SAFETY SERIES No. 35-G2



Safety in the Utilization and Modification of Research Reactors



SAFETY GUIDES

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1994

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SAFETY IN THE UTILIZATION AND MODIFICATION OF RESEARCH REACTORS

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FOREWORD

The first nuclear research reactor went critical on 2 December 1942. At present, there are over 300 research reactors in operation in about 60 IAEA Member States. There has evolved a 50 year tradition of emphasis on nuclear safety in the design and operation of research reactors.

From the inception of the IAEA in 1957, there has been broad interest at the IAEA in the benefits to be derived from the safe operation of research reactors by IAEA Member States. These benefits can be gained not only in the traditional areas of nuclear power technology, radioisotope production, nuclear medicine and personnel training but also in the vital areas of materials development and environmental pollution control. To achieve these benefits, the safety of research reactors must be ensured. The IAEA has a long tradition in the area of research reactor safety.

The first publication of the IAEA on research reactor safety was as early as 1960 (Safety Series No. 4), and this subject has since received continuous attention. In 1971, Safety Series No. 35 on the Safe Operation of Research Reactors and Critical Assemblies was issued. A major revision of this Safety Series, with the same title, was published in 1984. While this publication provided practical guidance on safe operation, it did not deal with many other aspects which arise in the course of a research reactor project and which influence safety.

To remedy this shortcoming, basic principles and requirements for the safety of research reactors and critical assemblies have been compiled in two Safety Standards, which present codes for the safety of nuclear research reactors, on design (for the first time) and on operation (Safety Series Nos 35-S1 and 35-S2). These codes, which supersede those of Safety Series No. 35 of 1984, also include the essential safety requirements for siting, quality assurance and regulatory control of research reactors.

In addition to these two Safety Standards, the research reactor safety programme includes Safety Guides and Safety Practices which provide detailed guidance on safety in a number of areas, such as commissioning, utilization, safety analysis and assessment, radiation protection and operating procedures.

This Safety Guide presents guidelines, approved by international consensus, for the safe utilization and modification of research reactors. While the Guide is most applicable to existing reactors, it is also recommended for use by organizations planning to put a new reactor into operation.

NOTE ON THE INTERPRETATION OF THE TEXT

When an appendix is included it is considered to be an integral part of the Guide and it has the same status as the main text. However, annexes, footnotes and bibliographies are only included to provide additional information or practical examples that may be helpful to the user.

In this document the word 'shall' denotes a firm requirement, the word 'should' denotes a desirable option, and the word 'may' denotes permission (neither a requirement nor a desirable option).

In several cases, the wording 'shall consider...' or 'shall ... as far as applicable...' is used. In these cases it is essential to give the matter in question careful attention, and the decision must be made in consideration of the circumstances of each case. The final decision must be rational and justifiable and its technical grounds must be documented.

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1. INTRODUCTION

BACKGROUND

101. This Safety Guide is part of the set of publications developed within the framework of the IAEA Research Reactor Safety Programme (RRSP), which covers all the important areas of research reactor safety. This set includes Safety Standards, Safety Guides and Safety Practices in the IAEA Safety Series. The Safety Standards are the top level publications, which establish the objectives and recommended requirements that must be met to ensure adequate safety in all stages of the lifetime of a research reactor. The Safety Guides and Safety Practices deal with the above mentioned areas, providing recommendations on how to fulfil the requirements established in the Safety Standards, giving guidance and presenting international practices in the areas of research reactor safety. In addition, a Safety Standard to which it refers. A list of publications related to the safety of research reactors is given at the end of this Guide.

102. 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 two Safety Standards, the Codes on the Safety of Nuclear Research Reactors on Design (Safety Series No. 35-S1) and on Operation (Safety Series No. 35-S2). 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 differences among operating organizations. These characteristics require flexibility in the implementation of objectives and the fulfilment of basic requirements when dealing with certain specific topics such as utilization and modification of research reactors. These circumstances have been taken into account in the present Safety Guide.

103. The organizations involved in ensuring the safety of research reactors and the protection of the public, the site personnel and the environment have a number of responsibilities which are interrelated. Most important are the safety analysis and the production and evaluation of safety related documents during the licensing process or on other special occasions, such as during utilization and modification of the reactor. Information on safety analysis and related documentation has been incorporated in the Safety Guide on the Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report (Safety Series No. 35-G1). This Guide has been taken into account in the preparation of the present Guide. In addition, the present Guide covers other aspects of experiments and modifications, such as commissioning and radiation protection provisions, which are further discussed in other publications of the above mentioned set.

OBJECTIVE

104. The objective of this publication is to provide practical guidance on the safety related aspects of the utilization and modification of research reactors such that these projects can be implemented without undue risks to personnel, the public, the environment or the reactor. It develops the general concepts presented in other IAEA publications on research reactor safety, such as Safety Series No. 35-S1 (paras 535-538), No. 35-S2 (paras 1201-1210 and 1301-305) and No. 35-G1 (paras A1102-A1105) and should be read in conjunction with them.

105. This Guide should be useful to the operating organization, the radiation protection staff and experimenters, the regulators and other persons involved in such projects. It provides guidance only on the safety implications of research reactor utilization and modification. It does not cover ways to make research reactor operation more effective or efficient. The reason for presenting the areas of reactor operation, utilization and modification in a single volume is to reduce effort and to avoid duplication, since most experiment and modification projects have similar treatments in common areas, such as categorization, safety review and assessment, project implementation and commissioning.

SCOPE

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

107. In the context of this Guide, a research reactor modification is a deliberate change of or an addition to the existing reactor or experimental facilities, with potential safety implications. This concept includes backfitting and upgrading as well as modifications for other reasons. It may involve safety systems or safety related items or systems, procedures, documentation or operating conditions.

108. In the context of this 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 also outside the biological shielding or confinement.

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

110. In the case of modifications which only concern changes to documentation, the requirements presented in Section 6 of this publication are not fully applicable. For such modifications, the additional guidance given in Safety Series No. 35-G1 should be considered.

