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# IAEA SAFETY STANDARDS

*for protecting people and the environment*

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# Safety in the Utilization and Modification of Research Reactors

## DRAFT SAFETY GUIDE
## DS397


Vienna, 2010

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# 1. INTRODUCTION

## BACKGROUND

1.1. This Safety Guide was developed under the IAEA programme for safety standards for research reactors, which covers all the important areas of research reactor safety. 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]. Also, the present Safety Guide provides guidance on implementing the requirements established in the IAEA Safety Requirements on the Safety of Research Reactors, NS-R-4 [2], for ensuring adequate safety at all stages of the lifetime of a research reactor. In particular, guidance is given on which analyses, verifications and evaluations should be performed to fulfil the safety objectives of the requirements for the operating organization that are established in paras 2.15; 2.17–2.20; 3.6–3.12 and 4.14 of Ref. [2].

1.2. The present publication supersedes IAEA Safety Series No. 35-G2[2]; it is harmonized with the body of IAEA Safety Standards and with the publications being developed within the framework of the IAEA programme on research reactor safety.

1.3. Owing to the particular characteristics of research reactors, the safety aspects related to design and operation have been given special emphasis and have been incorporated in Ref. [2]. These characteristics include the large variety of designs, the wide range of powers, the different modes of operation and purposes of utilization, the particularities of siting, and the major differences among the types of research reactor owners and operating organizations. These characteristics require a graded approach[3] in the application of the requirements (Ref. [2], paras 1.11.–1.14), i.e. flexibility in the implementation of objectives and the fulfilment of

[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).

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

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 protection of the public, site personnel and the environment have a number of responsibilities which are interrelated. Most important are the preparation of the safety analysis and the safety analysis report by the operating organization and its review and assessment by the regulatory body, as well as the production and evaluation of 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 information on safety analysis and related documentation in Ref. [4] and on the review and assessment by the regulatory body in Ref. [5] has been taken into account in the preparation of the present Safety Guide. In addition, the present Safety Guide discusses other aspects of experiments and modifications, such as commissioning and radiation protection provisions, for which detailed guidance is provided in Refs [6] and [7]. The IAEA Safety Glossary [8] defines and explains the safety related words and terms used in the present publication.

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OBJECTIVE

1.5. The objective of this publication is to provide practical guidance 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 risks to site personnel, the public and the environment. The present Safety Guide develops the general concepts in these areas, which are presented in the paragraphs related to utilization and modification in the Safety Requirements for Research Reactors [2]. Therefore, this Safety Guide should be read in conjunction with Ref. [2].

1.6. This Safety Guide gives guidance to the operating organization, including experimenters and technical support organizations and other persons involved in utilization and modification projects. It provides guidance only on the safety implications of research reactor utilization and modification. 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.

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SCOPE

1.7. The guidance provided in this Safety Guide applies to the utilization 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 operational or decommissioned nuclear power plants.

1.8. In the context of this Safety Guide, research reactor utilization is the use of the 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 facilities connected to the reactor, but may also be outside the biological shielding or containment or confinement.

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 reactor system or piece of equipment, an experiment or an experimental device, with potential safety implications. It may involve modification of safety systems, safety related items, procedures, documentation, or operating conditions for the reactor as well as for experiments.

1.10. The requirements for the utilization or modifications (i.e. the experiment or modification project) given in Ref. [2] depend on the type of reactor and the safety significance of the task. However, in all cases the preparation and implementation of a project should follow the logical sequence as outlined in this Safety Guide. In minor projects the particular stages may be very simple, but none of them should be omitted.

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

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1.12. In the case of modifications which only concern changes to documentation, the guidance presented in Section 6 of this publication are not fully applicable. For such modifications, the additional guidance provided in the Safety Guide on the Safety Assessment of Research Reactors and Preparation and Content of the Safety Analysis Report [4] should be considered and followed, as applicable.

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[4] Experiments and experimental facilities which have been approved over time or which have been analysed as a part of the safety analysis report are not considered as a deliberate change under the present Safety Guide.

STRUCTURE

1.13. This Safety Guide consists of ten sections and three Annexes. In most of these sections, the safety aspects of both the research reactor utilization and modification are described together. Section 2 provides guidance on the management system for the modifications and utilization. Categorization provides a basis for selecting the review and approval route; guidance on these topics is given in Section 3. Guidance on the design is provided in Section 4, which should be read in conjunction with Ref. [2]. Sections 5, 6 and 7 provide guidance on the various activities that should be considered during the stages of a typical project. Section 8 covers the additional guidelines for operational safety of experiments, and Section 9 gives guidance on the handling, dismantling, post-irradiation examination and disposal of experimental devices. Section 10 provides guidance to ensure the safety of out-of-reactor installations.

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

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GENERAL

2.1. A documented management system that integrates safety, health, environmental, security[5], quality and economic related objectives for the research reactor project should be in place. The management system documentation should describe the system that controls the development and implementation of all aspects of the research reactor project, including the 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; resource management; process implementation; and measurement, assessment and improvement. Generally:

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- Management responsibility includes providing the means and support needed to achieve the organization's objectives;
- Process implementation includes those actions and tasks needed to achieve quality;

[5] The management system aspects relating to physical protection and security might be confidential and are not discussed further in the present Guide.

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

Further management system requirements are provided in Ref. [2], paras 4.5–4.13 and Ref. [9].

2.2. The term 'management system' reflects and includes the concept of quality control, quality assurance and quality management. The management system is a set of interrelated or interacting elements that establishes policies and objectives and which enables those objectives to be achieved in a safe, efficient and effective manner. Further guidance is given in Ref. [10].

2.3. As part of the integrated management system, a management system for modifications and utilization should be established and put into effect by the operating organization early in the research reactor project. The system should be applied to all items and processes important to safety and should include means of establishing controls over utilization and modification activities to provide confidence that they are performed safely according to established requirements. The management system should also include provisions to ensure that the modification or utilization activities are planned, performed and controlled to ensure effective communication and clear assignment of responsibility. In establishing the system, a graded approach based on the relative importance to nuclear safety of each item or process should be used.

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

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- National laws and regulations;
- Regulatory body requirements;
- Design requirements and assumptions;
- The safety analysis report,
- The operating limits and conditions;
- Administrative requirements of reactor management.

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

MANAGEMENT RESPONSIBILITY

2.6. It is the responsibility of management to ensure that the management system for utilization and modification describes how these activities are to be assessed, managed, authorized and performed in order to ensure that the objectives of the utilization or modifications are met, and safe operation of the research reactor and its utilization are ensured. The documentation for the management system for utilization and modification should cover the organizational structure, functional responsibilities, levels of authority and interfaces for those assessing, managing, authorizing, performing, controlling or supervising these activities. It should also address other management measures, including planning, scheduling, resource allocation and human factors.

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2.7. The operating organization has the responsibility to prepare and issue specifications and procedures for the utilization and modification. The reactor manager[6] should be an active participant in executing and evaluating the utilization and modification activities. The detailed responsibilities of the reactor manager are presented in paras 2.30 and 2.31 of this Safety Guide.

