characteristics of research reactors, safety aspects relating to design and operation have been given special emphasis and have been

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[1] These are principles 1, 5, 6 and 8 (see Ref. [1]):

— "Principle 1: Responsibility for safety: The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks."

— "Principle 5: Optimization of protection: Protection must be optimized to provide the highest level of safety that can reasonably be achieved."

— "Principle 6: Limitation of risks to individuals: Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm."

— "Principle 8: Prevention of accidents: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents."

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety in the Utilization and Modification of Research Reactors, Safety Series No. 35-G2, IAEA, Vienna (1994).

incorporated into Ref. [2]. These characteristics include the large variety of designs; the wide range of reactor power levels; the different modes of operation and different purposes of utilization; the particularities of siting and the major differences in types of research reactors; and arrangements of operating organizations. These characteristics require a graded approach[3] in the application of the requirements (paras 1.11–1.14 of Ref. [2]), i.e. flexibility in the implementation of objectives and the fulfilment of basic requirements when dealing with certain specific topics, such as utilization and modification of research reactors.

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. Most important are the performance of the safety analysis by the operating organization, and the review and assessment of the safety analysis report by the regulatory body, as well as the preparation, submission and evaluation of other important safety related documents during the initial licensing process, periodic licensing renewals or other occasions, such as a periodic safety review or major modification(s) of the research reactor. The recommendations on safety analysis and related documentation, provided in Ref. [4], and on the review and assessment of nuclear facilities by the regulatory body, provided in Ref. [5], have been taken into account in the preparation of the present Safety Guide. In addition, this Safety Guide discusses other aspects of experiments and modifications, such as commissioning of research reactors and provisions for radiation protection, for which detailed recommendations are provided in Refs [6, 7]. The IAEA Safety Glossary [8] defines and explains the safety related words and terms used in the present publication.

## OBJECTIVE

1.5. The objective of this Safety Guide is to provide recommendations on meeting the requirements on the safety related aspects of the utilization and modification of research reactors, such that these projects can be implemented without undue radiation risks to the site personnel, the public or the environment. The present Safety Guide develops the general concepts in these areas, which are presented in paras 7.85–7.92 of Ref. [2] relating to utilization and modification. Therefore, this Safety Guide should be read in conjunction with Ref. [2].

[3] Further guidance on the graded approach is provided in Ref. [3].

1.6. This Safety Guide provides recommendations to the operating organization, including external users of the research reactor (i.e. experimenters), technical support organizations and other persons involved in utilization and modification projects. It provides recommendations only on the safety implications of the utilization and modification of research reactors. The reason for presenting the areas of utilization and modification together in a single volume is to avoid duplication, since most experiment and modification projects have similar treatments in common areas, such as categorization, safety review and assessment, project implementation and commissioning.

## SCOPE

1.7. The recommendations provided in this Safety Guide apply to the utilization of research reactors and to all modifications of research reactors. For some specific, highly complex experimental devices, additional guidance may be necessary. This Safety Guide does not cover experiments in prototype power reactors or experiments performed in operating or decommissioned nuclear power plants.

1.8. In the context of this Safety Guide, utilization is the use of the research reactor or of an experiment or an experimental device during reactor operation. The experiment or experimental device may be situated in the reactor core, the reactor reflector, the shielding or the experimental facilities connected to the reactor, but may also be located outside the biological shielding or outside the reactor building.

1.9. In the context of this Safety Guide, a modification is a deliberate change[4] in, or an addition to, an existing reactor, a structure, system or component, or item of software important to safety, an experiment or an experimental device. A modification may also involve a change in safety systems, safety related items, operational limits and conditions, procedures, documentation, or operating conditions for the reactor as well as for experiments.

1.10. The requirements for the utilization or modification (i.e. the experiment or modification project) established in Ref. [2] depend on the type of reactor and the

[4] Experiments and experimental facilities that have been approved in the past or that have been analysed as part of the safety analysis report are not considered to be modifications in the context of the present Safety Guide.

safety significance of the task. However, in all cases, the preparation and implementation of a project for utilization or modification should follow the logical sequence outlined in this Safety Guide. In small projects, the individual stages may be very simple but none of the stages should be omitted.

1.11. Modifications to systems with security aspects should follow the logical sequence outlined in this Safety Guide but will also be subject to confidentiality requirements and security review, which are not discussed.

1.12. In the case of modifications that concern only changes to documentation, the recommendations presented in Section 6 of this Safety Guide are not fully applicable. For such modifications, the additional guidance provided in Ref. [4] should be considered and followed, as applicable.

1.13. Reference [1] states that "Safety measures and security measures have in common the aim of protecting human life and health and the environment." This Safety Guide addresses nuclear security considerations only briefly in paras 3.35–3.37 and indicates the actions that need to be taken to incorporate security elements progressively into an effective nuclear security regime for a nuclear power programme. Nuclear security matters are covered in IAEA Nuclear Security Series publications. The scope of this Safety Guide includes consideration of the interface between nuclear safety and nuclear security (see Ref. [9] for further information on this issue).

## STRUCTURE

1.14. This Safety Guide consists of ten sections and three annexes. In most of these sections, the safety aspects of both the utilization and modification of research reactors are described together. Section 2 provides recommendations on the management system for the utilization and modification of a research reactor. Categorization of the experiment or modification provides a basis for selecting the review and approval route; recommendations on these topics are provided in Section 3. Recommendations on the design of experiments or modifications are provided in Section 4, which should be read in conjunction with the relevant requirements of Ref. [2]. Sections 5, 6 and 7 provide recommendations on the activities that should be considered in the various stages of a typical utilization or modification project. Section 8 covers additional recommendations for operational safety of experiments, and Section 9 provides recommendations on the handling, dismantling, post-irradiation examination and disposal of

experimental devices. Section 10 provides recommendations on the safety of out-of-reactor-core experimental devices and modifications.

## 2. MANAGEMENT SYSTEM FOR THE UTILIZATION AND MODIFICATION OF A RESEARCH REACTOR

### GENERAL

2.1. A documented management system that integrates safety, health, environmental, security, quality and economic objectives of the operating organization of a research reactor is required to be in place [10]. The documentation of the management system should describe the system that controls the planning and implementation of all activities at the research reactor throughout its lifetime, including utilization and modification projects. Approval of the management system (or parts thereof) by the regulatory body may be required. The management system should include four functional categories: management responsibility; process implementation; resource management; and measurement, assessment and improvement. In general:

- Management responsibility includes the support and commitment of management necessary to achieve the objectives of the operating organization.
- Process implementation includes the activities and tasks necessary to achieve the goals of the organization.
- Resource management includes measures necessary to ensure that the resources essential to the implementation of strategy and the achievement of the objectives of the operating organization are identified and made available.
- Measurement and assessment provide an indication of the effectiveness of management processes and work performance compared with objectives or benchmarks. It is through measurement and assessment that opportunities for improvement are identified.

The requirements for the management system are established in paras 4.5–4.13 of Ref. [2], and in Ref. [10], and further recommendations are provided in Refs [11, 12].

2.2. Processes for modifications and utilization should be established as part of the integrated management system. These processes should include the design, review, assessment and approval, fabrication, testing and implementation of a utilization and modification project. Relevant procedures describing the processes should be put into effect by the operating organization early in the utilization or modification project. The management system should cover all structures, systems and components, and processes important to safety, and should include a means of establishing controls over utilization and modification activities, thereby providing confidence that they are performed safely in accordance with established requirements. The management system should also include provisions to ensure that modification or utilization activities are planned, performed and controlled in a manner that ensures effective communication and clear assignment of responsibilities. In establishing the management system, a graded approach based on the relative importance to safety of each item or process may be applied.

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

— National laws and regulations;
— The requirements of the regulatory body;
— Design requirements and assumptions;
— The safety analysis report;
— Operational limits and conditions;
— The administrative requirements established by the management of the research reactor.

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

## MANAGEMENT RESPONSIBILITY

2.5. It is the responsibility of management to ensure that the procedures for utilization and modification describe how these activities are to be assessed, managed, authorized and performed in order to ensure that the objectives of the experiment or modification are met, and safe operation of the research reactor and its safe utilization are ensured. The documentation of the management system for utilization and modification should include descriptions of the organizational structure, functional responsibilities, levels of authority and interfaces for those

assessing, managing, authorizing, performing, controlling or supervising these activities. It should also cover other management measures, including planning and scheduling of activities, resource allocation and human factors.

2.6. The operating organization has the responsibility for preparing and issuing specifications and procedures for utilization and modification of the research reactor. The reactor manager[5] should be an active participant in the implementation and evaluation of utilization and modification activities. The detailed responsibilities of the reactor manager are set out in paras 2.23 and 2.24 of this Safety Guide, and the detailed responsibilities of the project manager in paras 2.18–2.22.

## IMPLEMENTATION OF A UTILIZATION OR MODIFICATION PROJECT

2.7. Activities relating to the utilization or modification of a research reactor should be performed and recorded in accordance with approved procedures and instructions.

2.8. For successful implementation of a utilization or modification project, consideration should be given to the following aspects:

- Planning and prioritization of work;
- Addressing all relevant regulatory requirements;
- Addressing the requirements derived from the operational limits and conditions;
- Evaluation of the feedback of operational experience from similar utilization or modification projects;
- Addressing the maintenance requirements for the experiment or the modified system or component;
- Ensuring the availability of qualified personnel with suitable skills;
- Establishing appropriate operating procedures, including those for assessing and correcting non-conforming items;
- Performing and documenting the required inspections and tests, including those required for commissioning an experiment or modification;
- Performing and documenting the required training and instruction.

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

2.9. The management system should include measures to control records essential to the performance and verification of utilization and modification activities, including justification and safety assessment, through a system for their identification, approval, review, filing, retrieval and disposal.

2.10. Documents such as the procedures, specifications and drawings for the utilization and modification project, including the operating procedures, should be controlled. In particular, measures should be established for their preparation, identification, review, updating, validation as required, as well as their approval, issue, distribution, revision and archiving.

## RESOURCE MANAGEMENT

2.11. The operating organization should provide adequate resources to execute the modification or utilization by:

— Determining the required staff competences and providing training, where appropriate, to ensure that the personnel of the operating organization are competent to perform their assigned work;
— Supervising external personnel (including suppliers) who perform safety related activities and ensuring that these personnel are adequately trained and qualified.