STRUCTURE

111. This Guide consists of eleven sections and two annexes. In most of these sections, the safety aspects of research reactor utilization and modification are described together. Sections 8 and 10 concern only experiments.

112. Section 2 gives guidance on the organization and responsibilities regarding the control of research reactor utilization and modification such that adequate safety is maintained. The need for early review of the implications of such projects so as to categorize¹ them is emphasized. Categorization provides a basis for selecting the review and approval route; guidance on these topics is given in Section 3.

113. Information on general and specific recommended requirements for design is provided in Section 4, which should be read in conjunction with Safety Series No. 35-S1.

114. Sections 5, 6 and 7 provide guidance on the various activities that will have to be considered during the stages of a typical project. Section 8 covers the additional operational safety requirements for experiments, and Section 9 gives advice on the handling, dismantling, post-irradiation examination and disposal of experimental devices.

115. Section 10 provides guidance to ensure the safety of out-of-reactor installations. Section 11 gives specific guidance on the requirements for quality assurance (QA) of experiments and modifications.

¹ To categorize a project is to classify it according to its safety implications. Categorization is discussed in paras 305-309. Recommended requirements and practices regarding the various categories considered are discussed in paras 310-326.

2. ORGANIZATION AND RESPONSIBILITIES

REGULATORY BODY

201. For a research reactor to be built and operated, adequate assurance of the safety of the facility shall be provided to the population around the site where it is intended to operate. The provision of such assurance requires the government of the State in which the reactor will be located to ensure that the legal and regulatory basis for overseeing the safety of the project is adequate. This provision shall include the establishment of a safety assurance system². Safety Series Nos 35-S1 and 35-S2 establish general requirements for regulatory supervision in paras 301–307 and 301–303, respectively.

202. A regulatory body that is effectively independent of the operating organization shall be established. However, in cases where a Member State has a relatively small nuclear programme, the regulatory body may include, as an exception, members of the operating organization. Even in such cases the regulatory body shall be independent of the reactor management of the research reactor facility, and it should include experts from other institutions.

203. Irrespective of the composition of the regulatory body, there shall be independent means of review and approval within the operating organization, such as a safety committee, which can provide judgement on the adequacy of the safety of the facilities and which may endorse proposals for actions by the reactor manager. To ensure that this requirement is satisfied, the regulatory body shall make it a prerequisite of its original approval of the construction and operation of the research reactor facility.

204. As required in Safety Series No. 35-S2, paras 302 (g) and (h), the regulatory body shall also ensure, as part of the basis for the original approval of the operation of the reactor, that the operating organization has in force adequate, approved arrangements to control the process for utilization and modification projects of different categories, according to safety significance.

 $^{^2}$ Guidance on the development of such a safety assurance system has been provided by the IAEA for nuclear power plants (Safety Series No. 50-C-G (Rev. 1)) and this guidance may be adopted for research reactors.

205. Thus, the regulatory body should ensure that these arrangements adequately cover, as a minimum:

- (a) The initial evaluation of the change;
- (b) The categorization criteria;
- (c) The safety documentation requirements for each category; and
- (d) The associated review, assessment and approval requirements.

206. The arrangements referred to in para. 205 shall include written procedures to ensure compliance with the regulatory requirements. Depending on the safety significance of a project, establishment of a formal licensing process may be required for its final approval. Detailed guidance on the functions and responsibilities of the regulatory body is given in Safety Series No. 35-G1, paras 214–216.

OPERATING ORGANIZATION

207. As outlined earlier, the operating organization shall establish and implement approved arrangements to control utilization and modification projects before the commencement of reactor operation.

208. The approved arrangements shall require that the operating organization remains responsible for all safety aspects of the preparation and implementation of a modification or experiment in a research reactor. The organization may delegate or subcontract the execution of certain tasks to other organizations, but it cannot delegate its responsibilities.

209. In the case of disposal of radioactive waste, for example, the operating organization may entrust the ultimate disposal of the waste to an appropriately authorized/licensed organization. Nevertheless, the operating organization is responsible for considering the waste management implications of a modification or experiment.

210. The operating organization therefore retains responsibility for ensuring that appropriate safety analyses of the proposed change are undertaken, that approved categorization criteria are applied, that the relevant safety documentation is followed and that associated requirements for review and approval are met. These requirements may include the need to obtain the approval of the regulatory body before proceeding with or establishing a formal licensing process, as referred to in para. 206.

211. The operating organization may delegate some of these duties to suitable persons such as the reactor manager or the project manager. In doing so it does not delegate its responsibility for safety.

212. The operating organization is responsible for the management of the project. For major projects this should include establishment of the objectives and the structure of the project, appointment of a project manager, determination of responsibilities and allocation of adequate resources.

213. In particular, through the establishment of appropriate project objectives, the operating organization shall ensure that proper safety precautions and controls are applied with regard to all persons involved in the implementation of the modification or the experiment, and with regard to the general public and the environment. These safety precautions should include the provision of advance information and training with regard to radiological hazards, the appropriate use of radiation protection and measuring devices, and the appropriate recording and evaluation of the radiation doses incurred. In this regard, it is necessary to meet the radiation protection objectives as stated in paras 202 and 203 of Safety Series Nos 35-S1 and 35-S2, which refer to the IAEA Basic Safety Standards for Radiation Protection and the Recommendations of the International Commission on Radiological Protection.³

214. Furthermore, the operating organization shall ensure that adequate quality assurance is applied at all stages in the preparation and implementation of the modification or experiment in order to ascertain that all agreed safety principles and criteria have been satisfied. This responsibility includes the proper identification, evaluation and approval of non-conformances, changes to designs, etc.

215. The operating organization shall ensure that all persons who will be involved in making the modification or in utilizing the reactor are suitably trained and qualified, and have experience in such work; if necessary, the personnel should also be trained with respect to the effect of such modification on the reactor operation and the reactor safety characteristics. All documents relating to these characteristics, such as the safety analysis report, the operational limits and conditions, and the relevant operation, maintenance and emergency procedures, shall be properly and promptly updated.