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IMPLEMENTATION OF THE UTILIZATION OR MODIFICATION PROJECT

2.8. The management system for utilization and modification should be outlined in a description of the processes, the approval routes to be applied and documented in operating procedures. These procedures should address all applicable requirements specified in the integrated management system established by the operating organization.

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2.9. The activities for utilization and modification should be performed and recorded in accordance with approved procedures and instructions.

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2.10. Successful implementation of the utilization and modification project requires:

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- Planning and prioritization of work;
- Addressing all relevant regulatory requirements;

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

- Addressing the requirements derived from the operational limits and conditions;
- Providing 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;
- Performing and documenting the required training and instruction.

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

2.12. Documents such as the procedures, specifications and drawings of the utilization and modification should be prepared, reviewed, updated, approved, issued, validated, as required, and archived.

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

RESOURCE MANAGEMENT

2.14. The operating organization should provide adequate resources to execute the modification or utilization.

- 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) performing safety related activities and ensuring that these personnel are adequately trained and qualified.

2.15. Personnel who are not directly working for the research reactor facility and personnel of contracting organizations who are involved in the utilization and modification should be appropriately trained and qualified for the work they are to perform. Contractors should perform their activities under the same controls, and to the same work standards, as facility personnel. Facility supervisors should review the work of these contractor personnel during

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preparation for work, at the job site during performance, and during acceptance testing and inspection.

2.16. The management system on the site should be extended to include suppliers. The operating organization should ensure that the suppliers, manufacturers and designers have acceptable management system. The operating organization should ensure through audits that they comply with the management systems.

2.17. The equipment, tools, materials, hardware and software needed to conduct the work in a safe manner and to ensure that the requirements can be met should be determined, provided and maintained.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

2.18. Measures should be established for assessments to determine whether, and for review and verification to ensure that, utilization and modification activities are accomplished as specified during the design. These measures should include:

- Review of the design and the design procedures;
- Verification of the implementation by inspection and witnessing;
- Review and verification of the design, implementation and operation records, results and reports, including those on the status of non-conformance control and corrective actions;
- Follow-up of the adequacy and timeliness of corrective actions.

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

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

RESPONSIBILITY OF THE PROJECT MANAGER

2.21. The operating organization should assign an individual person, normally a dedicated project manager, to be responsible for the implementation of the project objectives through the development of a project definition, adherence to established safety criteria, evaluation of

**Deleted:** <#>Before commencement of research reactor operation, pre-operational inspection data should be available to serve as baseline data.¶
<#>The scope and frequency of periodic tests should be specified and should be consistent with the operational limits and conditions and regulatory requirements. The recording and presentation of test results should permit easy comparison with previous tests, identification of historical trends and with reference or base value information.¶
<#>The competency requirements for staff personnel performing work should be determined and personnel should be competent to perform their assigned work.¶

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the options and the management of detailed design, project implementation, commissioning and decommissioning, if relevant.

2.22. 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 categorization and providing the safety documentation in order to enable the operating organization to obtain any necessary reviews and approvals from the safety committee or the regulatory body. Advice of outside specialists and consultants may be used in performing these duties.

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

2.24. The project manager should be responsible for ensuring that adequate precautions are in place to provide protection against radiological and other hazards arising from the project.

2.25. The possible interactions between different utilization or modification projects, which are being implemented or proposed, should be considered and analysed.

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RESPONSIBILITY OF THE REACTOR MANAGER

2.26. The reactor manager has direct responsibility for the safety aspects of reactor operation. In this respect he should ensure that any utilization or modification proposal has been demonstrated to be safe and as appropriate any additional review, and approval if required, by an appropriate body[7] has been carried out before the implementation.

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2.27. The reactor manager should be responsible for proper scheduling of the implementation of the utilization or modification project in a safe manner.

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## 3. CATEGORIZATION, SAFETY ASSESSMENT AND APPROVAL OF THE UTILIZATION OR MODIFICATION

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3.1. All utilization and modification projects should be subjected to a categorization process in order to determine their safety implication. Experiments with a repetitive[8] nature,

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[7] The appropriate body could be an expert in the relevant field of specialization, the reactor safety committee or regulatory body.

[8] A repetitive experiment is an experiment which was earlier approved and having only minor changes compared to the original design, which will not affect the original performed safety analyses. Isotope production with target material with the same physical and chemical behaviour and using the same irradiation facility within the

which 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 a change with minor effect on safety, see para. 3.9.

3.2. The categorization should provide the basis for the detail and the extent of the safety analysis and the review to be performed. The categorization should also be the basis for the authorization and approval route to be followed for the modification or utilization project. A checklist could facilitate the categorization process. An example of a checklist is given in Annex 1.

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3.3. For modification projects the approved safety classification of the structures, systems and components, which is a requirement in (Ref. [2] paras 6.12 and 6.13) should be used as a first step for the categorization in order to determine the safety impact of the modification as described in the paragraphs related to the Categorization Process, see below.

3.4. For utilization 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 for the categorization in order to determine the safety impact of the utilization. For the development of a classification system for the utilization at least the following aspects should be taken into account:

- Criticality aspects;
- Reactivity aspects;
- In-core/ out of core irradiation;
- In site/ out site biological shielding or containment;
- Physical conditions and behaviour;
- Chemical conditions and behaviour;
- Heat generation and thermal characteristics;
- Mechanical and thermal stresses and behaviour.

3.5. The review and approval route for a utilization project should be based on the safety categorization for the utilization, by which the nature of the experiment i.e. new, repetitive experiment or isotope production should be taken into account, see also paras 3.22–3.23 for repetitive experiments.

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approved maximum flux is also regarded as a repetitive experiment.

3.6. The proposal for the classification and categorization of modifications and utilization, including the approval route should be submitted to the safety committee and after 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 classification having potential impact on safety. The result of the detailed safety analysis should indicate the extent of safety implication, see paras 3.9–3.25. The safety analyses for the utilization could be incorporated in the safety analysis report of the research reactor or might be described in a separate safety analysis report. An example of a safety analysis report for an experiment is presented in Annex II.

3.8. New experiments should be subjected to the categorization process.

3.9. For repetitive experiments it should be proven that they can utilize earlier approved safety analyses.

3.10. For the determination of the potential effect on safety, the consequences on the reactor and the relation with other systems should be taken into account too.

3.11. The following aspects should be taken into account for the final categorization of the utilization or modification project and for the determination of the safety analyses to be performed and the documentation to be prepared:

- **Major safety significance**: modifications or new experiments, which:
  - could affect the design function or its ability to perform its design function as described in the safety analysis or safety analysis report;
  - are beyond the licence conditions or beyond the approved safety analysis report[9];
  - could introduce hazards, which are not earlier addressed.
- **Significant effect on safety**: modifications or experiments, which are within the approved licence, safety analysis and safety analysis report but which requires adaptation of the operational limits and conditions[10] or which need an adaptation of the safety related operating procedures.

[9] A modification beyond the licence or beyond the approved safety analysis report are implicitly also beyond the operational limits and conditions.
[10] Guidance on operational limits and conditions is provided in Ref.[11].

– **Minor effect on safety**: modifications or experiments, which are within the approved operational limits and conditions and still having significant margins and no effect on the safety system settings and 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 of modifications and experiments having safety significance should be documented in detail, together with the justification for the proposal.