2.12. Personnel who are not directly working for the research reactor and personnel of contracting organizations who are involved in the modification project or utilization should be appropriately trained and qualified for the work they are to perform. Such external personnel should perform their activities under the same controls, and to the same work standards, as reactor personnel. Reactor supervisors should review the work of these external personnel during preparation for work, at the job site during performance of the work, and during acceptance testing and inspection.

2.13. The management system of the operating organization should be extended to include suppliers. The operating organization should ensure that the suppliers, manufacturers and designers have an effective management system in place. The operating organization should ensure, through audits, that the assigned activities are carried out in compliance with the management system.

2.14. The equipment, tools, materials, hardware and software necessary to conduct the work in a safe manner and to ensure that the requirements are met should be determined, provided, checked and verified, and maintained.

## MEASUREMENT, ASSESSMENT AND IMPROVEMENT

2.15. Measures should be established for assessment, review and verification to determine whether and to ensure that utilization or modification activities are accomplished as specified in the design. Such measures should include:

— Review of the design and the design procedures;
— Verification of the implementation of activities by inspection and witnessing;
— Review and verification of records, results and reports relating to the design, the implementation of projects and the operation of the reactor, including those on the status of non-conformances and corrective actions;
— Audits of the relevant processes, procedures and documentation;
— Follow-up of the adequacy and timeliness of corrective actions.

2.16. Effective implementation of the management system for the utilization and modification of a research reactor should be assessed by qualified personnel who are not directly involved in performing these activities.

2.17. The operating organization should evaluate the results of such independent assessments and should determine and take the necessary actions to implement recommendations and suggestions for improvement. Operational safety of experiments should be subjected to periodic review by the reactor safety committee.

## RESPONSIBILITIES OF THE PROJECT MANAGER

2.18. The operating organization should assign a person, normally a dedicated project manager, to be responsible for the implementation of the project objectives. These responsibilities should include development of a project definition, determination of measures to ensure adherence to established safety criteria, evaluation of the options and management of detailed design, project implementation, commissioning and decommissioning, if relevant.

2.19. The project manager should be responsible for determining the impact of the project on the existing safety analysis report and on the operational limits and conditions. This involves making proposals for the categorization of the modification or experiment and providing the safety documentation in order to enable the operating organization to submit the project for review and approval, as necessary, by the safety committee(s) or the regulatory body. The advice of external specialists and consultants may be sought in performing these duties.

2.20. The project manager should ensure that any contractor or supplier involved in the preparation or implementation of a modification or utilization project is made aware of and complies with the appropriate requirements and regulations.

2.21. The project manager should be responsible for ensuring that adequate precautions are in place to provide protection against radiological and other hazards that may arise during or as a result of the project.

2.22. Possible interactions between different utilization or modification projects that are being implemented or proposed should be considered and analysed.

## RESPONSIBILITIES OF THE REACTOR MANAGER

2.23. The reactor manager has direct responsibility for the safety aspects of reactor operation. In this respect, he or she should ensure that any proposal for utilization or modification of the reactor has been demonstrated to be safe, and additional review, and approval, if required, has been carried out by an appropriate body[6] before implementation of the project commences.

2.24. The reactor manager should be responsible for ensuring that the scheduling of the implementation of the utilization or modification project does not affect safety.

[6] The appropriate body could be an expert in the relevant field of specialization, the safety committee(s) or the regulatory body.

# 3. CATEGORIZATION, SAFETY ASSESSMENT AND APPROVAL OF AN EXPERIMENT OR MODIFICATION

3.1. All utilization and modification projects should be subjected to a screening process in order to determine their implications for safety and the related safety category of the experiment or modification. The screening process should be documented and the selection of the safety category should be justified. Experiments of a repetitive[7] nature that have been assessed and approved earlier, and for which no changes in the safety analysis report, operational limits and conditions or operating procedures are required, could be considered as modifications with a minor effect on safety (see para. 3.9).

3.2. The categorization of the experiment or modification should provide the basis for determining the detail and the extent of the safety analysis and the review to be performed. The categorization should also provide the basis for the review and approval route to be followed for the modification or utilization project. A checklist could facilitate the categorization process. An example of such a checklist is provided in Annex I.

3.3. For modification projects, the safety class of the relevant structures, systems and components (as required in accordance with paras 6.12 and 6.13 of Ref. [2]) should be used as a first step in the safety categorization in order to determine the safety impact of the modification. This is described in paras 3.7–3.34 on the categorization process.

3.4. For utilization of a research reactor, a safety classification system should be developed, based on the possible safety implications of the utilization. This classification should also be used as a first step in the safety categorization, in order to determine the safety impact of the utilization. In developing a safety classification system for utilization of a research reactor, at a minimum, the following aspects should be taken into account:

[7] A repetitive experiment is an experiment that had been approved earlier and has only minor changes compared with the original design that would not affect the safety analyses originally performed. Isotope production using a target material with the same physical and chemical behaviour and using the same irradiation facility within the approved maximum flux would also be regarded as a repetitive experiment.

— Criticality aspects;
— Reactivity aspects;
— In-core and out-of-core irradiation;
— Experiments within or outside the biological shielding or containment;
— Physical conditions and behaviour of components;
— Chemical conditions and behaviour of components;
— Heat generation and thermal characteristics;
— Mechanical and thermal stresses and behaviour of components;
— The potential for a (significant) off-site dose to members of the public.

3.5. The review and approval route for a utilization project should be based on the safety category determined for the experiment, for which the nature of the experiment, i.e. a new experiment, a repetitive experiment or isotope production, should be taken into account (see also paras 3.29 and 3.30 for recommendations relating to repetitive experiments).

3.6. The proposal for the classification and categorization process for modification and utilization projects, including the proposed review and approval routes, should be submitted to the safety committee(s) for approval and, following approval by the reactor manager, the proposal should be submitted to the regulatory body for review and approval.

## CATEGORIZATION PROCESS

3.7. A more detailed and comprehensive safety assessment should be carried out for those experiments or modifications with a safety class having a potential impact on safety. The result of the detailed safety analysis should indicate the extent of the implications for safety (see paras 3.11–3.32). The results of the safety analysis for each experiment could be incorporated in the safety analysis report of the research reactor or might be described in a separate document (i.e. safety analysis report for the experiment). An example of the content of the safety analysis report for an experiment is presented in Annex II.

3.8. Modifications and new experiments should be subjected to the categorization process described in this Safety Guide.

3.9. For repetitive experiments, it should be proven that they can utilize earlier approved safety analyses that were performed according to the requirements of the management system.

3.10. In determining the potential effect on safety, the consequences for the reactor itself and the interactions with other systems should also be taken into account.

3.11. The safety significance or effect on safety of each modification or experiment, as defined in the following, as well as the potential for design errors or incorrect implementation of a project, should be taken into account in determining the safety category of the utilization or modification project, the safety analyses to be performed and the documentation to be prepared:

— Major effect on safety: modifications or experiments that:
  • Could affect the design function or the ability of structures, systems and components to perform their intended safety function as described in the safety analysis;
  • Are beyond the licence conditions or beyond the existing (i.e. approved) safety analysis[8];
  • Could introduce hazards that have not been previously addressed.
— Significant effect on safety: modifications or experiments that are within the approved licence conditions and safety analysis, but which require adaptation of the operational limits and conditions[9], and not of the remaining chapters of the safety analysis report, or which need an adaptation of the safety related operating procedures.
— Minor effect on safety: modifications or experiments that are within the approved licence conditions, safety analysis and operational limits and conditions, still having significant margins and no effect on the safety system settings and which do not require a change in the safety related operating procedures.
— No effect on safety: modifications or experiments that present no hazard and have no impact on safety.

3.12. The classification and categorization process for modifications and experiments having safety significance should be documented in detail, together with the justification for the proposed safety category.

[8] A modification beyond the licence conditions or beyond the approved safety analysis is implicitly also beyond the operational limits and conditions.

[9] Recommendations on operational limits and conditions for research reactors are provided in Ref. [13].

**Modifications or experiments with a major effect on safety**

3.13. Modifications or experiments with a major effect on safety should be subjected to safety analysis and to the same design, construction and commissioning procedures as applied for the research reactor, in order to ensure that they meet the same requirements as the existing structures, systems and components or existing experimental facilities.

3.14. An assessment of radiation exposure of the staff expected during or as a result of the project should be prepared. Measures to reduce exposures based on the principle of optimization of protection[10] should be determined for all reactor states (i.e. normal operation, anticipated operational occurrences and accident conditions), and any potentially necessary mitigation measures should be identified.

3.15. The safety documentation for the project should cover the responsibilities and duties of the operating personnel, the experimenters and others involved in the project.

3.16. A list of all new or modified items important to safety should be included in the safety documentation. Information required for accident analysis and for determining mitigation measures under accident conditions should also be defined.

3.17. The safety documentation for the project should be reviewed by the reactor manager with respect to safety, operability and compatibility with other experiments in the research reactor and with reactor systems.

3.18. Modifications and experiments having a major effect on safety should be reviewed by the safety committee(s) and submitted to the regulatory body for review and approval in accordance with the same procedures as those applied for the reactor itself.

3.19. If the modification or experiment will affect the operating licence or the licence documentation, an appropriate re-licensing process should be applied.

[10] Recommendations on applying the principle of optimization of protection are provided in Ref. [7].

3.20. The operating procedures, including emergency procedures, should be reviewed to ascertain whether they need to be revised as a result of the modification or experiment, and should be revised, reviewed and made subject to approval as appropriate.

**Modifications or experiments with a significant effect on safety**

3.21. The safety documentation for such projects, which may include complex experiments, experimental facilities and modifications, should include a comprehensive and detailed description of the experiment or modification and its design and construction.

3.22. The safety analysis should cover all operational states, as well as accident conditions. The analysis should demonstrate that the licence conditions and the original safety limits would not be affected and that the radiological consequences of the experiment or modification are within the accepted limits.

3.23. An assessment of radiation exposure of the staff expected during or as a result of the project should be prepared. Measures to reduce radiation exposures based on the principle of optimization of protection[11] should be described for all reactor states, and any potentially necessary mitigation measures should be identified.