³ See Basic Safety Standards for Radiation Protection, 1982 Edition, IAEA Safety Series No. 9, and the 1990 Recommendations of the International Commission on Radiological Protection, Publication 60, Pergamon Press (1991), for the radiaton protection principles. See also Basic Safety Principles for Nuclear Power Plants, IAEA Safety Series No. 75-INSAG-3, for the technical safety objective. (See the selection of IAEA publications related to the safety of research reactors at the end of this book.)

REACTOR MANAGER

216. The reactor manager has direct responsibility for the safety aspects of reactor operation. Hence the manager may delay or refuse the performance of an experiment or a modification which he considers not to be safe, and he may refer the proposed change to a higher authority for additional review.

PROJECT MANAGER

217. The project manager is the individual who is responsible for the implementation of the project objectives through the development of a project definition, adherence to established safety criteria, evaluation of the options, and the management of detailed design, project implementation, commissioning and decommissioning, if relevant.

218. Thus, the project manager is 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 internal safety committee or the regulatory body. Advice of outside specialists and consultants may be used in performing these duties, but the project manager retains overall responsibility.

219. Similarly, the project manager shall ensure that any contractor involved in the preparation or the implementation of the modifications or the experiment is made aware of and complies with the appropriate requirements, as agreed upon by the operating organization and the regulatory body.

220. The project manager shall be responsible for ensuring that adequate precautions are in place to provide protection against radiological hazards arising from the project.

3. SAFETY ASSESSMENT, CATEGORIZATION AND APPROVAL ROUTES

SAFETY ASSESSMENT

301. As part of its response to regulatory requirements, the operating organization shall establish an adequate basis for the safe operation of the research reactor, including an up to date safety analysis report and operational limits and conditions.

302. The safety aspects of modifications and experiments proposed for research reactors shall be subjected to an initial safety analysis to determine whether the change is within the regulatory constraints for the operation of the reactor, such as the approved operational limits and conditions.

303. Depending on the results of this initial evaluation, a more detailed and comprehensive safety assessment may be required, together with proposals and justifications for the necessary changes in safety documentation, operational limits and conditions, procedures, etc.

304. All such changes shall be subjected to appropriate review and approval as referred to in para. 206.

CATEGORIZATION

305. The approach to categorization and the associated criteria used will be dependent upon the particular regulatory regime in force in the country concerned. It shall be the responsibility of the national regulatory body to ensure that the approach and the criteria are appropriate for the circumstances in that country.

306. For example, in a prescriptive regulatory regime where the regulatory body has established a detailed basis for the operation of the research reactor through approval of operational limits and conditions, the categorization criterion may simply consist of a statement of whether or not the proposed change will put the operation outside these operational limits and conditions. If the proposed change is assessed to be outside the approved safety requirements, then the proposal shall be submitted to the regulatory body for approval, whatever the hazard associated with it. If the proposed change is assessed to be within the approved safety requirements, then only local approval is needed, such as that of the reactor manager (who may seek the advice of the local safety committee). 307. In other regulatory regimes the categorization requirements may be different. For example, the authorization and approval route may be determined by the safety significance of the proposed change. Thus, after the initial assessment of the project, which determines whether or not the project could put the operation of the reactor outside the operational limits and conditions, a more detailed assessment is needed to establish the hazard associated with the project. This assessment of hazard will determine the categorization and hence the authorization and approval routes and requirements for detailed analysis and independent review. Annex I provides some information on the criteria adopted for such categorization systems.

308. For the purpose of providing guidance on the requirements for changes with different hazard potentials, the following general classification is used here:

- (a) Changes that present a hazard that could have a major safety significance;
- (b) Changes that present a hazard that could have a significant effect on safety;
- (c) Changes that present a hazard that can only have a minor effect on safety;
- (d) Changes that present no hazard and have no impact on safety.

309. The hazard potential is not only that which is due to the experiment or modification itself but also any change in the hazard which is due to the reactor and the associated facilities as a result of the implementation of the change. As the basis of the categorization, the hazard potential is used rather than the risk.

Projects with major safety significance

310. Changes with major safety significance shall be subjected to safety analyses and design, construction and commissioning procedures in order to ensure that they satisfy the same requirements as the existing facilities, including appropriate review and approval by the regulatory body. Such projects shall be documented in detail in a safety analysis report which will include justification for requesting the change and which should follow the guidance given in Safety Series No. 35-G1, and in Sections 5, 6 and 7 of the present Guide.

Projects with a significant effect on safety

311. For those proposals which have a significant effect on safety but which do not violate the approved safety requirements, the responsibility for approval may rest with the reactor manager or with a higher authority in the operating organization. In either case, the approval shall be based on an independent review by an appropriate group such as the safety committee. No change should be performed which has not been accepted by this group.

312. This category of projects may include complicated experiments and modifications which require special review. The project manager shall be responsible for the preparation of a safety analysis report for the project.

313. The completed safety analysis report for the project should contain a comprehensive and detailed description of the experiment or modification and its design and construction, as well as evaluations of the experiments or operations to be performed, and an analysis of the functional characteristics and the radiological impact of the entire system under the various conditions to which it may be subjected, including accidents. In addition, the radiological consequences of reactor accidents, including a design basis accident, which may involve failures of experimental facilities or the behaviour of modified reactor systems, shall be re-examined and shall be within acceptable limits.

314. An assessment of personnel radiation exposure expected during or as a result of the project should be prepared. Measures to reduce the exposures based on the ALARA principle should be described for all possible states (i.e. normal operation, anticipated operational occurrences and accident conditions), and any mitigatory measures should be considered.

315. The completed safety analysis report for the project shall cover the responsibilities and duties of the operating staff, the experimental staff and others involved in the project.

316. A list of new or modified safety devices connected to the reactor should be included in the safety analysis report for the project. Information required for accident evaluation and for taking mitigatory measures under emergency conditions should also be given.

317. The completed safety analysis report for the project shall be approved first by the reactor manager, with respect to the safety, operability and compatibility with other experiments in the reactor and with reactor systems, before being sent for review to the safety committee or an equivalent group or for information to the regulatory body.