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**Changes with major safety significance**

3.13. Changes with major safety significance should be subjected to safety analysis and design, construction and commissioning procedures as applied for the research reactor, in order to ensure that they satisfy the same requirements as the existing structures, systems and components or existing facilities.

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3.14. An assessment of radiation exposure to the staff expected during or as a result of the project should be prepared. Measures to reduce the exposures based on the optimization principle[11] should be described for all possible states (i.e. normal operations, anticipated operational occurrences and accident conditions), and any mitigation measures should be considered.

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

3.16. A list of new or modified safety devices connected to the reactor should be included in the safety documentation. Information required for accident evaluation and for mitigation measures under emergency conditions should also be defined.

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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.

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[11] Guidance for the optimization principle is provided in Ref. [7].

3.18. Modifications and experiments having major safety significance should be reviewed by the reactor safety committee and send to the regulatory body for review and approval following the same procedures as applied for the reactor.

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

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**Changes with a significant effect on safety**

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

3.22. The safety analysis should cover all foreseeable operational, as well as accidents conditions. The analysis should demonstrate that the licence conditions and the original safety limits are not affected and that the radiological consequences of the utilization or modification are within the accepted limits.

3.23. An assessment of radiation exposure to the staff expected during or as a result of the project should be prepared. Measures to reduce the exposures based on the optimization principle[12] should be described for all possible states (i.e. normal operations, anticipated operational occurrences and accident conditions), and any mitigation measures should be considered.

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

3.25. A list of new or modified safety devices connected to the reactor should be included in the safety documentation. Information required for accident evaluation and for mitigation measures under emergency conditions should also be defined.

3.26. 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 reactor and with reactor systems.

[12] Guidance for the optimization principle is provided in Ref. [7].

3.27. Modifications and experiments having significance effect on safety should be reviewed by the reactor safety committee and send to the regulatory body for review and approval following approved procedures.

**Changes with minor safety significance**

3.28. Many experiments and modifications fall into this category. Besides the small modifications to structures, systems and components, research reactors are, by their nature, often used for repetitive sample irradiations or for repetitive experiments with minor modifications. The criteria for repetitive experiments, isotope production or modifications having only minor changes from the original approved design, which might be approved by the reactor manager without re-submission to the safety committee or to the regulatory body, should be defined. The guidance given in Sections 5, 6 and 7 should be applied using a graded approach.

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3.29. Clear criteria should be defined, which irradiation of large number of samples, (e.g. for isotope production or activation analyses) may be regarded as a repetitive experiment. The irradiation facility and the irradiation position (maximum allowable flux) should be specified. The information and documentation, which should be prepared to support the irradiation request and the review and approval route should also be specified in the procedure. This procedure should be submitted to the safety committee for review.

3.30. Records of experiments and minor modifications approved by the reactor manager should be periodically reviewed by the safety committee to ensure that there are no disagreements in the interpretation of the criteria for approval.

**Changes with no effect on safety**

3.31. Careful consideration should be given to a proposed change before classifying it as a modification or utilization with no effect on safety. Such consideration should be based on a description of the change, together with an assessment of its implications, and these should be submitted to the reactor manager for approval.

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3.32. Records of all such approvals should be kept, together with the related documentation.

3.33. The safety committee should periodically review the approval records, in order to ensure that no disagreement exists in the interpretation of the criteria for approval.

SECURITY AND PHYSICAL PROTECTION ASPECTS

3.34. Modifications of systems to protect the site and installation against sabotage and unauthorized removal of fissile and radioactive material should follow the recommendations given in the IAEA Nuclear Security Series[13].

3.35. Guidance on the security aspects of modifications on instrumentation and control systems and software important to safety for research reactors is provided in Ref. [12].

3.36. The modifications on physical protection systems may be described in a separate document and should be confidential.

## 4. GENERAL AND SPECIFIC SAFETY CONSIDERATIONS FOR DESIGN OF THE UTILIZATION OR MODIFICATION

GENERAL CONSIDERATIONS

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

- it can fulfil a necessary task;
- 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 reactor;
- during all operational states the radiation exposure of the site personnel and member of the public remains within the dose limits and, moreover, in accordance with the optimization principle;
- any equipment can be stored or disposed of safely during its operational lifetime and after decommissioning; and
- the amount of radioactive waste is limited to the extent possible and entailed by, for example, the appropriate selection of materials.

4.2. The objective of the design of an experiment or modification should be to minimize additional demands on the reactor shutdown system. In the case of experiments, consideration

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[13] Guidance on nuclear security is presented in the IAEA Nuclear Security Series [12–18].

should be given to provide the means for placing the experiment in a safe condition without involving the reactor shutdown system.

4.3. In addition to the normal reactor operations, such as startup, steady state and shutdown, other situations should be considered for their effects on the experiments or modifications. These conditions include unscheduled shutdowns followed by immediate restart, maintenance, extended shutdowns, fuel changes, low power operation, core configuration changes and failure of electric power and other utilities. Also the design basis accidents of the research reactor should be considered for their effects on the experiments or modifications. Similarly, the effects of all states of experiments or modifications on the reactor should be considered.

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

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SPECIFIC CONSIDERATIONS

**Reactivity**

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

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4.6. 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 major safety significance and implemented before the original proposed modification or experiment is implemented.

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4.7. 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 and potential failure modes). A calculated, or otherwise determined, reactivity worth should usually be checked by measurement, using a critical experiment procedure or an equivalent method. The design basis accident for the reactor should also be considered in the evaluation. The reactivity worth of experiments or modified systems should be within the approved operational limits and conditions.

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**Radiation protection**[14]

4.8. A utilization or modification should not significantly affect the overall radiation protection programme for the research reactor facility, particularly where doses have already been reduced to levels that are as low as reasonably achievable (optimization principle). 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 materials, and for all operational states and accident conditions. If the experiment or modification would otherwise affect the overall radiation protection measures, then additional measures may be necessary to reduce the dose to personnel during the installation of the project, operation, handling and dismantling of an experiment, or the implementation of a modification project. These measures may include the removal of sources of high radiation, the provision of additional shielding and/or the provision of remote handling devices.

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

4.10. The potential for an uncontrolled release of radioactive materials 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 phase, normal operation, removal, storage and shipment of experimental devices or modified systems.

**Safety devices**

4.11. 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).

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4.12. 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 possibility of deleterious interactions with the reactor protection system should be assessed.

4.13. If an experiment might create a hazard to the reactor or to personnel, the protection and control system of the experiment should be connected to the reactor systems in order to

[14] The basic safety standards for radiation protection can be found in Ref. [19]

reduce the power level or to shut down the reactor. The method of effecting this connection should receive special attention and should be qualified as a safety related system. Separate annunciators or other devices should be provided in the control room to notify the operating personnel whenever a safety action occurs when a safety system setting of the experiment has been reached. The reactor systems should not be used to control the experiment nor to provide indication of the progress of the experiment.

4.14. If a safety device is only used to protect the experiment itself or if the experimental device can fail without creating a hazard to the reactor or to personnel, then the safety device may have a lower level of safety categorization. Such safety devices should not be connected to reactor control and protection systems.

4.15. The annunciators provided should operate at an alarm level below the safety limit of the experiment. This may enable the reactor operator to take defined action to correct the situation.