3.24. The safety documentation for the project should cover the responsibilities and duties of the operating personnel, experimenters and others involved in the project.

3.25. A list of all new or modified items important to safety should be included in the safety documentation. Information required for accident analysis and for determining mitigation measures under accident conditions should also be defined.

3.26. The safety documentation for the project should be reviewed and approved by the reactor manager with respect to safety, operability and compatibility with other experiments in the reactor and with reactor systems.

[11] Recommendations on applying the principle of optimization of protection are provided in Ref. [7].

3.27. Modifications and experiments having a significant effect on safety should be reviewed by the safety committee(s) and submitted to the regulatory body for review and approval in accordance with the regulatory requirements.

3.28. The operating procedures, including emergency procedures, should be reviewed as to whether they need to be revised as a result of the modification or utilization, and should be revised, reviewed and approved as appropriate.

**Modifications or experiments with minor safety significance**

3.29. Many experiments and modifications are considered to have minor safety significance. Such modifications include small modifications to structures, systems or components. Research reactors are, by their nature, often used for repetitive sample irradiations or for repetitive experiments with minor modifications. Criteria should be defined for repetitive experiments, isotope production or modifications having only minor changes from the original design, for which approval by the reactor manager would be sufficient without the need for re-submission to the safety committee(s) or to the regulatory body. The recommendations provided in Sections 5, 6 and 7 should be applied using a graded approach.

3.30. Clear criteria should be defined according to which irradiation may be regarded as a repetitive experiment. The type and quantity of the samples for isotope production or activation analyses should be defined, and the irradiation facility and the irradiation position (maximum allowable flux) should be specified. The information and documentation to be prepared in support of a request to conduct an irradiation experiment, as well as the review and approval route, should also be specified. This proposed method of application to conduct an experiment or implement a modification with minor safety significance should be submitted to the safety committee(s) for review.

3.31. Records of experiments and modifications with minor safety significance approved by the reactor manager should be periodically reviewed by the safety committee(s) in order to ensure that there are no disagreements in the interpretation of the criteria for approval and that there has been no change in the original categorization due to, for example, ageing.

**Modifications or experiments with no effect on safety**

3.32. Careful consideration should be given to any proposed change before categorizing it as a modification or experiment with no effect on safety. Such

consideration should be based on a description of the modification or experiment, together with an assessment of its implications, and these should be submitted to the reactor manager for approval.

3.33. Records of all such approvals should be retained, together with the related documentation.

3.34. The safety committee(s) should periodically review the records of modifications and experiments with no effect on safety, in order to ensure that there are no disagreements in the interpretation of the criteria for approval.

### SECURITY AND PHYSICAL PROTECTION ASPECTS

3.35. Modifications of systems for protection of the site and installation against sabotage and unauthorized removal of fissile material and radioactive material should be carried out in accordance with the requirements of the relevant national security authorities and the guidance provided in publications in the IAEA Nuclear Security Series (see Refs [14–21]).

3.36. Guidance on the security aspects of modifications to instrumentation and control systems and software important to safety for research reactors is provided in Ref. [14].

3.37. Modifications carried out on physical protection systems (or other security sensitive equipment) may be described in a separate document and may need to be kept confidential.

## 4. SAFETY CONSIDERATIONS FOR THE DESIGN OF AN EXPERIMENT OR MODIFICATION

### GENERAL CONSIDERATIONS

4.1. The design of an experiment or modification should demonstrate that:

— It can fulfil the task for which it is intended.
— It can be installed and operated without compromising the safety of the research reactor.
— The experiment can be removed or decommissioned without compromising the safety of the research reactor.
— In all operational states, the radiation exposure of site personnel and members of the public will remain within the dose limits and, moreover, in accordance with the principle of optimization of protection.
— Any equipment can be stored or disposed of safely during its operational lifetime and after decommissioning.
— The amount of radioactive waste is limited, to the extent possible, by means of, for example, appropriate selection of materials.

4.2. The design of an experiment or modification should be such as to minimize additional demands on the reactor shutdown system. In the case of experiments, consideration should be given to providing the means for placing the experiment in a safe condition without the need for activation of the reactor shutdown system.

4.3. In addition to the reactor operations, such as startup, steady state and shutdown, other reactor conditions should be considered for their effects on the experiment or modification. These conditions include unscheduled shutdown followed by immediate restart, maintenance, extended shutdown, refuelling, low power operation, changes in core configuration, and failure of electrical power and other services. The accidents considered in the design of the research reactor should also be considered for their effects on the experiment or modification. Similarly, the effects of all states of the experiment or modification on the reactor should be considered.

4.4. The design requirements for a utilization or modification project should be defined early in the project and should be selected on the basis of the safety significance of the project.

4.5. The interfaces between safety and security should be considered to be part of the design process. These interfaces should be considered in such a way that the impacts of safety measures on security and the impacts of security measures on safety are taken into account from the design stage and an appropriate balance is achieved.

SPECIFIC CONSIDERATIONS

## Reactivity

4.6. If the experimental device or modified system, or its failure, could lead to an increase in the reactivity of the reactor, the experiment or modification should be designed so as to limit the positive reactivity effects to those that can safely be accommodated by the reactor control and shutdown systems.

4.7. If modification of the reactor control and shutdown systems is necessary to accommodate an increase in the reactivity of the reactor core, then this modification should be treated as a separate modification with a major effect on safety and should be implemented before the originally proposed modification or experiment is implemented.

4.8. The reactivity worth of an experiment or reactor modification should be determined for all situations (e.g. insertion of the experiment into the reactor core, removal of the experiment and potential failure modes). A calculated, or otherwise determined, reactivity worth should usually be checked by measurement, by carrying out a critical experiment or by an equivalent method. The design basis accidents for the reactor should also be considered in the evaluation.

## Radiation protection[12]

4.9. An experiment or modification should not significantly affect the radiation protection programme for the research reactor. The original design will typically have been based on a combination of shielding, ventilation filtration and decay to reduce radioactive releases, with associated monitoring instrumentation for radiation and airborne radioactive substances, for all operational states and for accident conditions. If the experiment or modification would otherwise affect the radiation protection measures, then additional measures should be taken to reduce the dose to site personnel and the public during the installation of the project, the operation, handling and dismantling of an experiment, or the implementation of a modification project to levels as low as reasonably achievable (principle of optimization of protection). Such measures may include the removal of sources that generate high radiation fields, the provision of additional shielding and/or the provision of remote handling devices.

[12] The safety requirements for radiation protection are established in Ref. [22].

4.10. If the failure of the experimental device or modified system could lead to degradation of either the original system or the additional system of barriers to the release of radioactive substances, the effects of such an accident should be considered in the design of the experiment or modification.

4.11. The potential for an uncontrolled release of radioactive substances should be limited and the amounts of such material released should be minimized by measures such as the use of delay tanks, filters or recirculation. This applies for all stages of the project, including the installation stage, for all operational states (i.e. normal operation and anticipated operational occurrences) and for removal, storage and shipment of experimental devices or modified systems.

**Safety devices**

4.12. Whenever possible, experiments and modifications should be designed to minimize the need for active safety devices (e.g. by the use of inherent safety features, passive systems and fail-safe design).

4.13. If safety devices are interconnected with the reactor protection system, they should be designed so as to maintain the quality and effectiveness of the reactor protection system. The potential for detrimental interactions with the reactor protection system should be assessed.

4.14. If an experiment might pose a hazard to the reactor or to personnel, the protection and control system of the experiment should be connected to the reactor systems, so that the reactor power level would be reduced or the reactor would be shut down in the event of failure of the experimental device. The method of effecting this connection should receive special attention and the connection should be qualified as a safety system. Separate annunciators or other devices should be provided in the control room to notify the operating personnel whenever a safety action is initiated when a safety system setting of the experiment is reached. The reactor systems should not be used to control the experiment, nor to provide an indication of the progress of the experiment.

4.15. If a safety device is to be used only to protect the experiment itself or if the experimental device can be permitted to fail without causing a hazard to the reactor or to personnel, then the safety device may be assigned a lower safety category. Such safety devices should not be connected to reactor control and protection systems.

4.16. Annunciators should operate at an alarm level below the safety limit of the experiment. This will enable operating personnel to take predefined actions to correct the situation.

**Heat generation and cooling**

4.17. Special consideration should be given to the possibility of an experiment or modification affecting the capability for heat removal from the reactor core.

4.18. A dominant cause of failure for many irradiation experiments is related to either excessive heat generation or insufficient cooling. Thus, adequate heat removal under all conditions considered in the design of the experiment and of the reactor itself should be one of the main aspects addressed in the safety analysis for the experiment. In addition, the effect of the presence or absence of an experimental device on the power distribution in the reactor core should be carefully addressed, as this may influence the safety margins of the reactor. Particular attention should be given to the calculation of the power distribution in the experimental device, in which all material compositions and the neutron and gamma heat deposition should be taken into account. Such calculations should be performed for all operational states. Adequate cooling should be provided to keep the temperature within acceptable limits. To avoid excessively high temperatures in all circumstances, means to place the experiment in a safe configuration should be provided. Means to reduce the reactor power or to shut down the reactor, as discussed in paras 4.6–4.8, should be analysed and ensured.

4.19. In addition to the above considerations, particular consideration should be given to irradiation of fissile material or moderating material with respect to the potential for inadvertent criticality and to cooling provisions during and after irradiation to prevent overheating of the target material.

**Pressure**

4.20. Possible effects of high or low pressure in the experimental device or modified system on the reactor should be assessed and appropriate means to keep the pressure within acceptable limits should be ensured.

4.21. Special precautions should be taken in the design for irradiating material, including their enclosures. Such material can readily decompose or otherwise change state, or its chemical reactivity may be enhanced, producing an overpressure, or gases that may be flammable and/or explosive. It should be

ensured that pressures within the enclosures and chemical concentrations of the target material do not endanger the reactor or the experiment.

**Selection of materials**

4.22. In the design of experiments, the selection of materials should take into account material compatibility, corrosion, changing of material properties due to irradiation (e.g. creep, embrittlement, radiolytic decomposition), including transmutation of material, differential thermal expansion, ageing effects and ease of decontamination, dismantling and final disposal.