Projects with minor safety significance

318. Many experiments and modifications fall into this category, because research reactors, by their nature, are often used for repetitive sample irradiations or, with minor modifications or changes, for existing experiments.

319. The safety committee or an equivalent group and the reactor manager may establish and maintain criteria, based on the safety analysis report, which will allow the reactor manager to approve minor changes without resubmission to the safety committee or the equivalent group. For example, tables of suitable amounts of materials and criteria for encapsulation and testing can be developed and reviewed by the safety committee to establish the basis for approval of irradiation samples by the reactor manager.

320. When large numbers of similar samples are irradiated, e.g. for activation analysis, it is sometimes desirable to arrive at even more simplified rules for approval which may permit the experimenters to perform the irradiations under the control of the reactor shift supervisor.

321. The safety committee may also endorse the safety arrangements for a range of experiments of a general type rather than for one specific experiment, with the reactor manager providing the approval of individual experiments in this range.

322. Records of experiments and minor modifications approved by the reactor manager shall be reviewed at intervals by the safety committee or an equivalent group to ensure that there are no disagreements in the interpretation of the criteria for approval.

Projects with no effect on safety

323. All changes shall be assessed for their effect on safety.

324. Careful consideration should be given to a proposed change before specifying that it has no effect on safety. Such consideration should be based on a description of the change, together with an assessment of its implications, and this shall be submitted to the reactor manager for approval.

325. Records of all such approvals shall be kept, together with the related documentation.

326. The safety committee or an equivalent group shall review these records periodically, in order to ensure that no disagreement exists in the interpretation of the criteria for approval.

4. GENERAL AND SPECIFIC SAFETY REQUIREMENTS FOR DESIGN

GENERAL SAFETY REQUIREMENTS FOR DESIGN

401. The general requirements for the design of an experiment or a modification are that it is justified in that it can fulfil a necessary task; that it can be installed and operated without compromising the safety of the reactor; that during operational states the radiation exposure of the site personnel and members of the public remains within the dose limits and, moreover, as low as reasonably achievable (ALARA); and that any equipment can be stored or disposed of safely after decommissioning. Another general requirement is to limit the amount of radioactive waste entailed by, for example, the appropriate selection of materials.

402. A reactor modification or experiment shall not adversely affect the safety of the reactor.

403. The aim 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 should be given to providing the means for putting the experiment in a safe condition, without involving the reactor shutdown system.

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

SPECIFIC SAFETY REQUIREMENTS FOR DESIGN

Reactivity

405. If human error or failures associated with an experimental device or a modified system can lead to an increase in the reactivity of the reactor, the experimental installation or modification shall be designed so as to limit the positive reactivity effects to those which can be responded to safely by the reactor shutdown system.

406. The reactivity worth of an experiment or reactor modification shall be estimated in all situations (e.g. installation, removal and failure) in order to evaluate related hazards. This estimate is usually checked by measuring the reactivity worth of the experimental device or modification, using a critical experiment procedure or an equivalent method. The reactivity worth of experiments or modified systems shall be within the authorized limits and conditions.

Radiation protection

407. The experiment or modification should not significantly affect the overall radiation protection concept of the initial design, particularly the reduction of doses to levels that are as low as reasonably achievable (ALARA principle). This design will have been based on a combination of shielding, ventilation filtration and decay 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 provisions, then additional measures may be necessary to reduce the dose to personnel due to the installation, operation and dismantling of an experiment, the removal of irradiated samples 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.

408. If it is found to be necessary, barriers additional to those in the original design should be provided in order to contain radioactive or any other materials that could pose a hazard if released. If 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 shall be considered in the design.

409. The potential for uncontrolled release of radioactive material shall be limited and the amounts of such material released shall be minimized by measures such as the use of delay tanks, filters or recirculation. This applies for all stages of the project, including installation, normal operation, and removal, storage and shipment of experimental devices or modified systems.

Safety devices

410. Whenever possible, experiments and modifications shall 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).

411. If safety devices are interconnected with the reactor protection system, they shall be designed so as to maintain the quality of the reactor protection system. The possibility of deleterious interactions with the reactor protection system shall be assessed.

412. If an experiment might create a hazard to the reactor or to personnel, the safety device of the experiment should be connected to the reactor protection system to shut down the reactor when safe operation limits for the experiment are approached. The method of effecting this connection shall receive special attention since it is a possible source of trouble. Annunciators or other devices should be provided in the control room to notify the operator whenever a safety action occurs because a safety system setting of the experiment has been reached.

413. 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 reliability. Such safety devices shall not be used to lower the power level or to shut the reactor down, as are those mentioned in paras 411 and 412.

414. The annunciators provided should operate at an alarm level somewhat below the safety limit of the experiment. This may enable the reactor operator to take whatever preplanned action is possible to correct the situation.

Heat generation

415. The dominant failure potential of many irradiation experiments is related to the possibility of either overpower or insufficient cooling. Thus, the identification of heat generation/heat removal should be one of the main concerns of 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 always be a point of major concern, as this may influence the safety margin of the reactor. Hence, heat generation due to neutron and gamma rays shall always be considered. If temperature is a problem, it should be monitored and provision should be made to limit it to a safe value by cooling or shutting down the reactor, by reducing the reactor power, or by some other means.

416. Irradiation of fissile material warrants special attention because of the generation of heat during the irradiation. Care should be taken to provide cooling.

Cooling

417. Special consideration shall be given to the impact of the experiment or modification on the cooling capabilities and the possible deterioration of the capability of heat removal from the reactor core.

Pressure

418. Precautions shall be taken against the possible effects of high pressure in the experimental devices or modified systems on the core itself.

419. Special precautions should be taken when 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 concentrations do not endanger the experiment or the reactor.

Corrosion

420. Special precautions should be taken when irradiating corrosive materials (e.g. mercury, rhenium, magnesium) or materials that may have enhanced corrosive properties as a result of irradiation.

421. 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.

Compatibility of materials

422. Special attention should be paid to the possibility of incompatibilities between materials under the conditions of use which could lead to a failure of containment (e.g. formation of eutectics).