**Heat generation and cooling**

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

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4.17. A dominant failure potential of many irradiation experiments is related to the possibility of either excessive heat generation or insufficient cooling. Thus, adequate heat removal under all design basis conditions for the experiment and the design basis accident conditions of the reactor itself, should be one of the main aspects to be addressed in any safety analysis. 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 safety margins of the reactor. Heat generation due to neutron and gamma deposition needs to be considered. Adequate cooling should be provided to limit the temperature within acceptable limits. To avoid excessive high temperatures in all circumstances, means to place the experiment in a safe configuration should be provided. To reduce the reactor power or shutting down the reactor as discussed in paras 4.11–4.12 or other means, should be analysed and assured.

4.18. In addition to the above considerations, irradiation of fissile material warrants special attention for inadvertent criticality and cooling provisions during and after irradiation to prevent overheating of the target material.

**Pressure**

4.19. Possible effects of high pressure in the experimental devices or modified systems on the reactor should be assessed and appropriate means to limit the pressure within acceptable limits should be ensured.

4.20. Special precautions should be taken in the design for irradiating material that can readily decompose or otherwise change state, or whose chemical reactivity may be enhanced, producing an overpressure, or gases which may be flammable and/or explosive, in order to ensure that pressures and chemical concentrations of the target material do not endanger the reactor on the experiment.

**Selection of materials**

4.21. Selection of materials during the design of experiments should be taken 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 aspects.

4.22. Special safety consideration for the design of experiments should be given to the irradiation of corrosive materials (e.g. mercury, rhenium, magnesium) or materials that may have enhanced corrosive properties as a result of irradiation. For example materials such as copper, lead, 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 due to their neutronic properties. Galvanic effects should also be considered. Use of mercury should be particularly excluded in facilities with aluminium components due to the extremely corrosive interactions between these elements.

4.23. Furthermore, certain corrosion products (such as silver) tend to plate out on cooling circuit surfaces, thus creating contamination and radiation problems during handling and maintenance.

4.24. Special consideration should be given for design of experiments to provide additional barriers to contain toxic material that could pose a hazard if released; e.g. beryllium is particularly toxic if ingested.

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**Flux perturbations**

4.25. The effect of neutron interaction of an experiment or modified system on core components, fuel or other experiments should be considered. Neutron flux perturbations 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 effect on the power distribution in fuel assemblies and on the controllability of reactivity changes must be carefully assessed.

**Protection against external and internal hazards**

4.26. The design of experiments and modifications should include measures to withstand or mitigate the effects of external and internal events, e.g. earthquakes, floods, fires and explosions, as have been taken into account for the reactor. The design should be reviewed by the appropriate specialist and the implementation of the recommendations should be documented.

4.27. If temporary equipment is to be used during the construction and implementation phase the proper measures should be taken to protect the temporary equipment against external hazards, e.g. anchoring of them, fire protection, etc.

**Mechanical interaction of experiments and the reactor**

4.28. The vibration of experimental devices or modified components due to coolant flow should be considered. Special attention should be paid to avoid resonance frequency vibrations.

**Testability and ageing management**

4.29. During the design special attention should be given to the proper testability of the modification or experiment during the 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.

4.30. Special attention should be given to providing appropriate features to support the same level of ageing management and In Service Inspection programme as of the original system.

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

GENERAL

5.1. Sections 5, 6 and 7 give detail guidance for the various phases in a typical modification or utilization project. The guidance should be followed for a project with major safety implications. For projects with lesser safety implications the guidance should be used with a graded approach as a basis for development of less restrictive requirements. Figure 1 is a flow chart for a project with major safety implications and shows the relationship between the operating organization and the regulatory body during the execution of the project. Other organizations could 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 where possible. However, the overall responsibility remains at the operating organization. The following paragraphs provide a detailed discussion of each aspect of Figure 1.

5.2. The extent of the involvement of the reactor safety committee and the regulatory body depends on the safety categorization of the utilization or modification and guidance for these steps are provided in Section 3.

5.3. Projects with minor effect on safety should follow the same steps, but with 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 applied.

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

5.5. At an early stage of the project the necessity to develop a mock-up should be considered to facilitate the development of procedures for the implementation, operating procedures, operator training or to ensure the feasibility of the modification or utilization project.

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 and equipment suppliers. Modifications can involve changes to equipment, reactor operating conditions or procedures.

Whatever the source of the need for a modification or an experiment, it is extremely important that the general concept be discussed by the reactor management and the regulatory body at an early phase of the project. It may also be appropriate to include other groups, such as the safety committee, experimenters, equipment suppliers and independent consultants.

5.7. The reasons for modifications to and experiments with research reactors may also arise from a variety of considerations. These considerations are discussed in Annex III