4.23. In the design of experiments, particular consideration should be given to the irradiation of corrosive materials (e.g. mercury, rhenium, magnesium) or materials whose corrosive properties may become enhanced as a result of irradiation. For example, materials such as copper and cadmium should not be used without cladding; plastics and other organic or synthetic compounds will disintegrate under irradiation; cadmium, beryllium, silver, boron compounds (e.g. $B_4C$), and alloys containing these materials, should be used with extreme caution owing to their neutronic properties. Galvanic effects, in particular those due to interactions between water and aluminium, should also be considered. In particular, the use of mercury should be excluded in research reactors with aluminium components owing to the extremely corrosive interactions between these elements.

4.24. Furthermore, certain activated corrosion products (such as silver) tend to plate out (i.e. form a coating) on cooling circuit surfaces, thus creating contamination and the potential for radiation exposure during handling and maintenance.

4.25. In the design of experiments, particular consideration should be given to the provision of additional barriers to contain toxic material that could pose a hazard if released; for example, beryllium is particularly toxic if ingested.

**Flux perturbations**

4.26. Consideration should be given to the effects of interactions of neutrons from an experiment or modified system with core components, fuel or other experiments. Perturbations in the neutron flux should be evaluated, especially in the vicinity of safety related devices (e.g. neutron detectors). Where experiments can be inserted, withdrawn or otherwise relocated while the reactor is at power,

the effects on the power distribution in fuel assemblies and on the controllability of reactivity changes should be carefully assessed.

**Protection against external and internal hazards**

4.27. At each stage of the project, the design of the experiment or modification should include measures to withstand or mitigate the effects of external and internal events, e.g. earthquakes, floods, fires and explosions that have been taken into account for the reactor. The design should be reviewed by the appropriate experts and the implementation of the recommendations made should be documented.

4.28. If temporary equipment is to be used in the construction and installation stages, the proper measures should be taken to protect the structures, systems and components of the reactor as well as the temporary equipment against external hazards, e.g. anchoring them, fire protection measures.

**Mechanical interaction of experiments and the reactor**

4.29. The possible vibration of experimental devices or modified components due to coolant flow should be considered. Particular consideration should be given to avoiding vibrations at resonance frequency.

**Testability and ageing management**

4.30. In the design, particular consideration should be given to the proper testability of the modification or experiment during commissioning as well as during operation. If necessary for the ability to execute a commissioning programme successfully, special measuring and testing provisions should be made available to ensure accessibility of the modified system or experiment for measurements.

4.31. Particular consideration should be given to providing appropriate features to support the same degree of ageing management and in-service inspection as for the original system, taking into consideration the envisaged duration of the utilization project.

# 5. PRE-IMPLEMENTATION PHASE OF A MODIFICATION OR UTILIZATION PROJECT

## GENERAL

5.1. Sections 5, 6 and 7 provide detailed recommendations for the various phases of a typical modification or utilization project. These recommendations should be followed for a project with a major effect on safety. For projects with lesser safety implications, the recommendations should be applied using a graded approach. Figure 1 shows a flow chart for a project with a major effect on safety and the relationship between the operating organization and the regulatory body throughout the execution of the project. Other organizations could also be involved in the utilization or modification project, e.g. a design organization or sub-contractors. For the design of a modification, the operating organization should consult the designer to the extent possible. However, the overall responsibility remains with the operating organization. The following paragraphs provide a detailed discussion of each aspect of Fig. 1.

5.2. The extent of the involvement of the safety committee(s) and the regulatory body depends on the safety category of the experiment or modification; recommendations for determining the safety category are provided in Section 3 of this Safety Guide.

5.3. The implementation of projects with a minor effect on safety should follow the same steps, but using a graded approach, especially regarding the extent and detail of the safety analysis, the documentation to be prepared, and the review and approval route to be followed.

5.4. Each phase of the project should be clearly defined and should be understood by all persons involved. In particular, the transition points between phases should be formally acknowledged and recorded.

5.5. Early in the project, the need to develop a mock-up should be considered to facilitate the development of procedures for the implementation of the project, operating procedures, training of operating personnel and workability within a confined space, or to ensure the feasibility of the modification or utilization project.

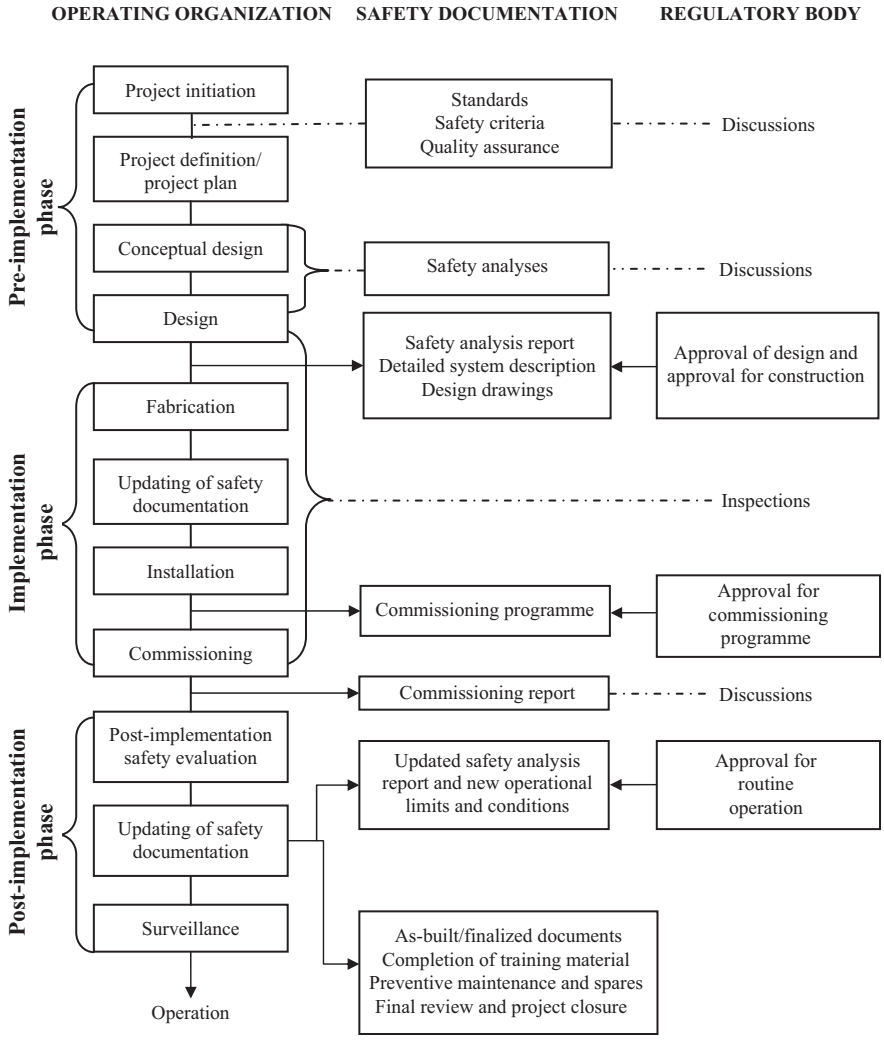


*FIG. 1. Phases of a modification or utilization project with a major effect on safety.*

## PROJECT INITIATION

5.6. The need for a modification or experiment can arise from different groups of persons, such as the reactor management, the regulatory body, experimenters or equipment suppliers. Modifications can involve changes to safety systems,

safety related items, operational limits and conditions, procedures, documentation, or operating conditions for the reactor as well as for experiments. Whatever the reason for a modification or an experiment, the general concept should be discussed by the reactor management and the regulatory body early in the project. It may also be appropriate to include other groups, such as the safety committee(s), experimenters, equipment suppliers and independent consultants.

5.7. Modifications and experiments at research reactors may also arise from a variety of considerations. These considerations are discussed in Annex III.

## PROJECT DEFINITION

5.8. The project definition stage involves development of the specific objectives and the scope of the proposed modification or experiment and, thus, provides the starting point for the technical design. Limiting conditions, safety criteria and quality requirements with regard to the implementation of the project should also be developed at this stage.

5.9. General organizational and administrative arrangements for the subsequent project steps should also be dealt with at the project definition stage.

### Categorization and selection of safety codes and standards

5.10. The process of categorization of the experiment or modification, as discussed in Section 3, should be applied at this stage in order to determine the safety implications of the project and the review and approval route to be applied.

5.11. The applicability of relevant existing safety codes and national and international standards to the structures, systems and components should be evaluated, and in some cases, development of some additional codes and standards may be necessary (see also paras 6.14 and 6.15 of Ref. [2]).

### Data collection

5.12. The use of relevant technical data and information on performance and material properties and process characteristics as input in the design stage is essential to ensure the quality and safety of modifications and experiments. Considerations such as those provided in paras 4.17–4.25 should also form part of such design inputs.

5.13. The existing documentation for the research reactor, component or software, including all modifications, should be provided to establish a pre-design database. A review of this documentation should be made to verify that it is up to date. This may require inspection of the equipment affected by the modification or experiment, and an evaluation of the operating and maintenance history of this equipment to verify that the documentation is up to date and that the existing equipment is capable of performing its intended function.

5.14. The establishment of the pre-design database may also require specific measurements or tests to be carried out on relevant reactor systems, in order to complete or update the information. Verification of historical data may be necessary, and the data should be carefully authenticated. Historical information on repeated failures or generic common cause failures should also be collected.

5.15. Inclusion of information on similar modifications or experiments carried out at other research reactors may provide an important contribution to the pre-design database. Operating experience, including information on ageing effects, should also be collected.

**Pre-design appraisal**

5.16. The design process is usually an iterative process. For each experiment or modification, several technical options should be evaluated. This appraisal will provide the basis for subsequent evaluation of the safety and the technical and financial feasibility of the modification or experiment, and for justification for the chosen option. The appraisal of options should cover not only the hardware for the modification or experiment (i.e. equipment, materials) but also the implementation and operational aspects, including surveillance requirements, as well as decommissioning and disposal aspects. These may determine the degree of interference with the reactor under normal operation, anticipated operational occurrences or accident conditions, the required radiation protection measures and the projected volume of radioactive waste, and thus will affect the safety, effectiveness and costs of the project. A technical description and a preliminary safety analysis should be provided for each option. The review scheme used for carrying out comparisons between the available options and for selection of the optimum solution should be documented and provided. Reasons for the rejection of other options should also be documented.

