LEM/TEK/53Sem.1
29 December 2015

STANDARD FOR MODIFICATION OF RESEARCH REACTORS

Atomic Energy Licensing Board
Ministry of Science, Technology & Innovation
Batu 24, Jalan Dengkil, 43800 Dengkil Selangor Darul Ehsan

Tel: 03-8922 5888
Fax: 03-8922 3685
Laman Web: http://www.aelb.gov.my

TABLE OF CONTENTS

(This page is intentionally left blank)

1. INTRODUCTION

Background

1.1. This Standard was developed mainly to address the pertinent issues related to the modification of the research reactors. The "*IAEA Fundamental Safety Principles*" [SF-1] set forth principles for ensuring the protection of workers, the public and the environment. This standard directly addresses four of these principles, i.e. responsibility for safety, optimization of protection, limitation of radiation risks to individuals and prevention of accidents. In addition, this standard provides requirements on meeting the requirements established in the IAEA Safety Requirements entitled "*Safety of Research Reactors*" [NS-R-4], for ensuring adequate safety at all stages of the lifetime of a research reactor.

1.2. This standard is developed mainly based on the IAEA Specific Safety Guides No. 24 "*Safety in the Utilization and Modification of Research Reactors*", which comprises of cumulative experience in utilization and modification of research reactors worldwide, and IAEA Member State's feedback on the application of requirements stipulated previously in IAEA Safety Series No. 35-G2.

1.3. This publication supersedes previous issued LEM/TEK/53 (dated 4 December 2009).

Objective

1.4. The objective of this standard is to establish requirements on the safety related aspects of the modification of research reactors such that these projects can be implemented without undue risks to personnel, the public, the environment or the reactor.

1.5. This standard does not specifically address requirements on the limitation and flexibility of utilization aspects of research reactors (e.g. for experiments, material testing or repeated/long-term sample irradiation).

1.6. This standard does not address requirements for a modification activities associated with:

a) Decommissioned research reactors; and
b) Security and physical protection system (or other sensitive technology).

Interpretation

1.7. For the purposes of these Standards, unless the context requires otherwise:

“Items important to safety” means item that is at of a safety group and/or whose malfunction or failure could lead to radiation exposure of the site personnel, or members of the public. Items important to safety include:

a) Structure, systems, and components (SSCs) whose malfunction or failure could lead to undue radiation exposure to site personnel or members of the public;
b) SSCs that prevent anticipated operational occurrences from leading to accident conditions; and
c) Those features that are provided to mitigate the consequences of malfunction or failure of SSCs.

“Structure, System and Components (SSCs)” means a general term encompassing all of the elements (items) of a facility or activity which contribute to protection and safety, except human factors;

“Modification” means a deliberate change in or addition to the existing reactor or experimental facilities, 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;

“Operating organization” means the organization authorized by the AELB to operate a specific reactor;

“Operating personnel” means individual workers engaged in operation of an authorized facility;

“Operational limits and conditions” means a set of rules which set forth parameter limits, the functional capability and the performance levels of equipment and personnel approved by the AELB for safe operation of the research reactor facility. They include safety limits, safety system settings, limiting conditions for safe operation, surveillance requirements, and administrative requirements;

“Management system” means a set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner;

“Safety committee” means safety, health and environment committee established by the operating organization;

“Reactor Operation” means all activities performed to achieve the purpose for which an authorized facility was constructed; and

“Experimental Facility” means any equipment and apparatus for utilization of the neutron and other ionizing radiation produced by the research reactor that have the potential to affect its safe operation.

2. MANAGEMENT SYSTEM FOR MODIFICATION OF RESEARCH REACTOR

General

2.1. A documented management system that integrates safety, health, environmental, security, quality and economic objectives of the operating organization of a research reactor is required to be in place. The documentation of the management system shall describe the system that controls the planning and implementation of all activities at the research reactor throughout its lifetime, including modification projects.

2.2. Approval (or rather endorsement) of the management system (or parts thereof) by the AELB may be required.

2.3. The management system shall include four functional categories, which are: *management responsibility*; *process implementation*; *resource management*; and *measurement, assessment and improvement*. In general:

a) *Management responsibility* (para 2.7-2.9) includes the support and commitment of management necessary to achieve the objectives of the operating organization.

b) *Process implementation* (para 2.10-2.14) includes the activities and tasks necessary to achieve the goals of the organization.

c) *Resource management* (para 2.13-2.18) includes measures necessary to ensure that the resources essential to the implementation of strategy and the achievement of the objectives of the operating organization are identified and made available.

d) *Measurement, assessment and improvement* (para 2.19-2.21) provide an indication of the effectiveness of management processes and work performance compared with objectives or benchmarks. It is through measurement and assessment that opportunities for improvement are identified.

2.4. Processes for modifications shall be established as part of the integrated management system. These processes shall include the design, review, assessment and approval, fabrication, testing and implementation of a utilization and modification project. Relevant procedures describing the processes shall be put into effect by the operating organization at early stages in the modification project.

2.5. The management system shall cover all structures, systems and components, and processes important to safety, and shall include a means of establishing controls over modification activities, thereby providing confidence that they are performed safely in accordance with established requirements. The management system shall also include provisions to ensure that modification or utilization activities are planned, performed and controlled in a manner that ensures effective communication and clear assignment of responsibilities. In establishing the management system, a graded approach based on the relative importance to safety of each item or process may be applied.