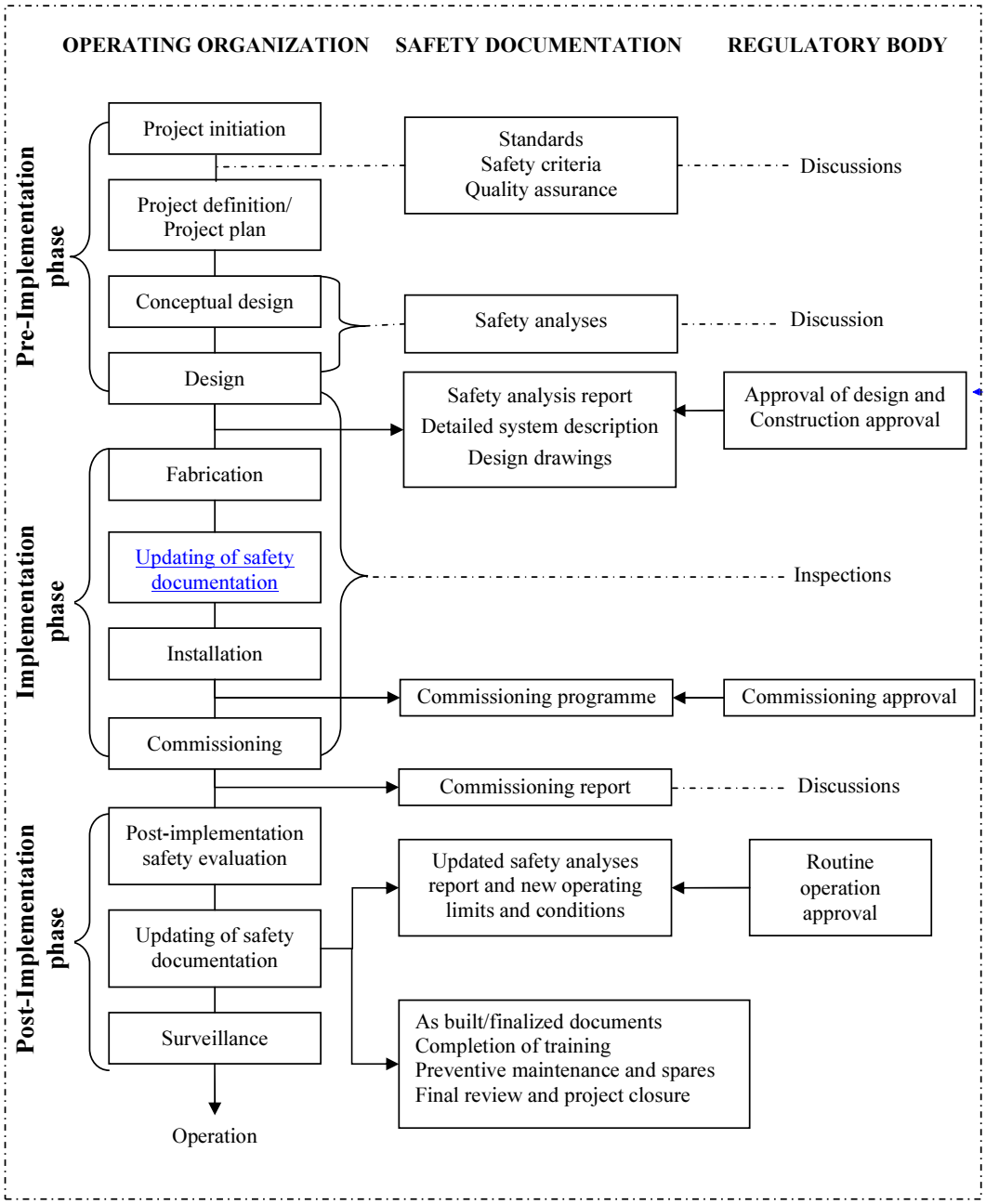


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*FIG. 1. Stages of a modification or utilization project with major safety implications.*

PROJECT DEFINITION

5.8. The project definition stage involves the development of the specific objectives and 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 during this stage.

5.9. The project definition stage should also deal with general organizational and administrative arrangements for the subsequent project steps.

**Categorization and selection of safety codes and standards**

5.10. The process of categorization as discussed in Section 3 should be applied during this stage in order to determine the implication of the safety aspects of the project and to determine the authorization and approval route to be applied.

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

**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 the quality and safety of modifications and experiments. Considerations, such as those given in paras 4.19–4.22, should also form part of such design inputs.

5.13. The existing documentation for the facility, component or software, including all modifications, is required for establishing a pre-design database. A review of this documentation should be made to ensure it is up to date. This may require inspection of the equipment affected by the modification or experiment, and an evaluation of the operational and maintenance history of this equipment to verify that the documentation is up to date.

5.14. The establishment of the database may also require specific measurements or tests, carried out on relevant reactor systems, in order to complete or update the information. Verification of historical data may be of importance, and the data should be carefully

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authenticated. Historical information on repeated or generic common cause failures should also be collected.

5.15. Inclusion of information on similar modifications or experiments carried out elsewhere may provide an important contribution to the database. Operational experiences, including ageing, should also be collected.

**Pre-design appraisal**

5.16. The design process is usually an iterative operation. For experiments or modifications several technical options should be evaluated. This appraisal will provide the basis for a subsequent evaluation of the safety and the technical and financial feasibility of the modification or experiment and a justification for the chosen option. The appraisal of options should cover not only the hardware for the modification or experiment (equipment, materials) but also the implementation and the operational, decommissioning and disposal aspects. These may determine the degree of interference with normal reactor operation, anticipated operational occurrences or accident conditions, the required radiological safety precautions, the volume of radioactive waste, and thus affect the safety, effectiveness and costs of the project. A technical description and a preliminary safety analysis should be provided for each option. A review scheme for comparisons between the available options and for selection of the optimum solution should be provided.

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

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

DESIGN

5.19. During the design stage the chosen option should be developed into a fully documented and justified design of 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 produced at this stage. Commissioning, post-implementation safety evaluation and

surveillance requirements should also be determined during the design stage (see paras 7.2 and 7.6).

5.20. Management system criteria on design control should be established and implemented, covering all aspects of the design, including inspection and testing methods, and construction. For the design, 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 individuals other than those who made the original design. Further recommendations and guidance are given in Section 2.

5.21. Detailed safety analyses should be provided to the extent necessary for the potential hazards. The analyses should determine whether the design will be safe, and in particular showing that:

- a new system or component complies with all relevant safety standards and that it will function safely, for all conditions of operation;
- new systems will not adversely affect the safety characteristics of other items important to safety under any conditions of operation, or the safety relevant characteristics of the reactor;
- an experiment or modification can be carried out without significantly increasing the doses to staff personnel and members of the public; this should be in accordance with the radiation protection optimization principle, or with the risk of an accident;
- a modification or experiment can be carried out without adversely affecting the safety of reactor operation and that it will not introduce new hazards 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 does not adversely affect the consequences, in terms of radiological or other hazards, for any conditions of reactor operation; and that
- failure of the new system does 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, with each of the accident sequences considered in the safety analysis report for the reactor, should be evaluated. The implications of the modification or experiment for the management of potential accidents and of their consequences should be analysed.

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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 the direct effects on the reactor, but also the effect on the items important to safety, such as systems for accident prevention and 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 of NS-R-4 and guidance provided in Ref. [4]. Attention should be paid to review and update, as necessary, 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 facility.

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

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

- A statement of the objectives to be achieved.
- Details of the structure of the organization set up for the project and the responsibilities of this organization.
- A description of the activities, techniques and procedures to be employed, including 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 different stages of the project.

– The necessary design calculations, drawings and specifications for the complete project.

– The staff training programme designed to enable staff to cope with unusual operations during the implementation of the project. (The staff should also be informed about the special safety considerations and provisions applying during the various stages of the project.)

– The preparation of all documentation, such as procedures for the amended state of the reactor, including any new or temporary emergency procedures and the associated staff training programme.

– A commissioning plan to verify that the objectives have been achieved.

– An outline of the decommissioning plan.

– A special surveillance programme, including ageing management and In Service Inspection requirements, if necessary (see para. 7.6). It should be demonstrated that the system is safe during such continuing surveillance.

– An overview of the safety related spare parts which should be available before the implementation of the modification or utilization project.

5.29. For ageing management the project should follow the relevant guidance in the IAEA Safety Standards.[15]

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5.30. For decommissioning, dismantling and removal of major reactor components, the project should follow the relevant guidance in the IAEA Safety Standards Series.[16]

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. 3.13 should be considered at this stage.

[15] Further guidance on ageing management is given in Ref. [20].
[16] For further guidance, see the IAEA safety standards on radioactive waste management, in particular Decommissioning of Nuclear Power Plants and Research Reactors, Safety Series No. WS-G-2.1, IAEA, Vienna (1999) [21].

## 6. IMPLEMENTATION PHASE OF A MODIFICATION OR UTILIZATION PROJECT

GENERAL

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

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

6.3. Nevertheless, if a stage places a constraint or a requirement on a subsequent stage, procedures to ensure that such constraints/requirements are satisfied should be in place.

FABRICATION

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

6.5. New components or existing ones that have to be modified are generally fabricated or modified by suppliers in accordance with the detailed specifications that have been established during 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 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 involved suppliers have an adequate management system.

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

INSTALLATION OF THE UTILIZATION OR MODIFICATION PROJECT

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

6.9. The installation of the experiment or the modification should not commence until all approvals has been obtained and before the relevant staff involved in the installation has 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 to ensure that the reactor is placed in a safe state before commencing the activity.