5.17. Depending on the safety category of the modification or experiment, the pre-design appraisal should be discussed with the regulatory body and, if applicable, the safety codes and design standards that have been selected for the

project should be submitted to the regulatory body for assessment and review, and the associated time schedule should be discussed with the regulatory body at the pre-design stage.

5.18. The pre-design appraisal may lead to a decision not to execute the modification or experiment.

## DESIGN

5.19. At the design stage, the selected option should be developed into a fully documented and justified design for the modification or experiment. Thus, project plans, specifications, design assessments, safety analyses, detailed drawings for manufacture and the installation of the modification or experiment and all associated documentation should be prepared at this stage. Requirements for commissioning, post-implementation safety evaluation and surveillance should also be determined at the design stage (see paras 7.2 and 7.5).

5.20. Management system criteria for design control should be established and implemented, covering all aspects of the design, including inspection and testing methods, and construction. Measures should be established and documented to ensure that the applicable codes, standards and regulatory requirements are correctly incorporated into design documents for safety related items. Measures should also be provided for verification of the adequacy of design. This verification should be performed by qualified individuals other than those who developed the original design. Further recommendations are provided in Section 2.

5.21. Detailed safety analysis should be carried out to the extent necessary for the potential hazards. The analyses should be capable of demonstrating that the design is safe and, in particular, of showing that:

— Any new system or component complies with all relevant safety standards and that it will function safely for all operational states.
— New systems will not adversely affect the safety characteristics of other items important to safety under any operational states, or the safety relevant characteristics of the reactor.
— The experiment or modification can be carried out without significantly increasing the dose to staff and members of the public; this should be determined in accordance with the principle of optimization of protection, or with the risk of an accident.

— The modification or experiment can be carried out without adversely affecting the safety of reactor operation.
— Any new hazards introduced by the modification or experiment can be safely managed at any stage of the project.

Care should be taken that up to date safety documents and data are used in these analyses.

5.22. It should be demonstrated and documented that:

— The introduction of the new system would not adversely affect the consequences, in terms of radiological hazards or other hazards, for any operational states.
— The failure of the new system would not result in any new event scenario with significantly increased risks (different failure modes may have to be considered).

5.23. The technical and operational relationship of the proposed modified system or experiment should be evaluated for each of the accident sequences considered in the safety analysis report for the reactor. The implications of the modification or experiment for the management of potential accidents and for their consequences should be analysed.

5.24. Furthermore, each credible failure mode of the changed system should be considered as a postulated initiating event for a new event scenario, and its consequences should be analysed by appropriate evaluation methods. Care should be taken to include in the assessment not only direct effects on the reactor, but also the effect on items important to safety, such as systems for accident prevention and for mitigation of the consequences of accidents.

5.25. At the end of this analysis, an updated version of the reactor safety documentation should be produced, which may include an update of the safety analysis report and the operational limits and conditions.

5.26. The safety documentation should be written and maintained according to the requirements established in Ref. [2] and recommendations provided in Ref. [4]. Attention should be paid to the review and updating, as necessary, of the documentation covering the design, operational limits and conditions, operating procedures, and other safety documentation, to be used as a basis for approval for normal operation of the experiment or modified research reactor.

5.27. Testing of experimental devices and equipment prior to their installation in the reactor should be considered. Tests should be planned as part of the design and the commissioning of the experiment or modification.

5.28. The output from the design stage should also include the following:

— A statement of the objectives to be met.
— Details of the structure of the organization set-up for the project and the responsibilities of the parties involved.
— A description of the activities, techniques and procedures to be employed, including those for the implementation programme.
— A safety evaluation of the specific procedures and techniques to be used.
— A description of the expected state of the reactor at the various phases of the project.
— The necessary design calculations, drawings and specifications for the complete project.
— The training programme designed to enable staff to cope with anticipated operational occurrences during the implementation of the project. (Staff should also be informed about the special safety considerations and provisions that apply during the various stages of the project.)
— Documentation, such as procedures for the modified state of the reactor, including any new or temporary emergency procedures and the associated training programme.
— A plan for commissioning to verify that the design objectives have been achieved.
— An outline of the preliminary decommissioning plan.
— A special surveillance programme, including ageing management and in-service inspection requirements, if necessary (see para. 7.5). Such surveillance should be used to demonstrate the continued safety of the reactor systems.
— An overview of the safety related spare parts that should be available before implementation of the modification or utilization project.

5.29. For ageing management, the relevant recommendations in Ref. [23] should be followed.

5.30. For decommissioning, dismantling and removal of major reactor components, the relevant recommendations in Ref. [24] should be followed.

5.31. The need for approval of the experiment, approval of the design and approval for construction of the modification or the need for formal licensing as referred to in para. 3.19 should be considered at this stage.

# 6. IMPLEMENTATION PHASE OF A MODIFICATION OR UTILIZATION PROJECT

## GENERAL

6.1. This section covers the fabrication, installation and commissioning stages of the implementation phase of the modification or utilization project. Not all of the recommendations provided are relevant for some projects, for example in cases where the project involves only changes to procedures.

6.2. Irregularities encountered at a particular stage should be dealt with immediately, rather than at a subsequent stage.

6.3. Nevertheless, if the outcome of a certain stage could place a constraint or a requirement on a subsequent stage, procedures to ensure that such constraints or requirements are satisfied should be put in place.

## FABRICATION

6.4. For the fabrication stage of the project, measures should be established for the control of procurement of materials, development, revision and use of documents and drawings, and for processing of materials as well as for the inspection of such activities.

6.5. New components or existing components that have to be modified are generally fabricated or modified by suppliers in accordance with the detailed specifications that have been established in the design phase. Before selecting a supplier, the project manager should ensure that the supplier has gained the necessary experience for the work and is aware of all of the particular constraints of the project, including management system criteria (see para. 5.20). Preliminary visits to the supplier are generally indispensable.

6.6. The project manager should also ensure that the suppliers involved have an appropriate management system.

6.7. During fabrication, technical audits and quality audits should be conducted in order to check and handle all aspects of fabrication, such as deviations from specifications, quality control and deadlines.

INSTALLATION

6.8. Measures should be established for the control of the installation of equipment, and any potential hazards, for example, radiation, chemical and industrial hazards, should be taken into consideration.

6.9. The installation of the experiment or the modification should not commence until all approvals have been obtained and the relevant staff involved in the installation have been trained satisfactorily.

6.10. The schedule for the installation of the experiment or for the modification should be prepared in consultation with the reactor manager, in order to ensure that the reactor is placed in a safe state before commencing the activity.

**Management**

6.11. Management of the installation stage of the project should cover at least the following:

— Clear identification of all responsibilities, including those relating to management system procedures and radiation protection.
— Frequent meetings to inform on progress and exchange information with all staff (i.e. technical, operational and health physics staff) involved in or affected by the project.
— Clear procedures with respect to the control (i.e. reporting, assessment and disposition) of deviations from approved methods and specifications, or from expected behaviour.
— Clear procedures to ensure that no foreign objects, e.g. assembly or installation tools and equipment, have been left in the area around the modification.
— Measurement and registration of all characteristics of the system as built; this is required for updating relevant technical documents, drawings and procedures.

— Training and provision of information to operating personnel and external personnel with respect to the conduct of the experiment or modification, methods to be used, safety aspects and safe working practices.
— Contingencies in the project plans to accommodate unforeseen events and operational deviations that may require a revision of the working practices and the project planning.

**Safety aspects**

6.12. The designer should carry out a sufficiently detailed safety evaluation of the installation process, which should be based on a detailed installation plan, describing activities, methods, hazards and temporary provisions, and the technical or administrative measures or precautions that should be implemented to minimize risk during the installation activities.

6.13. If temporary equipment has to be installed, the external and internal events that have been taken into account for the research reactor should be taken into account for the design and installation of temporary equipment (see also para. 4.28).

6.14. Specific safety topics that should be considered for the installation stage are related to:

— Identification of the hazards and the steps to be taken to control the hazards in order to minimize the risk to personnel, the reactor and the reactor systems and the environment;
— Management of radioactive waste, including transport, decontamination and dismantling aspects, as applicable;
— External exposure to radiation;
— Provisions required to prevent the spread of contamination and internal exposure to radiation;
— Safe storage of the fuel, radioactive material and other radiation sources and chemicals during the modification period;
— Industrial hazards, such as high voltage, vacuum, working in high places or confined spaces, fire, local flooding, and the use of chemicals and of potentially dangerous tools.

6.15. All temporary adaptations (such as connections, procedures or arrangements) that are necessary for implementation of a modification or experiment should be documented and should be made subject to approval by the reactor manager before they are applied.

6.16. Special temporary emergency procedures should be drafted as required, made subject to approval and exercised (see para. 5.28) in cases where potentially hazardous situations have been identified in connection with the installation of the experiment or the modification at the research reactor. These temporary procedures should be formally withdrawn once the installation is completed (see also para. 6.21).

## COMMISSIONING

6.17. Commissioning[13] of an approved modification or utilization project, which may include pre-installation tests of experimental devices and equipment, as discussed in para. 5.27, should be aimed at demonstrating the functionality and safety of the project.

6.18. The reactor manager should be given the responsibility to ensure that a review of the commissioning plan is conducted in accordance with established procedures.

6.19. The safety of a modification or experiment that is to be implemented should be verified through a commissioning programme involving tests and checks, and measurements and evaluations prior to and during implementation of the modification or experiment. The requirements in paras 7.42–7.50 of Ref. [2] are also applicable for the commissioning of a modification or experiment.

6.20. The adequacy of the commissioning programme for each modification or experiment should be reviewed with respect to the following objectives:

— Determination (by measurement under realistic conditions met in normal operation conditions and in anticipated operational occurrences to the extent possible) of all reactor characteristics relevant to safety with respect to the modified system;
— Demonstration that the structures, systems and components of the reactor that have not been modified (in particular all items important to safety) will not be compromised;
— Verification (on the basis of measured data) of the relevant safety parameters and proper performance of all safety functions;

[13] Additional recommendations for the commissioning process and for the various stages of commissioning for large modifications are provided in Ref. [6].