Flux perturbations

423. The neutron interaction of an experiment or a modified system with core components or other experiments should be considered. Neutron flux perturbations should be evaluated, especially in the vicinity of safety related devices (e.g. neutron detectors).

Protection against external hazards

424. The design of experiments and modifications should include measures to mitigate the effects of earthquakes, fires, explosions, etc., as applicable.

Mechanical interaction of experiments and the reactor

425. The vibration of experimental devices or modified components due to water flow shall be considered. Special attention should be paid to resonance frequency vibrations.

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

GENERAL

501. The guidance provided in Sections 5, 6 and 7 details the requirements for the various phases in a typical modification or a new experiment. The guidance shall be followed for a project with major safety implications. For projects with lesser safety implications the guidance may be used 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.

PROJECT INITIATION

502. The requirement for a modification or an experiment can arise from different groups of persons, such as the reactor management, the regulatory body, experimenters, equipment suppliers, etc. Modifications can involve changes to equipment, reactor operating conditions or procedures. Whatever the source of the requirement 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.

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



FIG. 1. Flow chart for a project with major safety implications.

PROJECT DEFINITION

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

505. The project definition stage shall also deal with general organizational and administrative arrangements for the subsequent project steps. At this stage, the regulatory body should be involved in the project.

Safety codes and standards

506. The applicability of existing relevant safety codes and standards shall be evaluated, and in some cases development of some additional codes and standards may be required. For further guidance, see paras 533 and 534 of Safety Series No. 35-S1.

Data collection

507. The use of relevant technical data and information on material properties, process characteristics, etc., as input in the design stage is essential to the quality and safety of modifications and experiments.

508. The existing up-to-date documentation for the facility, component or software, including all modifications, is required for establishing a pre-design database. A review of this documentation shall be made. This may require physical 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.

509. 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 authenticated.

510. Inclusion of information on similar modifications or experiments carried out elsewhere may provide an important contribution to the database.

Pre-design appraisal

511. The design process is usually an iterative operation. For large, complicated and/or expensive projects, 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, etc.) but also the implementation and the operational, decommissioning and disposal aspects. These may determine the degree of interference with normal reactor operation, the required radiological safety precautions, the volume of radioactive waste, etc., and thus may 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.

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

DESIGN

513. During the design stage the chosen option shall 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 installation and all associated documentation shall be produced at this stage. Commissioning, post-implementation safety evaluation and surveillance requirements shall also be determined during the design stage (see paras 702 and 706).

514. A QA programme shall be established and implemented, covering all aspects of the design, including inspection and testing methods, installation, construction, etc. For the design, measures shall be established and documented to ensure that the applicable codes, standards and regulatory requirements are correctly incorporated into the design documents for safety related items. Measures shall also be provided for verification of the adequacy of design. This verification shall be performed by individuals other than those who made the original design. Further requirements and guidance are given in Section 11.

515. Detailed safety analyses, which may use probabilistic safety assessment methodology, where appropriate, shall be provided, to the extent necessary for the potential hazard. The analyses shall determine whether the design will be safe, in particular showing:

- (a) That the new system or component complies with all relevant safety standards and that it will function safely, for all conditions of operation;
- (b) That 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 system;
- (c) That the experiment or modification can be carried out without significantly increasing the doses to personnel and to members of the public; this should be in accordance with the ALARA principle or with the risk of an accident;

(d) That the modification or experiment can be carried out without adversely affecting the safety of reactor operation, if this continues during the implementation, and that it will not introduce new hazards as a consequence of the implementation scenario and methods.

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

- 516. It shall be documented:
- (a) 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
- (b) 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).

517. These requirements may be addressed by assessing the technical or operational relationship of the changed system, with each of the accident sequences considered in the safety analysis report for the reactor, and by subsequently determining the implications of the modification or experiment for the consequences of potential accidents.

518. Furthermore, each credible failure mode of the changed system shall be considered as a postulated initiating event for a new event scenario, and its consequences shall be analysed by appropriate evaluation methods. Care shall 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.

519. At the end of this analysis an updated version of the reactor safety documentation shall be produced.

520. The need for formal licensing or approval of the experiments or modifications as referred to in para. 206 shall be considered at this stage.

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

- (a) A statement of the objectives to be achieved.
- (b) Details of the structure of the organization set up for the project and the responsibilities of this organization.
- (c) A description of the activities, techniques and procedures to be employed, including the implementation programme.

- (d) A safety evaluation of the specific procedures and techniques to be used.
- (e) A description of the expected state of the reactor at the different stages of the project.
- (f) The necessary design calculations, drawings and specifications for the complete project.
- (g) 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 of the special safety considerations and provisions applying during the various stages of the project.)
- (h) 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.
- (i) A commissioning plan to verify that the objectives have been achieved.
- (j) An outline of the decommissioning plan.
- (k) A special surveillance programme if this is necessary (see para. 706) for design verification. It shall be demonstrated that the system is safe during such continuing surveillance.

522. For decommissioning, dismantling and removal of major reactor components, the project should follow the relevant guidance in the IAEA Safety Series.⁴

6. IMPLEMENTATION PHASE OF A UTILIZATION OR MODIFICATION PROJECT

GENERAL

601. This section covers the fabrication, installation and commissioning stages of the approved project. Not all requirements are relevant for some projects, for example in cases where the project only involves changes to procedures.

602. 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.

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

⁴ For further guidance, see the IAEA Radioactive Waste Safety Standards (RADWAS) programme publications.

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

FABRICATION

605. 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.

606. New components or existing ones that have to be modified are generally fabricated or modified by suppliers in accordance with the detailed specifications (including accident criteria) that have been established during the design phase. Before selecting a supplier, the project manager shall ensure that the supplier has gained the necessary experience for the work and is aware of all particular constraints of the project, including QA requirements (see para. 514). Preliminary visits to the supplier are generally indispensable.

607. If necessary, the project manager shall also ensure that the supplier has an appropriate QA programme.

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

INSTALLATION

609. Measures shall be established for the control of installation of equipment, and any radiation problems shall be taken into consideration.