**Management**

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

- Clear identification of all responsibilities, including those related to the management system procedures and radiological protection.
- Frequent progress/information meetings with all (technical, operational and health physics) staff involved in or affected by the implementation.
- Clear procedures with respect to the control (reporting, assessment and disposition) of deviations from approved methods and specifications or from the expected behaviour.
- Measurement and registration of all characteristics of the system as built; this is required for updating relevant technical documents and procedures.
- Training and provision of information to internal and external staff with respect to the implementation scenario, methods, safety aspects, safe working practices.
- Contingencies in the project plans to accommodate unforeseen events and operational deviations which may require a revision of the working practices and the project planning.

**Safety aspects**

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

6.13. If temporary equipment have to be installed the external and internal events which have been taken into account for the research reactor, should be taken into account for the design and installation of temporary equipment, see also paras 4.24 and 4.25.

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

- External exposure to radiation;
- 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 its reactor systems and the environment.
- Radioactive waste management, including transport, decontamination and dismantling aspects, as applicable;
- Provisions required to prevent the spread of contamination and internal exposure to radiation;
- Safe storage of the fuel, radiation sources or other radioactive material and chemicals during the modification period; and
- Industrial hazards, such as high voltage, vacuum, working in high places, confined spaces, fire, local flooding, and use of chemicals and of potentially dangerous tools.

6.15. All temporary adaptations (connections, procedures, arrangements), which are necessary for implementation, should be documented and approved by the reactor manager before they will be applied.

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

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COMMISSIONING[17]

6.17. Commissioning of an approved 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.

[17] Additional guidance for the commissioning process and the different commissioning stages for large modifications can be found in Ref. [6].

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

6.19. The safety of an implemented modification or experiment should be verified through a commissioning programme involving tests and checks, measurements and evaluations prior to and during implementation of the modification or experiment. The requirements of NS-R-4 (Ref. [2] paras 7.42–7.50) are also applicable for the commissioning of a modification or experiment.

6.20. The adequacy of a specific commissioning programme should be reviewed with respect to the following objectives:

- Determination (by measurement under realistic conditions during normal operation as well as transient conditions) of all reactor characteristic relevant to safety with respect to the changed system;
- Demonstration that the unchanged reactor systems (in particular all items important to safety) are not compromised;
- Verification (on the basis of measured data) of the relevant safety constraints;
- 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 when ever necessary during the commissioning process.

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

6.23. The need for a formal approval of the commissioning results and permission for operation with the experiment or with the modified system should be considered in 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 utilization or modification for routine operation should be the successful completion of all stages of the commissioning stage, and the verification of all information and experience against the requirements as specified for the design. The results of the commissioning tests and the as built drawings and documentation should be reviewed in accordance with standing procedures to demonstrate that the modification or experiment has been built conform to the approved specifications and to assure safe operation.

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

### UPDATING OF SAFETY DOCUMENTATION

7.3. The revision of the safety documentation and the safety analysis report mentioned in Section 5.26 should be reviewed and revised as appropriate, to include the as built description of the utilization or modification, taking into account the results of the commissioning process. The project manager should be responsible for such revisions.

7.4. If the safety documentation has been revised, the approval and distribution of the documentation should follow the approved procedures based on the safety significance of the utilization or modification. This could require involvement of the reactor safety committee 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 safety justification for certain modifications and experiments may be dependent on technical or material characteristics that may be affected by long term reactor operation through 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 to monitor the behaviour of the relevant

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characteristics. Any special surveillance requirements determined during the design stage (see paras 5.16 and 5.28) should be implemented.

## 8. OPERATIONAL SAFETY GUIDELINES FOR EXPERIMENTS AT A RESEARCH REACTOR

8.1. Although the guidance presented in the following paragraphs are in principle applicable for both modifications as well as for experiments, for modification projects or major utilization projects the guidance for a new research reactor facility should be followed where applicable, see Refs [3] [4] [7] [11] [20] and [22].

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RADIATION PROTECTION

8.2. Experiments at research reactors can present significant radiological hazards for persons conducting the experiments, for operating personnel and, in some cases, for persons outside the facility. In addition to the design, which should minimize these radiological hazards and which is backed up by the commissioning process, the experimenters and persons involved in the operation of the experiment should be trained and 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 experiments and that include operating instructions for them.

8.4. In addition to general training of persons in radiation protection, specific training should be provided for all experiments. This should include:

- Operating procedure for these experiments;
- Rules and instructions for radiological protection associated with the performance of the experiment in the facility; and
- Emergency plans and procedures.

8.5. The areas in which there can be significant radiation fields during reactor operation, such as the radiation fields created by open beam tubes, reactor loops or handling of irradiated materials, should be determined before reactor startup. After reactor startup, a radiation survey should be made, which covers especially the area of the experiment. The actual radiation fields should be measured, displayed and, when appropriate, recorded. Where

necessary, the areas should be cordoned off and appropriate radiation warning signs should be placed.

INFORMATION NECESSARY FOR SAFE PERFORMANCE OF EXPERIMENTS

8.6. In addition to the information in the safety analysis report the experimenter should prepare for the operating personnel a detailed description of the experimental device; a list of credible possible hazards of the experiment, the boundary conditions for operation of the experiments; and a list of all connections to the reactor protection system that may cause the reactor to be shut down.

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8.7. The reactor manager should be responsible for the coordination necessary for the performance of experiments.

8.8. For every experiment the reactor operating personnel and experimenters should have information available necessary for the safe performance of the experiment and 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 of these limits being approached should be clearly stated in written instructions. These will 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 which will be called upon for advice if difficulties arise.

8.9. The limiting condition both for the reactor as well as for the experiment to assure safe operation as well as the procedures for the operational personnel regarding handling and operation of the experiment should be approved by the reactor manager. Special attention should be given to the startup of the reactor or the experiment, transient conditions and emergency situations.

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

COOPERATION BETWEEN EXPERIMENTERS AND OPERATORS

8.11. To ensure safe operation of the experimental devices requires that the experimenter and the operating personnel work closely together. Special arrangements should be considered

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for startup of the reactor or the experimental device, special handlings required by the operating personnel or the experimenter, operation outside the normal schedule of either the experimental device or the reactor. Procedures should be prepared, approved and implemented to ensure adequate communication. The following aspects should be considered for these procedures:

- The need to announce through a public address system that the reactor is starting up;
- The need for the reactor operator 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 to be contacted after working hours if special actions are required.

These communication needs are additional to any interlock or other safety devices provided in the design.

8.12. Coordination between the experimenter and the reactor operating personnel should be maintained 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 operator should be available at all times, and the actual status of the experiment should always be known to the operator. These needs are additional to the design provisions.

OPERATIONAL CHANGES IN EXPERIMENTS

8.13. 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 modifications, and the guidance given in this Safety Guide should be followed.

RESPONSIBILITY FOR SAFE OPERATION OF EXPERIMENTS

8.14. The reactor manager has direct responsibility for the safety of the reactor operation. Accordingly, the reactor manager or a designated member of the manager's staff should have

the authority to control any necessary operation of the experimental equipment to ensure the safety of the reactor and the personnel, including stoppage of any experiment which the manager considers hazardous.

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

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

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

8.18. The responsibilities of the operating personnel and the experimenters should be clearly defined and approved 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 as per approved procedures.