— Provision of additional information and data from commissioning, in order to update the safety documentation, the technical documentation and the operating procedures;
— Provision of opportunities for familiarization and training of operating and maintenance personnel;
— Adjustment of the reactor systems affected by the modification or experiment for optimum performance.

6.21. Special temporary safety provisions or procedures should be developed and exercised whenever necessary throughout the commissioning process.

6.22. The completion of the commissioning process should include a check to confirm that all temporary adaptations (such as connections, procedures or arrangements) that were necessary for implementation have been removed or cancelled and that the research reactor has been returned to full operational status.

6.23. The need for formal approval of the commissioning results and permission for operation with the experiment or with the modified system should be considered at this stage.

# 7. POST-IMPLEMENTATION PHASE OF A UTILIZATION OR MODIFICATION PROJECT

## POST-IMPLEMENTATION SAFETY EVALUATION AND APPROVAL FOR ROUTINE OPERATION

7.1. The basis for final approval of the experiment or modification for routine operation should be the successful completion of all stages of commissioning, and the verification of all information and experience against the requirements as specified in the design. The results of the commissioning tests and the as-built drawings and documentation should be reviewed in accordance with existing procedures, to demonstrate that the modification or experiment has been built in a manner that conforms to the approved specifications and to ensure safe operation.

7.2. A final commissioning report should be produced in which the results of commissioning are presented and assessed. The report should be subject to approval in accordance with established procedure.

UPDATING OF SAFETY DOCUMENTATION

7.3. Revision of the safety documentation and the safety analysis report, as mentioned in para. 5.26, should be carried out as appropriate, to include the as-built description of the utilization or modification, and to take into account the results of the commissioning process. The project manager should be responsible for such revisions. The time schedule for the revision of the documentation should be made subject to approval by the reactor manager, in accordance with the regulatory requirements.

7.4. If the safety documentation has been revised, the approval and distribution of the documentation should be carried out in accordance with the approved procedures on the basis of the safety significance of the experiment or modification. This could require involvement of the safety committee(s) and review and approval by the regulatory body, as appropriate. Obsolete safety documentation should be removed from service and archived.

SPECIAL SURVEILLANCE

7.5. The justification for certain modifications and experiments may be dependent on technical or material characteristics that may be affected in long term reactor operation by irradiation embrittlement, corrosion or other ageing effects. In cases where such effects cannot be predicted with sufficient accuracy from previous experience or by analysis, a safety surveillance programme should be defined for monitoring the behaviour of the relevant characteristics. Any special surveillance requirements determined at the design stage (see paras 5.16 and 5.28) should be implemented.

# 8. OPERATIONAL SAFETY OF EXPERIMENTS AT A RESEARCH REACTOR

8.1. Although the recommendations provided in the following paragraphs are, in principle, applicable for both modifications and experiments, for modification projects and for major utilization projects the recommendations for a new research reactor should be followed where applicable (see Refs [3, 4, 6, 7, 13, 23, 25]).

## RADIATION PROTECTION

8.2. Experiments at research reactors can present significant radiological hazards for persons conducting the experiment, for operating personnel and, in some cases, for persons outside the research reactor. In addition to the design, which should be such as to minimize radiological hazards and which is supported by the commissioning process, the experimenters and persons involved in the operation of the experiment should be trained and should follow approved procedures for the performance of their tasks.

8.3. Every experiment should be performed using approved operating procedures that describe the responsibilities of those involved in the experiment and that include operating instructions for the experiment.

8.4. In addition to general training in radiation protection, specific training should be provided for all experiments. Such specific training should cover:

— Operating procedures for the experiment;
— Rules and instructions for radiation protection associated with the performance of the experiment;
— Emergency plans and procedures.

8.5. Areas in which there can be significant radiation levels during reactor operation and during reactor shutdown, such as areas close to open beam tubes, reactor loops or irradiated materials, should be determined before reactor startup. Such areas should be categorized as controlled and supervised areas in accordance with Refs [2, 21]. After reactor startup, a radiation survey (of alpha, gamma and neutron radiation) should be made that especially covers the area around the experiment. The actual radiation fields should be measured, displayed and, where appropriate, recorded. Where necessary, such areas should be cordoned off or physically secured to prevent inadvertent or unauthorized access, and appropriate radiation warning signs should be exhibited.

## INFORMATION NECESSARY FOR SAFE PERFORMANCE OF EXPERIMENTS

8.6. In addition to the information in the safety analysis report, experimenters should prepare for the operating personnel: a detailed description of the experimental device; a list of credible possible hazards posed by the experiment; the boundary conditions for operation of the experiment; and a list of all

connections to the reactor protection system that may cause the reactor to shut down.

8.7. The reactor manager should be made responsible for the coordination necessary (e.g. to take into account the reactor shutdown periods needed for maintenance) for the conduct of experiments.

8.8. For every experiment, the operating personnel and experimenters should have the necessary information available for the safe performance of the experiment, and the information that may be needed in the event of a safety related problem or operating difficulties. The required information should list any operational limits and conditions for the experiment, such as maximum temperatures and pressures. The actions to be taken in the event that these limits are approached or exceeded should be clearly stated in written instructions. These actions should be provided mainly in the form of procedures for all operational states and for emergencies. A tabulation of the expected radiation levels or other hazards associated with the experiment should be provided, as well as a list of the personnel allowed to run the experiment and of those persons associated with the experiment who can be called upon for advice if difficulties arise.

8.9. The limiting conditions both for the reactor and for the experiment to ensure safe operation, as well as the procedures for handling and operation of the experiment, should be subject to approval by the reactor manager. Particular consideration should be given to the approval of limiting conditions and procedures relating to the startup of the reactor or the experiment, anticipated operational occurrences, and emergency situations.

8.10. Records should be kept of material, samples, equipment and devices inserted into the reactor, and such items should be retrieved and accounted for at the end of their irradiation. These records should also include the measured or estimated activity of each item.

## COOPERATION BETWEEN EXPERIMENTERS AND OPERATING PERSONNEL

8.11. To ensure safe operation of experimental devices, the experimenter and the operating personnel will need to work closely together. Special arrangements should be considered for startup of the reactor or the experimental device, such as any special handling necessary by the operating personnel or the experimenter or operation outside the normal schedule of either the experimental device or the

reactor. Procedures should be prepared, made subject to approval and implemented to ensure adequate communication between experimenters and operating personnel. The following aspects should be considered for these procedures:

— The need to announce, through a public address system, that the reactor is starting up or that the experiment will commence;
— The need for the reactor manager to check all experiments and the locations of all experimenters;
— The use of warning lights or other visible signs in experimental areas to indicate that the reactor is operating;
— The use of dedicated communication provisions;
— Contact details of persons who can be contacted after working hours if special actions are required.

Such communication needs should be considered in addition to any interlock or other safety devices provided in the design.

8.12. The activities of experimenters and the operating personnel should also be coordinated during routine operation. If an experiment involves operations that may influence reactor parameters (e.g. displacement of a fuel test rig), a method of direct vocal communication between the experimenter and the operating personnel should be available at all times, and the actual status of the experiment should always be known to the operating personnel. These provisions should be put in place in addition to design provisions.

8.13. The operating instructions should clearly define the tasks and responsibilities of the operating personnel and experimenters, so as to avoid conflicts of interest between the progress of experiments and the safe operation of the experiments or the reactor. These responsibilities should be reviewed by the safety committee(s) and made subject to approval by the reactor manager.

## OPERATIONAL CHANGES IN EXPERIMENTS

8.14. For some experiments, it might be necessary to change the operating conditions in some manner, such as changing the experimental set-up, or the safety system setting of the experiment, or the operating sequence agreed to when the experiment was originally approved. Such proposed changes should be treated as a modification, and the guidance given in this Safety Guide should be followed.

RESPONSIBILITY FOR SAFE OPERATION OF EXPERIMENTS

8.15. The reactor manager has direct responsibility for the safety of the reactor operation. Accordingly, the reactor manager or a designated member of the reactor manager's staff should be given the authority to assume control of any necessary operation of the experimental equipment to ensure the safety of the reactor and the personnel, including stopping any experiment that the manager considers hazardous and placing it in a safe condition.

8.16. Experimenters should report any deviation from normal operation of their experiment directly to the operating personnel.

8.17. As part of his or her responsibility for safety, including all safety aspects of experiments, the reactor manager should enforce any safety rule or any limitations to experiments, if necessary, to ensure the safe operation of both the experiment and the reactor, as well as to ensure the safety of staff.

8.18. Within the approved procedures and within the approved operational limits for their experiment, the experimenters should assume responsibility for the safe operation of the equipment of their experiment.

8.19. The responsibilities of the operating personnel and the experimenters should be clearly defined and made subject to approval by the reactor manager.

# 9. SAFETY CONSIDERATIONS IN THE HANDLING, DISMANTLING, POST-IRRADIATION EXAMINATION AND DISPOSAL OF EXPERIMENTAL DEVICES

GENERAL RECOMMENDATIONS

9.1. The handling, dismantling and disposal of experimental devices or other irradiated equipment that requires storage and eventual disposal in connection with the project should be carried out in accordance with approved procedures.

9.2. The procedures should take into account the safety evaluation of all operations connected with the handling, dismantling, post-irradiation examination, transport and storage or disposal of irradiated equipment. The

activity and contamination of irradiated equipment should be evaluated in advance, under each of two assumptions:

— The most probable course of the experiment;
— The worst possible combination of equipment failures and human errors.

9.3. Radiological hazards should be assessed for all relevant conditions. The radiation protection measures (e.g. shielding, cleaning of air, decontamination procedures and the use of movable provisions such as shielding and ventilation provisions to facilitate handling operations) should be demonstrated to be adequate to deal with the worst possible situation.

9.4. The equipment to be used for the handling, dismantling and safe storage or disposal of irradiated materials and devices should be procured and tested in advance.

9.5. The operations should be planned such that the exposures of personnel are as low as reasonably achievable, and the amounts of radioactive substances released are minimized. Measures necessary to prevent contamination of equipment and personnel should be developed and put in place.

9.6. If the irradiated equipment can give rise to airborne contamination, a handling process to prevent this should be developed and put in place (e.g. by keeping the equipment in leaktight containers or by providing a system of negative pressures and filters). Criteria for items important to safety (e.g. single failure criterion, to ensure that no single failure or single maintenance action or any other single human action could disable a safety function, redundancy) should be used in planning such a process. The requirements are established in Ref. [2].