610. Installation should not commence before approval has been obtained from the regulatory body and before the relevant staff involved in the installation has been trained satisfactorily.

Management

611. The management of the installation stage of the project shall cover at least the following:

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

Safety aspects

612. Development of the designer's safety evaluation of the installation is required and should be based on a detailed installation plan, describing activities, methods, temporary provisions, etc. Technical or administrative measures or precautions to minimize risk during installation shall be prescribed, giving detailed procedures, and enforced.

613. Specific safety topics that have to be considered for the installation stage are related to:

- (a) External exposure to radiation;
- (b) Radioactive waste management, including transport, decontamination and dismantling aspects, as applicable;
- (c) Provisions required to prevent the spread of contamination and internal exposure to radiation;
- (d) Safe storage of the fuel during the modification period; and
- (e) Industrial hazards, such as high voltage, vacuum, working in high places, fire, and use of chemicals and of potentially dangerous tools.

614. Special temporary emergency procedures may have to be drafted, approved and exercised (see para. 521 (h)) in cases where potentially hazardous situations have been identified in connection with the reactor facility conditions during installation.

COMMISSIONING

615. Commissioning of an approved project, which may include pre-installation tests of experimental devices and equipment, should be aimed at demonstrating the functionality and safety of the project.

616. Testing of experimental devices and equipment prior to installation in the reactor shall be considered. Tests should be planned as part of the original design of the experiment or modification. The test plan should be reviewed by the reactor manager or his representative.

617. The safety of an implemented modification or experiment shall be verified through a commissioning programme involving checks, measurements and evaluations prior to and during implementation of the modification or experiment (see Section 8 of Safety Series No. 35-S2).

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

- (a) Determination (by measurement under realistic conditions) of all reactor characteristics relevant to safety with respect to both the changed system and the reactor systems (in particular all items important to safety);
- (b) Verification (on the basis of measured data) of the relevant safety requirements;
- (c) Provision of additional information and data from commissioning, in order to update the safety documentation, the technical documentation and the operating procedures;
- (d) Provision of opportunities for familiarization and training of operating and maintenance personnel;
- (e) Adjustment of the reactor systems, affected by the modification or experiment, for optimum performance.

619. The ability to execute a commissioning programme successfully and efficiently may depend on the accessibility of the modified system or experiment for online measurements and may require special measuring and testing provisions. The necessity of such provisions should have been assessed already during the design stage of the project.

620. The completion of the project shall include a check to confirm that all temporary connections, procedures, arrangements, etc., which were necessary for implementation, have been removed or cancelled and that the facility has been returned to full operational status. 621. The basis for final approval of the modification or experiment for routine operation shall be the successful completion of the commissioning stage, and the verification of all information and experience against the requirements of the design. To assist in this task, a commissioning report should be produced in which the results of commissioning are presented and assessed. The report should be approved by the reactor management, the safety committee and/or the regulatory body, as appropriate, and this should be the basis for permitting normal operation of the changed facility.

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

POST-IMPLEMENTATION SAFETY EVALUATION

701. During the commissioning stage of the project, sufficient data should have been collected to allow verification of the safety assessment.

702. Some projects may, however, require a certain period of operation before sufficient information on their effects on the operation, reliability and safety of the reactor can be obtained and evaluated. In these cases, a post-implementation evaluation after a suitable trial operation period may be required. The need for such a post-implementation safety evaluation shall be identified during the design phase (see para. 513). The required measurements and the evaluation methods and criteria should be specified in the project plan. Such activities can be seen as an extension of the commissioning stage before full operation.

UPDATING OF SAFETY DOCUMENTATION

703. The safety documentation shall be revised, to include the description of the modified reactor and experiments, taking into account the safety analysis performed, and it shall also account for results from the commissioning process. The project manager shall be responsible for such revisions.

704. The safety documentation should be written and maintained according to the instructions given in Safety Series Nos 35-S1, 35-S2 and 35-G1. Attention shall be paid to reviewing and updating, as necessary, the documentation covering the operational limits, conditions and operating procedures, and other safety documentation, to be used as a basis for approval for normal operation of the changed facility.

705. Obsolete safety documentation shall be removed from service and archived.

SPECIAL SURVEILLANCE

706. 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 may be required to monitor the behaviour of the relevant characteristics. Any special surveillance requirements determined during the design stage (see paras 513 and 521 (k)) shall be implemented.

8. OPERATIONAL SAFETY REQUIREMENTS FOR EXPERIMENTS

RADIOLOGICAL PROTECTION

801. Experiments in research reactors can present significant radiological hazards for persons conducting the experiments, for operating personnel and, in some cases, for persons outside the facility. Thus, in addition to ensuring that the design takes account of these radiological hazards and is backed up by conscientious and rigorous commissioning, the experimenters and persons involved in the operation of the experiment shall follow approved procedures for the performance of their tasks.

802. Thus, every experiment shall be performed using operating procedures that describe the responsibilities of those involved in the experiments and that include operating instructions for them.

803. In addition to general training of persons in radiological practices, specific training should be provided for all experiments; this should include:

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

804. 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 shall be made which covers especially the area of the experiment. The actual radiation fields shall be measured and signalled.

INFORMATION REQUIRED FOR SAFE PERFORMANCE OF EXPERIMENTS

805. The required information should include: A description of the experimental device; a list of credible possible hazards of the experiment and any safety measures provided; the requirements for operation of the reactor and experiments; and a list of all connections to the reactor protection system that may cause the reactor to be shut down.

806. The reactor manager shall be responsible for the co-ordination necessary for the performance of experiments.

807. For every experiment the reactor operating staff and experimenters shall have available information 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 shall include any operational limits and conditions for the experiment, such as the maximum temperatures and pressures, which should be listed. 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 who will be called upon for advice if difficulties arise.