9.2. The procedures should take into account the safety evaluation of all operations connected with the handling, dismantling, post-irradiation examination and storage or disposal of irradiated equipment. The activity and contamination of irradiated equipment should be evaluated in advance, under two assumptions:

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

9.3. The radiological hazards should be assessed for all relevant conditions. The radiation protection measures (e.g. shielding, cleaning of air, decontamination procedures and use of

movable provisions (i.e. shielding, ventilation provisions) to facilitate handling operations) should be demonstrated to be adequate to deal with the worst possible situation.

9.4. The equipment 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 personnel exposures and the amounts of radioactive materials released are minimized. Measures necessary to prevent contamination should be developed.

9.6. If the irradiated equipment can release airborne contamination, a handling process to prevent this release should be developed, (e.g. by keeping the material in leak tight 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 presented in Ref. [2].

9.7. Decontamination schemes should be developed for all surfaces that may be contaminated by the experiment. The storage or disposal of decontaminants 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 personnel and should be available throughout the time of handling, dismantling, post-irradiation examination and storage of irradiated elements until final disposal.

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

**Storage**

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

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

10.1. The group of out-of-reactor core installations includes two categories: those which utilize the radiation produced by the reactor but which are outside the reactor (biological) shielding (e.g. a neutron spectrometer), and those which 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 for the generation of liquid nitrogen).

10.2. Both groups should be subjected to the categorization process as described in paras 3.7–3.25.

10.3. For the out-of-reactor core installations which constitute a potential hazard in addition a “conventional” safety impact, analyses should be performed, identifying the potential hazards and the safety provisions to be implemented to reduce the hazards to the extent possible.

10.4. In addition to the review by the reactor safety committee, if required, the safety analysis should be reviewed according to management system procedures by appropriate specialists, e.g. in the field of occupational hazards, chemical hazards, electrical hazards, etc,

10.5. The reactor manager should approve the proposal, including the safety analysis for implementation. Based on its safety significance, (i.e. major, significant) the proposal should be submitted to the reactor safety committee 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 THE CATEGORIZATION OF A MODIFICATION OR UTILIZATION PROJECT AT A RESEARCH REACTOR

| **Form should be completed by the designated Project Manager** | | | |
|---|---|---|---|
| **Document No.** | | **Rev.** | |

**Part 1 - Description of Modification or Utilization**

**Define the Modification or Utilization**

*Describe the modification or activity to be undertaken, or refer to other documentation, e.g. Project Initiation Document.*

**Part 2 - Safety Screen**

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

| **No.** | **Question** | **Answer** | | **Justification** |
|---|---|---|---|---|
| 1 | Does the proposed modification or utilization activity involve a change to, or an effect on, a structure, system or component (SSC) 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 utilization activity 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 | ☐ | ☐ | |

| | | | | |
|---|---|---|---|---|
| | utilization activity involve revising or replacing an evaluation methodology described in the safety analysis report, used in establishing the design bases or used in the safety analyses? | Yes | No | |
| 4 | Does the proposed modification or utilization activity involve a test, experiment or activity not described in the safety analysis report, where a SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC, or is inconsistent with analyses or description 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>• Operating Limits and Conditions (operational limits and conditions)?<br>• Safety related operating procedures? | ☐ Yes | ☐ No | |
| **Result of the Safety Screen** *(tick the appropriate box)* | | | | |
| 1 | All the questions have been answered "NO".<br>The proposed change does have minor effect on safety. Safety Category 3 "Minor effect on Safety" should be recommended.<br>Go to Part 4 Safety Categorization. | | | ☐ |
| 2 | **At least one question has been answered "YES"**.<br>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 on Accidents and Malfunctions Previously Evaluated** | | | | |
| **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 SSC important to safety previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| 4 | Could the proposed change affect the consequences of a malfunction of an SSC important to safety previously evaluated in the safety analysis report? | ☐ Yes | ☐ No | |
| **Potential for Creation 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 an SSC 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 bases 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 to 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, which impacts the safety case in a way not considered in Questions 1 to 8 above? | ☐ Yes | ☐ No | |
| 12 | Does the proposed change require a change to the Plant Procedures, other than an editorial or typographic change, which impacts the safety case in a way not considered in Questions 1 to 8 above? | ☐ Yes | ☐ No | |

| **Result of the Safety Evaluation** *(tick the appropriate box)* | |
|---|---|
| **All the questions have been answered "NO"**.<br>The proposed change will have significant effect on safety. Safety Category 2 "Significant effect on Safety" should be recommended. **Go to Part 4 Safety Categorization**. | ☐ |
| **At least one question has been answered "YES"**.<br>The proposed change does have a major effect on safety. Safety Category 1 "Major effect on Safety" should be 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 or no effect on safety |
| **Justification** | | | |
| | | | |

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

# ANNEX II

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

GENERAL

The following list of topics is the minimum requirement for the table of contents of a Safety Analysis Report for an experiment. The topics should be discussed using a graded approach based on the safety categorization as defined in chapter 3. The topics which are not relevant for the safety analysis report of the utilization project should be mentioned with the remark "not applicable".

The layout of the report should be such that the main chapters only contain technical descriptions, summaries of calculation and analysis methods used, the main results and conclusions. The evaluations with detailed descriptions, calculations, are incorporated in the necessary appendices if required.

Furthermore the safety analysis report for the utilization project should include figures, sketches and/or flow diagrams indicating overall dimensions, weights, temperatures pressures. All computer codes used should be fully validated and benchmarked for their specific application and valid references must be given. Technical drawings should be printed in A3 format.

STANDARD LAYOUT

- Summary
- Table of Contents

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 rates, nuclear 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);
- Design drawing;
- Fabrication method and quality procedures[18].

## 4. IRRADIATION FACILITY

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

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

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

Remarks

a. General assembly drawings (two sets) and sufficient information of all components must be submitted to the Reactor Manager.
b. A complete description of all joints, penetrations, which are part of the safety containment(s), must be provided.

### 4.2. In-site/out-site biological shielding

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

Remarks

a. General assembly drawings (two sets) and sufficient information of all components must be submitted to the Reactor Manager.

[18] A detailed description of the quality control procedures that are applied, is needed 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 which are of importance for the determination of uncertainty factors in the safety analyses must be specified.

b. A complete description of all joints, penetrations, which are part of the safety containment(s) must be provided.

4.3. External system(s)

- Functional description of all components, classified into sub-systems, 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 (pumps, valves).

4.4. Instrumentation

4.4.1. General
- general description of the different groups of instrumentation

4.4.2. Process instrumentation
- objective of the process instrumentation
- components and diagrams

4.4.3. Operational instrumentation
- objective of the operational instrumentation

4.4.4. Scientific instrumentation
- objective of the scientific instrumentation

4.4.5. Safety instrumentation (essential to ensure safe operation of the experiment)
- design of the safety instrumentation
- connection with the reactor protection system (Interlock instrumentation)

4.4.6. Additional experimental instrumentation
- instrumentation not covered by the previous categories.

4.5. Data registration and control

- Functional description of data acquisition and evaluation.
- Block schemes, illustrating total set-up.