9.7. Decontamination schemes should be developed for all surfaces that may be contaminated by the experiment. The safe storage or disposal of decontaminants used should be ensured.

## SPECIFIC RECOMMENDATIONS

### Training

9.8. All documentation describing the sequence of operations and the instructions for operating the equipment should be known to the operating

personnel and should be available during the handling, dismantling, post-irradiation examination and storage of the irradiated equipment or components until their final disposal.

9.9. The personnel performing the handling, dismantling, post-irradiation examination and storage of experimental devices should be given the necessary training in all aspects of these operations, including, if necessary, exercises using mock-ups, before work with irradiated objects is commenced. A method for determining the effectiveness of training should be put in place.

**Storage**

9.10. If the irradiated equipment of the dismantled experiment, experimental facility or system is to be stored on-site, the volume and the characteristics of the materials to be stored, including their measured or estimated activities, should be evaluated and the safe storage of such equipment should be demonstrated.

## 10. SAFETY ASPECTS OF OUT-OF-REACTOR-CORE INSTALLATIONS

10.1. The out-of-reactor-core experimental devices or modifications (installations) include two groups: (i) those that utilize the radiation produced by the reactor but are located outside the reactor (biological) shielding (e.g. a neutron spectrometer); and (ii) those that are at or near the reactor and which do not utilize the radiation produced by the reactor, but which constitute a potential hazard (e.g. a cryostat containing liquid nitrogen).

10.2. Both groups of installations should be subjected to the categorization process as described in paras 3.7–3.34.

10.3. For the out-of-reactor-core installations that constitute a potential hazard, in addition to an analysis of ‘conventional’ safety, analyses should be performed to identify the potential hazards and determine the safety provisions to be implemented to reduce the hazards to the extent possible.

10.4. In addition to the review by the safety committee(s), if required, the safety analysis should be reviewed in accordance with management system procedures

by appropriate specialists, e.g. in the field of occupational hazards, chemical hazards and electrical hazards.

10.5. The proposal for an out-of-reactor-core installation should be subject to approval by the reactor manager, including the safety analysis for its implementation. Based on its effect on safety (i.e. major, significant), the proposal should be submitted to the safety committee(s) and to the regulatory body for review and approval of the analysis, as appropriate.

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## Annex I

## EXAMPLE OF A CHECKLIST FOR CATEGORIZATION OF AN EXPERIMENT OR MODIFICATION AT A RESEARCH REACTOR

| Form to be completed by the designated project manager | | | |
|---|---|---|---|
| **Document No.** | | **Rev.** | |

**Part 1 — Description of the modification or experiment**

**Describe the modification or experiment**

*Describe the modification or experiment to be undertaken, or refer to other documentation, e.g. project initiation document.*

**Part 2 — Safety screening**

**Screening questions** *(tick the appropriate box)*

| No. | Question | Answer | | Justification |
|---|---|---|---|---|
| 1 | Does the proposed modification or experiment involve a change to, or an effect on, a structure, system or component that could affect its design function or its ability to perform its design function as described in the safety analysis report? | ☐ Yes | ☐ No | |
| 2 | Does the proposed modification or experiment involve a change to a procedure that could affect how the design functions of structures, systems and components described in the safety analysis report are performed or controlled? | ☐ Yes | ☐ No | |
| 3 | Does the proposed modification or experiment involve revising or replacing an evaluation methodology | ☐ Yes | ☐ No | |

| | | | | |
|---|---|---|---|---|
| | described in the safety analysis report, used in establishing the design bases or used in the safety analyses? | | | |
| 4 | Does the proposed modification or experiment involve a test, experiment or activity not described in the safety analysis report, where a structure, system or component is utilized or controlled in a manner that is outside the reference bounds of the design for that structure, system or component, or the modification or experiment is inconsistent with analyses or descriptions in the safety analysis report? | ☐ Yes | ☐ No | |
| 5 | Does the proposed change require a change to any of the following other than an editorial or typographic change:<br>• Licence?<br>• Safety analysis report?<br>• Operational limits and conditions?<br>• Safety related operating procedures? | ☐ Yes | ☐ No | |
| **Result of the safety screening** *(tick the appropriate box)* | | | | |
| 1 | **All the questions have been answered with "NO".** | | | ☐ |
| | 1A | If the proposed modification or experiment falls within the lowest safety classification, then Safety category 4 'no effect on safety' is recommended. **Go to Part 4, Safety categorization.** | | ☐ |
| | 1B | If the proposed modification or experiment falls within a higher safety classification, then Safety category 3 'minor effect on safety' is recommended. **Go to Part 4, Safety categorization.** | | ☐ |
| 2 | **At least one question has been answered with "YES".** A safety evaluation (**Part 3**) is required to evaluate the safety implications of the project prior to assigning a safety category. **Go to Part 3, Safety evaluation.** | | | ☐ |

| **Part 3 — Safety evaluation** |
|---|
| **Evaluation questions** *(tick the box for the appropriate answer)* |

| **Effect in relation to accidents and malfunctions previously evaluated in the safety analysis report** | | | | |
|---|---|---|---|---|
| **No.** | **Question** | **Answer** | | **Justification** |
| 1 | Could the proposed change affect the frequency of occurrence of a design basis accident previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| 2 | Could the proposed change affect the consequences of a design basis accident previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| 3 | Could the proposed change affect the likelihood of occurrence of a malfunction of a structure, system or component important to safety previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| 4 | Could the proposed change affect the consequences of a malfunction of a structure, system or component important to safety previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| **Potential for occurrence of a new type of event not previously evaluated** | | | | |
| 5 | Could the proposed change create a possibility for an accident of a different type than any previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| 6 | Could the proposed change create a possibility for a malfunction of a structure, system or component important to safety with a different result than any previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| **Impact on fission product barriers as described in the safety analysis report** | | | | |
| **No.** | **Question** | **Answer** | | **Justification** |
| 7 | Could the proposed change result in a design basis limit for a fission product barrier as described in the safety analysis report being exceeded or altered? | ☐ Yes | ☐ No | |
| **Impact on evaluation methodologies described in the safety analysis report** | | | | |
| **No.** | **Question** | **Answer** | | **Justification** |
| 8 | Does the proposed change result in a departure from a method of evaluation described in the safety analysis report used in establishing the design basis or in the safety analyses? | ☐ Yes | ☐ No | |

| Changes to safety documentation | | | | |
|---|---|---|---|---|
| **No.** | **Question** | **Answer** | | **Justification** |
| 9 | Does the proposed change require a change to the safety analysis report, other than an editorial or typographic change, that impacts the safety case in a way not considered in questions 1–8 above? | ☐ Yes | ☐ No | |
| 10 | Does the proposed change require a change to the operational limits and conditions, other than an editorial or typographic change? | ☐ Yes | ☐ No | |
| 11 | Does the proposed change require a change to licensing basis documents, other than an editorial or typographic change, that impacts the safety case in a way not considered in questions 1–8 above? | ☐ Yes | ☐ No | |
| 12 | Does the proposed change require a change to the reactor procedures, other than an editorial or typographic change, that impacts the safety case in a way not considered in questions 1–8 above? | ☐ Yes | ☐ No | |
| **Result of the safety evaluation** *(tick the appropriate box)* | | | | |
| **All the questions have been answered with "NO".**<br>The proposed change will have a significant effect on safety. Safety category 2 'significant effect on safety' is recommended. **Go to Part 4, Safety categorization.** | | | | ☐ |
| **At least one question has been answered with "YES".**<br>The proposed change will have a major effect on safety. Safety category 1 'major effect on safety' is recommended. **Go to Part 4, Safety categorization.** | | | | ☐ |

| **Part 4 — Safety categorization** | | | | |
|---|---|---|---|---|
| **Category requested** *(tick the appropriate category)* | 1 ☐ Major effect on safety | 2 ☐ Significant effect on safety | 3 ☐ Minor effect on safety | 4 ☐ No effect on safety |
| **Justification** | | | | |
| | | | | |
| **References** | | | | |
| | | | | |

| **Part 5 — Review and approval** | | | | | |
|---|---|---|---|---|---|
| ***Prepared by (project manager)*** | | | | | |
| **Name** | | **Signature** | | **Date** | |
| ***Section manager approval*** | | | | | |
| **Name** | | **Signature** | | **Date** | |
| ***Reactor manager approval*** | | | | | |
| **Name** | | **Signature** | | **Date** | |
| **Review and approval by the regulatory body required Yes ☐ No ☐** | | | | | |
| Approved safety category *(tick the appropriate category)* | 1 ☐ | 2 ☐ | 3 ☐ | 4 ☐ | |
| **Comments** | | | | | |
| | | | | | |
| **Name** | | **Signature** | | **Date** | |
| **Original to be retained in the project file** | | | | | |

## Annex II

## EXAMPLE OF THE CONTENT OF THE SAFETY ANALYSIS REPORT FOR AN EXPERIMENT AT A RESEARCH REACTOR

### GENERAL

II–1. The following list of topics sets out the minimum requirement for the table of contents of the safety analysis report for an experiment. The topics are to be discussed using a graded approach based on the safety category of the experiment, as defined in Section 3 of this Safety Guide. The topics that are not relevant for the safety analysis report of the utilization project should be indicated with the remark 'not applicable'.

II–2. The layout of the safety analysis report is to be such that the main chapters contain only technical descriptions, summaries of calculation and analysis methods used, the main results and conclusions. Evaluations with detailed descriptions and calculations may be incorporated in the appendices if necessary.

II–3. Furthermore, the safety analysis report for the utilization project has to include figures, sketches and/or flow diagrams indicating overall dimensions, masses, temperatures and pressures. All computer codes used are to be fully validated and benchmarked for their specific application and valid references have to be given. A summary has to be provided at the beginning of the safety analysis report.

### STRUCTURE OF THE SAFETY ANALYSIS REPORT

1. Introduction

Short description of:

— Purpose of the utilization project;
— General nature of the irradiation target;
— General nature of the irradiation facility;
— If applicable, reference to earlier experiments or periodic review of the safety analysis report for the utilization project.

2. Experimental requirements

Specification of required:

— Nuclear conditions (fluence, radiation heating, linear power);
— Process conditions (target environment, temperature distribution, pressure characteristics);
— On-line measurements;
— Off-line measuring or inspection possibilities.