CO-OPERATION BETWEEN EXPERIMENTERS AND OPERATORS

808. The safe operation of experimental devices requires that the experimenter and the reactor operating staff work closely together. Co-ordination is especially important during operation outside the normal schedule of either the experimental device or the reactor. Startup of the reactor or the device, removal of radioactive equipment from the reactor and other operations are also apt to cause difficulties if the experimenters and operators do not keep each other informed. Reactor startup may cause a particular hazard. For example, the experimenter may be performing some operation which may cause exposure to increased levels of radiation from the reactor startup. Therefore, procedures shall be available to ensure adequate communication on such occasions. These procedures may include:

- (a) A requirement to announce through a public address system that the reactor is starting up;
- (b) A requirement for the reactor operator to check all experiments and the locations of all experimenters; and

(c) The use of warning lights or other visible signs in experimental areas to indicate that the reactor is operating.

These requirements are additional to interlocks and other safety devices provided in the design.

809. Co-ordination between the experimenter and the reactor operating staff shall 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 requirements are additional to the design provisions.

OPERATIONAL CHANGES IN EXPERIMENTS

810. For some experiments it may 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 shall be treated as modifications, and the appropriate guidance given in this Safety Guide shall be followed.

RESPONSIBILITY FOR THE SAFE OPERATION OF EXPERIMENTS

811. 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 shall have the authority to control any necessary operation of experimental equipment to ensure the safety of the reactor and the personnel, including stoppage of any experiment which the manager considers hazardous. In actual practice, such occasions seldom arise. However, experimenters should be aware of the responsibility of the reactor operating staff and of the staff's authority in safety matters.

812. At most research reactors it is customary for the reactor manager to be responsible for all safety issues, including all safety aspects of experiments, to the extent that the manager enforces safety rules and applies limitations related to the safety of experiments associated with the reactor operations.

813. If the experimenters are separate from the operating staff, they shall assume responsibility for the safe operation of their equipment. The experimenters shall observe the limits and conditions agreed upon in the safety review and shall follow the operating instructions. The responsibilities of the reactor manager and of the personnel handling the experiments should be defined clearly.

814. The reactor manager shall ensure that an appropriate safety review has been performed for each experiment, that the approved procedures for authorization have been followed, and that an appropriate QA programme is available (see Section 11).

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

GENERAL REQUIREMENTS

901. Procedures for handling, dismantling and disposal of experimental devices or other irradiated equipment that requires storage and eventual disposal in connection with the project shall be established at an early phase of the project. No project can be approved before establishing how the irradiated equipment will be handled, safely stored and disposed of and who is responsible for the necessary actions.

902. A safety evaluation for all operations connected with the handling, dismantling, post-irradiation examination and storage or disposal of irradiated equipment shall be prepared and submitted for approval, as discussed in Section 3.

903. The equipment for the handling, dismantling and safe storage or disposal of irradiated materials and devices shall be procured and tested before the operational phase of the project begins.

904. 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.

The radiological hazards must be assessed for all relevant conditions. The radiation protection measures (e.g. shielding, cleaning of air, decontamination procedures and use of movable installations to facilitate handling operations) shall be demonstrated to be adequate to deal with the worst possible situation.

905. A careful inventory shall be kept of material, samples, equipment and devices put into the reactor, and they shall be retrieved and accounted for at the end of their irradiation. This inventory shall also include the measured or estimated activity.

906. The operations should be planned such that the personnel exposures and the amounts of radioactive materials released are minimized. Measures necessary to prevent contamination of the reactor system shall be developed and their effective-ness shall be verified.

907. If the irradiated equipment can release airborne contamination, a handling process to prevent this release shall be developed (e.g. by keeping the material in leaktight containers or by providing a system of negative pressures and filters). Criteria for items important to safety (e.g. single failure criterion and redundancy) shall be used in planning such a process. For further guidance see, for example, Safety Series No. 35-S1.

908. 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 REQUIREMENTS

Storage

909. If the irradiated equipment of the dismantled installation is to be stored on the site, the volume and the characteristics, including the measured or estimated activities of the materials to be stored, shall be evaluated and the storage available shall be shown to be suitable.

Training

910. All documentation describing the sequence of operations and the instructions for operating the equipment shall be known to the personnel and shall be available throughout the time of handling, dismantling, post-irradiation examination and storage of irradiated elements until final disposal.

911. The personnel performing the handling, dismantling, post-irradiation examination and storage of the experimental device shall 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.

10. SAFETY ASPECTS OF OUT-OF-REACTOR INSTALLATIONS

1001. The group of out-of-reactor installations includes two categories: those which utilize the radiation produced by the reactor but which are outside the reactor 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). For these outof-reactor installations the reactor manager should determine the hazards that they present to the reactor and its associated systems. If such a hazard exists, a safety assessment shall be prepared and reviewed, using the procedures for the review and approval of an experiment or a modification.

11. QUALITY ASSURANCE OF EXPERIMENTS AND MODIFICATIONS

1101. In order to provide assurance that the design, construction, commissioning and operation of an experiment or a modification have been executed in conformance with the objectives set for it, an appropriate QA programme is required. This programme shall be planned and initiated by the operating organization before the start of the design stage and shall be related to the overall QA programme for the operation of the reactor (see Safety Series No. 35-S2).

1102. A description of the QA programme, including a definition of its purpose, scope and extent, should be included in the project definition.

1103. The QA programme shall be reviewed and approved at the appropriate levels of management within the operating organization and, if necessary, by the regulatory body.

1104. The QA programme shall provide controls over the design, fabrication, installation, testing, commissioning, operation, dismantling and decommissioning of the modified system or the experimental devices, to the extent that these relate to reactor safety.

1105. Non-conformance with requirements or specifications of equipment, materials, services, activities, processes or tests shall be controlled and appropriate measures for corrective actions shall be taken.

1106. A suitable person (or group of persons) shall be assigned responsibility, together with the authority and resources to monitor and audit the implementation of the QA programme. Such persons may work within the framework of the project, but they should report independently to the operating organization.

1107. The basic responsibility for achieving quality in the performance of a particular task (e.g. design and manufacturing) shall rest with those persons who have been assigned for the task and not with those who seek to ensure by means of monitoring and audit that the quality has been achieved. Thus, QA is an essential aspect of the safety culture of the organization.