4.6. Service and Supply Systems

Functional description of all external supply systems which have fixed connections to the irradiation facility, subdivided in:
4.6.1. Electrical power supply systems
4.6.2. (Make-up) water supply system
4.6.3. (Service) gas supply systems
Each description should indicate anticipated (power, water, air, helium) consumption rate.

4.7. Waste systems

Functional description of all systems for waste retrieval, which are permanently connected to the irradiation facility, subdivided in:
4.7.1. Off-gas system
4.7.2. Water disposal system(s)
Each description should include a specification of the anticipated amount and radioactivity content of the effluents disposed under:

- normal operation;
- special measurements or actions;
- emergency situations.

4.8. Shielding

Description of shielding provisions, specifications of anticipated radiation levels in service areas during:
- normal operation including post irradiation handling;
- specific measurements;
- emergency situations.

## 5. CHARACTERISTICS[19]

### 5.1. Nuclear characteristics

- Specification of anticipated fluence rate values.
- Description of (or reference to) measurements and/or calculations made to verify the fluence rate characteristics:
  a. prior to irradiation;
  b. during irradiation (dosimetry).
- Reference to or summary of calculated and applied nuclear data.

### 5.2. Reactivity and criticality characteristics

Specification (based upon calculation and/or measurement) of:
a. criticality aspects,
b. reactivity effect of entire in-core facility in case it was removed from the core at once, with respect to a waterhole,
c. reactivity effect associated with voids which can be filled with water in case of leakage,
d. reactivity aspects in case of fast movement of the experimental facility

### 5.3. Radioactivity characteristics

Calculation of total activity of radio nuclides produced in:
- irradiation target (if fissionable, specify all noble gases, halogens, actinides and other dangerous nuclides);
- gases, liquids, which may escape due to 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 radioactivity due to decay of the major activity contributors at end of irradiation, 10 hours, 10 days and 100 days after the end of irradiation.

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

5.4. Thermal characteristics

- Calculation of specific heating rates (due to nuclear fission and nuclear heating) of all in-core materials.
- Calculation of:
  a. radial and axial heat flux density and temperature distribution;
  b. coolant temperature increase.
- Calculation of temperature control margin which can be achieved by the available control systems (heaters, mixed gas systems).
- Calculation of the margin against film boiling (burn-out), under the worst possible operating conditions (max. power, minimum cooling), applying all relevant uncertainty (hot spot) factors. A justification of the correlation(s) used must be given.

Remark:
All calculations are to be made for nominal reactor power, and cooling conditions as well as during accident and reactor shutdown power.

5.5. Mechanical and thermal stress characteristics

The calculation methods and the applied criteria should be described for all safety related mechanical components. The tensile, thermal and admissible stresses should be presented and special attention should be addressed 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 amongst others incoming goods inspection, 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 must separately be documented, i.e. in a quality assurance/quality control report and a commissioning report.

## 7. OPERATION AND PERIODICAL TESTING

7.1. General

Outline of check-out, startup, operation, special measurements and emergency procedures. The detailed operation and handling must be specified in a separate "Operation and Handling Manual".
In this section, special periodic testing requirements and dedicated check-out procedures, to be performed by the project engineer, should be described. In case of extended programmes, reference could be made to a special document.

### 7.2. Operational Experience

Summarize the relevant operational experience during the execution of comparable irradiation experiments in the past. Aspects to be mentioned are operational behaviour, loading and unloading experience and if applicable possible improvements made.

## 8. HANDLING, DISMANTLING, TRANSPORT AND DISPOSAL

Outline of various handling procedures, both for normal and abnormal (e.g. target failure) conditions with description of (or reference to) special tools, containers which must be applied.
Specify the transport container and facilities to be used for internal or external transport and summarize specific container criteria required by (inter-)national legislation.

## 9. POST IRRADIATION EXAMINATION

Description (summary) of post irradiation examination (dismantling mode, scientific measurements) of targets and/or the irradiation facility. Indicate if the PIE is scheduled to be done at the institute or in another research institute.

## 10. SAFETY ANALYSIS

### 10.1. Failure analysis

In this section the consequences based on single failure principle of components, systems and instruments are treated with respect to the possible hazards for personnel, the reactor facility and the environment. The failure analyses must show that any such failure will not result in intolerable conventional and/or radiological hazards to personnel, in major disturbances in the operation of reactor and (other) experimental facilities, in damage to the reactor or experimental facilities or in reduced access to reactor, experimental facilities or reactor building. The failure analyses will at least treat the following subjects:

- Target failure;
- Failure of (some) safety containment;
- Cooling (system) failure;
- Electrical power failure;
- Instrumentation failures;
- Utility failures;
- (other) Component failures;
- Operating errors;
- Handling errors.

### 10.2. Enveloping Design Base Accident

In this section the consequences are treated of the worst combination of two simultaneously occurring but mutually independent failure-failure (or failure-human error) situations. All other systems and components not directly affected by the postulated failure, may be assumed to be functioning correctly. In this analysis, the total and sudden failure of structural

components, which have been designed and are operating under conditions within the safety limits of accepted (and applicable) mechanical codes, are supposed to occur but each failure mode or human error must be "credible". The design basis accident as considered for the research reactor should be taken into account for the analyses.
The enveloping design basis accident analysis must prove that the postulated double failure does not result in intolerable health hazards to personnel or in damage to reactor core or reactor systems. The results must remain within the envelope of the Safety Analysis of the reactor.

## ANNEX III:

# EXAMPLES OF JUSTIFICATIONS OF A MODIFICATION PROJECT 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 major events of safety significance are the primary means of safety verification. In addition, systematic safety reassessment, termed periodic safety review (PSR), are being performed to assess the cumulative effects of plant ageing and plant modifications, operating experience, technical developments and siting aspects. The reviews include an assessment of the design and operation 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 the routine and special safety reviews and do not replace them. These reviews could indicate the need for the modification of the existing reactor systems or procedures to meet the current safety standards.

AGEING

III-2. Ageing of SSC or of an experimental facility, obsolescence of equipment, problems related to spare parts, or experience from maintenance and operation may call for modification of reactor systems and operational procedures. Another incentive for such 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 PROJECT

III-5. The need for modifications may also arise from considerations of reactor economy, fuel availability, human factors, and physical security.

III-6. The relevance of these or other considerations to a particular reactor depends strongly on the reactor type, age and utilization, and on national safety criteria. Therefore, the reason for modification for each of the many existing research reactors cannot be identified and discussed in this Safety Guide.

## CONTRIBUTORS TO DRAFTING AND REVIEW

| | |
|---|---|
| Abou Yehia, H. | International Atomic Energy Agency |
| Boogaard, J.P. | International Atomic Energy Agency |
| Couturier, J. | Institut de Radioprotection et de Sûreté Nucléaire, France |
| D'Arcy, A.J. | Nuclear Energy Corporation of South Africa |
| Garea, V. Ms. | INVAP, Argentina |
| Hargitai, T. | Consultant, Hungary |
| Mendis, K. | Australian Nuclear Science and Technology Organisation, Australia |
| Moons, F. | CEN/SCK Mol, Belgium |
| Shokr, A.M. | International Atomic Energy Agency |
| Shukla, D.K. | Bhabha Atomic Research Centre, India |