3. Irradiation target

— Detailed description (materials, composition, dimensions, special features);
— Codes and standards applied (e.g. ASME, RCC-M, RCC-MR, etc.);
— Thermal and mechanical characteristics;
— Design drawing;
— Fabrication method and quality procedures[1].

4. Irradiation facility

When a standard irradiation facility is used for the irradiation, a brief description will be sufficient, complemented by reference to document(s) in which the facility is described in detail.

4.1. In-core/out-of-core irradiation

— Functional description of the experimental facility and all in-core and out-of-core components (e.g. thermocouples, heaters);
— Sketches, showing vertical and horizontal cross-sections;
— Detailed assembly drawing (including parts list, list of materials used and material specifications).

[1] A detailed description of the quality control procedures that are applied is necessary for irradiation targets containing fissionable materials, actinides or other potentially hazardous materials, in order to ensure that these are manufactured in conformity with specifications and that the acceptance criteria are met. The acceptance criteria (tolerances) for materials and dimensions that are important for determining uncertainty factors in the safety analyses have to be specified.

Remarks:

(a) General assembly drawings (two sets) and sufficient information about all components need to be submitted to the reactor manager.
(b) A complete description of all joints, penetrations, etc. that are part of the containment(s) has to be provided.

4.2. Radiation shielding

— Functional description of the experimental facility, including all components (e.g. thermocouples, heaters);
— Sketches, showing vertical and horizontal cross-sections;
— Detailed assembly drawing (including parts list, list of materials used and material specifications).

Remarks:

(a) General assembly drawings (two sets) and sufficient information of all components need to be submitted to the reactor manager.
(b) A complete description of all joints, penetrations, etc. that are part of the safety containment(s) has to be provided.

4.3. External system(s)

— Functional description of all components, classified into subsystems, such as:
  4.3.1. Cooling system
  4.3.2. Gas supply and circulation system
— Flow sheet, block schemes of external systems;
— Functional characteristics and design requirements of major components (i.e. pumps, valves).

4.4. Instrumentation

4.4.1. General

— General description of the different groups of instrumentation.

4.4.2. Safety instrumentation (essential to ensure safe operation of the experiment)

— Design of the safety instrumentation;
— Connection/interference with the reactor protection system, and interlock instrumentation;
— Connections with the experiment;
— Components and diagrams.

4.4.3. Process instrumentation

— Objective of the process instrumentation;
— Components and diagrams.

4.4.4. Scientific instrumentation

— Objective of the scientific instrumentation;
— Components and diagrams.

4.4.5. Additional experimental instrumentation

— Instrumentation not covered by the previous categories.

4.5. Data registration and control systems

— Functional description of data acquisition and evaluation systems;
— Block schemes illustrating entire set-up.

4.6. Service and supply systems

Functional description of all external supply systems that have fixed connections to the irradiation facility, subdivided into:

4.6.1. Electrical power supply systems
4.6.2. (Make-up) water supply system
4.6.3. (Service) gas supply systems

Each description has to indicate anticipated consumption rates (of power, water, air, gases, etc.).

4.7. Waste systems

Functional description of all systems for waste retrieval that are permanently connected to the irradiation facility, subdivided into:

4.7.1. Off-gas system
4.7.2. Water disposal system(s)

Each description has to include a specification of the anticipated amount and activity of the effluents disposed under:

— Normal operation;
— Specific measures or actions;
— Emergency situations.

4.8. Shielding

Description of shielding provisions and specifications of anticipated radiation levels in service areas during:

— Normal operation including post-irradiation handling;
— Specific measures or actions;
— Emergency situations.

5. Characteristics[2]

5.1. Nuclear characteristics

— Specification of anticipated fluence values;
— Description of (or reference to) measurements and/or calculations made to verify fluence characteristics:
  (a) Prior to irradiation;
  (b) During irradiation (dosimetry).
— Reference to or summary of calculated and applied nuclear data.

[2] The main section of the report is to contain mostly the results (tables, graphs) of the various calculations. Detailed calculations are to be reported either in appendices to the safety report or in separate reports, which will be referred to in the safety analysis report of the utilization project.

5.2. Reactivity and criticality characteristics

Specification (based upon calculation and/or measurement) of:

— Criticality aspects;
— Total reactivity worth of the experiment;
— Reactivity effect of the in-core experimental facility for non-fixed experiments;
— Reactivity effect associated with voids which can be filled with water in case of leakage;
— Reactivity aspects in case of fast movement of the experimental facility;
— Effect on the reactivity worth of the control and safety systems.

5.3. Radioactivity characteristics

Calculation of total activity of radionuclides produced in:

— Irradiation target (if fissionable, specify all noble gases, halogens, actinides and other dangerous nuclides);
— Gases or liquids that may escape as a result of containment failure;
— Structural parts of in-pile assembly.

All calculations to be relevant for the end of the anticipated irradiation period:

— Calculation of the decrease in activity owing to decay of the major activity contributors at the end of irradiation and 10 h, 10 d and 100 d after the end of irradiation.

5.4. Thermohydraulic characteristics

— Calculation of specific heating rates (due to nuclear fission and radiation heating) of all in-core materials;
— Calculation of:
  • Radial and axial heat flux density and temperature distribution;
  • Coolant temperature increase.
— Calculation of temperature control margin that can be achieved by the available control systems (heaters, mixed gas systems);

— Calculation of the margins to the thermohydraulic critical phenomena under the worst possible operating conditions (i.e. maximum power, minimum cooling, etc.), applying all relevant uncertainty (hot spot) factors. A justification of the correlation(s) used has to be provided.

Remark:

All calculations are to be made for all operational states and cooling conditions as well as for accident conditions and reactor shutdown conditions.

5.5. Mechanical and thermal stress characteristics

The calculation methods and the applied criteria are to be described for all safety related mechanical components. The tensile, thermal and admissible stresses are to be presented and particular consideration is to be given to:

— Transient behaviour;
— Containment lids;
— Cryogenic material behaviour;
— Standard gas supply pressures.

6. Fabrication, assembly and commissioning

6.1. Fabrication

6.2. Assembly

6.3. Commissioning

Summarized description of the quality programme, with, inter alia, inspection of incoming goods, inspection and testing during assembling and final inspection and testing to which the irradiation facility will be subjected prior to operation. The detailed management system programme is to be documented separately, i.e. in a quality assurance or quality control report and a commissioning report.

## 7. Operation, maintenance and periodic testing

### 7.1. General

Outline of the startup, operation, special measurements and emergency procedures: The detailed operation and handling are to be specified in a separate ‘operations and handling manual’. Special periodic testing requirements and maintenance procedures to be performed by the project engineer are to be described. In case of extensive programmes, reference could be made to a special document.

### 7.2. Operational experience

Summary of the relevant operational experience during the execution of comparable irradiation experiments in the past: Aspects to be mentioned are reactor behaviour during operation, experience in loading and unloading of experimental devices and which improvements were implemented or could be introduced.

## 8. Handling, dismantling, transport and disposal

Outline of the various handling procedures, for both normal conditions and abnormal conditions (e.g. target failure) with a description of (or reference to) special tools or containers that have to be used; specification of the transport container, and means to be used for transport within or off the site, and summary of specific container criteria required by national legislation and international regulations.

## 9. Post-irradiation examination

Description (summary) of post-irradiation examination of targets (i.e. dismantling mode, scientific measurements) and/or the irradiation facility. Specification as to whether the post-irradiation examination is scheduled to be performed at the research reactor itself or at another research institute.

10. Safety analysis

In this section, the postulated initiating events for the experiment are to be presented and the consequences of the postulated initiating events are to be analysed for all operational states of the reactor, in which analysis the single failure criterion is to be applied. The postulated initiating events are not to be restricted to the experimental facility, but also possible internal and external hazards as defined for the reactor itself or for similar experiments at other reactors are to be analysed. The safety analyses need to be such as to prove that neither conduct of the experiment nor any failure would result in unacceptable conventional hazards and/or radiological hazards to personnel, in major disturbances to the operation of the reactor and (other) experimental facilities, in damage to the reactor or experimental facilities or in reduced access to the reactor, experimental facilities or the reactor building.

The safety analysis is to include at least the following subjects:

— Target failure;
— Failure of (some) containment(s);
— Cooling (system) failure;
— Electrical power failure;
— Failures of instruments;
— Failures of services (e.g. electricity supply);
— Failures of (other) components;
— Operating errors;
— Handling errors;
— Applicable internal and external events.

## Annex III

## EXAMPLES OF REASONS FOR A MODIFICATION AT A RESEARCH REACTOR

### PERIODIC SAFETY REVIEW

III–1. Routine reviews of operation (including modifications to hardware and procedures, significant events, operating experience, management and personnel competence) and special reviews following events of major safety significance are the primary means of safety verification. In addition, systematic safety reassessment, termed periodic safety review, is performed to assess the cumulative effects of plant ageing and plant modifications, operating experience, technical developments and siting aspects. Such reviews include an assessment of the design and operation of the reactor against current safety standards and practices, and they have the objective of ensuring a high level of safety throughout the operating lifetime of the research reactor. They are complementary to routine and special safety reviews and do not replace them. Such reviews could lead to an indication that a modification of the existing reactor systems or procedures is necessary to meet current safety standards.

### AGEING

III–2. Ageing of structures, systems and components or of an experimental facility, obsolescence of equipment, problems relating to spare parts, or experience from maintenance and operation may call for modification of reactor systems and operating procedures. Another incentive for modification may be the availability of new materials or improved components.

### UPGRADING

III–3. Reactor systems or reactor operating conditions may be upgraded in response to the need for improved irradiation conditions, more experimental capacity or improved reactor availability.

## NEW EXPERIMENTS

III–4. A major reason for modifications is the need to cater for new experiments or to extend existing experiments. Such modifications can entail new hazards.

## ADDITIONAL REASONS FOR A MODIFICATION

III–5. The need for modifications may also arise from considerations of reactor economy, fuel availability, human factors or physical protection at the reactor.

III–6. The relevance of these or other considerations for a particular reactor will depend strongly on the reactor type, its age and utilization, and on national safety criteria.

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*"Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them."*

**Yukiya Amano**
**Director General**

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