Annex I

CATEGORIZATION CRITERIA

TWO-CATEGORY SYSTEM

I-1. In the two-category system, the first category is the category for which the modification or experiment is submitted to the regulatory body for review and approval. It includes modifications or experiments which:

- (a) Involve changes in the approved operational limits and conditions⁵; or
- (b) Affect items of major importance to safety; or
- (c) Entail hazards different in nature or more likely to occur than those previously considered.

I-2. The second category requires local review and approval of the modification or experiment, with notification to the regulatory body for information.

MULTICATEGORY SYSTEM

I-3. Criteria for a multicategory system can be based on a consideration of the potential radiological hazard. For example:

- Category A: Changes having the potential for an off-site hazard and thus requiring consideration for off-site emergency planning.
- Category B: Changes having the potential for an on-site hazard but not for an off-site hazard.
- Category C: Changes giving rise to no potential hazard outside the reactor hall (or the room containing the experiment).

⁵ Some items included in operational limits and conditions, such as safety set points and surveillance requirements, could be changed in a way which introduces an additional margin of safety (but not in another way which may not meet criterion (b) or criterion (c)). Such a modification could be considered to fall under Category B, requiring local review and approval. Example: changing the level of an overpower trip to a value lower than that required in the operational limits and conditions, or increasing the frequency of a periodic testing procedure related to a safety system so that it becomes higher than that required in the operational limits and conditions.

Category D: Changes with no potential for a radiological hazard.

I-4. Criteria can also be related to the hazard potential to workers engaged in the project, e.g. serious injury or death; radiation exposure above the regulatory limits but with no acute effects; radiation exposure below the regulatory limits but above the operational annual targets; exposure within the operational annual targets.

Annex II

JUSTIFICATION OF A PROJECT

BACKFITTING

II-1. Continued safe operation of a reactor requires regular inspection and review by the reactor management of both the equipment and the procedures used. Inspection and review should be supplemented by an independent assessment at an appropriate level. To meet revised safety criteria, it may be necessary to introduce modifications or additions to existing reactor systems or components, or to perform experiments in order to provide the new data required.

AGEING

II-2. Ageing and 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

II-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

II-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

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

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

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DEFINITIONS

The definitions presented in this Guide are intended principally for use in the IAEA's safety related documents for research reactors and do not necessarily conform to definitions adopted elsewhere for other use. In all cases these definitions are identical with, or at least consistent with, those used in the IAEA Nuclear Safety Standards (NUSS) for nuclear power reactors.

accident conditions

Deviations from operational states in which the releases of radioactive material are kept to acceptable limits by appropriate design features. These deviations do not include severe accidents.⁶

anticipated operational occurrences

All operational processes deviating from normal operation which are expected to occur once or several times during the operating life of the reactor and which, in view of appropriate design provision, do not cause any significant damage to items important to safety or lead to **accident conditions**.

critical assembly

An assembly of sufficient fissionable and other material intended to sustain a controlled fission chain reaction at a low power level and providing an opportunity for investigating the core geometry and composition.

disposal

The emplacement of waste in a repository, or at a given location, without the intention of retrieval. Disposal also covers the approved direct discharge of waste to the environment, with subsequent dispersion.

experiment (or experimental device)

A device installed in or around the reactor to utilize neutron flux and ionizing radiation from the reactor for research, development, isotope production or any other purpose.

⁶ A severe accident is an accident which is beyond **accident conditions** and is a concept used exclusively for nuclear power reactors.

interim storage (storage)

Storage of radioactive material such that: (a) isolation, monitoring, environmental protection and human control are provided; and (b) subsequent action, involving treatment, transport and disposal or reprocessing, is expected.

maintenance

The activity of keeping equipment in good operating condition, including both preventive and corrective (or repair) aspects.

modification (or reactor modification)

A deliberate change in or an addition to the existing reactor configuration, with potential safety implications, intended for continuation of the reactor operation. It may involve **safety systems** or safety related items or systems, procedures, documentation or operating conditions.

normal operation

Operation of a research reactor and associated experimental devices within specified operational limits and conditions, including startup, power operation, shutting down, shutdown, maintenance, testing and refuelling (*see* operational states).

operating organization

The organization authorized by the regulatory body (or by the government) to operate the reactor facility.

operational limits and conditions

A set of rules which set forth parameter limits, the functional capability and the performance levels of equipment and personnel approved by the regulatory body for safe operation of the research reactor facility.

operational states

The states defined under normal operation and anticipated operational occurrences.

protection system

A system which encompasses all electrical and mechanical devices and circuitry, from sensors to actuation device input terminals, involved in generating signals associated with the protective function (see also shutdown system).

quality assurance

All planned and systematic actions necessary to provide adequate confidence that an item or service will satisfy given requirements for quality.

reactor management

The members of the **operating organization** who have been delegated responsibility and authority for directing the operation of the research reactor facility.

reactor manager

The single member of the **reactor management** who has been delegated direct responsibility by the **operating organization** for the operation of the reactor and whose duties comprise mainly the discharge of this responsibility.

research reactor

A nuclear reactor used mainly for the generation and utilization of neutron flux and ionizing radiation for research and other purposes.⁷

safety (or nuclear safety)

The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of site personnel, the general public and the environment from undue radiation hazards.

safety related items or systems

Items or systems important to safety which are not safety systems.

⁷ In this publication, the term **research reactor** also includes associated experimental facilities and critical assemblies.

safety systems⁸

Systems important to safety, provided to ensure the safe shutdown of the reactor or heat removal from the core, or to limit the consequences of **anticipated** operational occurrences and accident conditions.

shutdown system

The system necessary to execute the shutdown of the reactor by rapid reactivity reduction either manually or on the receipt of a signal from the **protection system**.

storage (see interim storage)

utilization (or reactor utilization)

The use of the reactor or of experiments or experimental devices during operation of the reactor.

⁸ The functions of **safety** systems are initiated upon receipt of a signal from the **protection system** or manually. Some aspects of **safety** systems are often referred to as engineered safety features, particularly in the context of emergency heat removal and confinement.

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