2.6. The management system shall support the development, implementation and enhancement of a strong safety culture in all aspects of modification projects.

Operating Organization Responsibility

2.7. The operating organization shall have the prime responsibility on the safety of research reactor through its lifetime, including, modification. The responsibility of the operating organization on the safe planning and implementation of a modification project shall not be delegated, even if execution of the related tasks is delegated to an external organization (e.g. contractors).

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

2.9. The operating organization has the responsibility for preparing and issuing specifications and procedures for utilization and modification of the research reactor.

Implementation of a Modification Project

2.10. Activities relating to the modification of a research reactor shall be performed and recorded in accordance with approved procedures and instructions.

2.11. For successful implementation of a modification project, consideration shall be given to the following aspects:

a) Planning and prioritization of work;
b) Addressing all relevant regulatory requirements;
c) Addressing the requirements derived from the operational limits and conditions;
d) Evaluation of the feedback of operational experience from similar utilization or modification projects;
e) Addressing the maintenance requirements for the experiment or the modified system or component;
f) Ensuring the availability of qualified personnel with suitable skills;

g) Establishing appropriate operating procedures, including those for assessing and correcting non-conforming items;

h) Performing and documenting the required inspections and tests, including those required for commissioning an experiment or modification; and

i) Performing and documenting the required training and instruction.

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

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

2.14. The operating organization shall ensure that proper safety precautions and controls are applied with regard to all persons involved in the implementation of modification, and with regard to the public and the environment. These include provision of advance information and training with regard to radiological hazards, appropriate use of radiation protection and measuring devices, and the appropriate recording and evaluation of the radiation doses incurred.

Resource Management

2.15. The operating organization shall provide adequate resources to execute the modification project by:

a) 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;

b) Supervising external personnel (including suppliers) who perform safety related activities and ensuring that these personnel are adequately trained and qualified; and

c) Provision for sufficient financial resources.

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

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

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

Measurement, Assessment and Improvement

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

a) Review of the design and the design procedures;

b) Verification of the implementation of activities by inspection and witnessing;

c) Review and verification of records, results and reports relating to the design, the implementation of projects and the operation of the reactor, including those on the status of non-conformances and corrective actions;
d) Audits of the relevant processes, procedures and documentation; and
e) Follow-up of the adequacy and timeliness of corrective actions.

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

2.21. The operating organization shall evaluate the results of such independent assessments and shall determine and take the necessary actions to implement recommendations and suggestions for improvement.

Responsibilities of the Project Manager

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

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

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

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

2.26. For the case of multiple modifications project performed, possible interactions between each modification projects that are being implemented or proposed shall be considered and analysed.

Responsibilities of the Reactor Manager

2.27. The reactor manager has direct responsibility for the safety aspects of reactor operation. In this respect, he/she shall ensure that any proposal for modification of the reactor has been demonstrated to be safe and additional review, and approval from other appropriate authority, if required, has been carried out before implementation of the project commences.

2.28. The reactor manager shall be responsible for ensuring that the scheduling of the implementation of the modification project does not affect safety of reactor operation.

3. CATEGORIZATION, SAFETY ASSESSMENT AND APPROVAL OF A MODIFICATION PROJECT

General

3.1. All modification projects shall be subjected to a screening process in order to determine their implications for safety and the related safety category of the modification. The screening process shall be documented and the selection of the safety category shall be justified.

3.2. The categorization of the modification shall provide the basis for determining the detail and the extent of the safety analysis and the review to be performed. The categorization shall also provide the basis for the review and approval route to be followed for the modification project. A checklist as provided in **Appendix I** could facilitate the categorization process.

3.3. For modification projects, the safety class of the relevant structures, systems and components shall be used as a first step in the safety categorization in order to determine the safety impact of the modification.

3.4. The proposal for the classification and categorization process for the modification project shall be prepared by Project Manager, with consensus of Reactor Manager. Following that, such proposal shall be submitted to the AELB for review

Categorization Process

3.5. Any proposed modification shall be categorized on the basis of its importance to safety under one of the following three categories:

a) **Category A Modification**: Modifications that involved major effect on safety (See para 3.12-3.17)

b) **Category B Modification**: Modifications that are involved minor effect on safety (See para 3.18-3.20)

c) **Category C Modification**: Modifications that are not categorized as Category A and Category B (No effect on safety, see para 3.21-3.23)

3.6. For the purposes of the categorization, the following interpretation is used:

"*Major effect on safety*" means any modifications that:

a) Could affect the design function or the ability of structures, systems and components to perform their intended safety function as described in the safety analysis;

b) Are beyond the approved licence conditions, operational limits and conditions, or beyond the existing approved safety analysis which require changes of safety analysis and related operating procedures;

c) Could introduce hazards that are different in nature to occur than those previously considered, or it has not been previously addressed;

d) are within the approved license conditions and safety analysis, but which require adaptation of the operational limits and conditions, and not of the remaining chapters of the safety analysis report, or which need an adaptation of the safety related operating procedures.

"*Minor effect on safety*" means any modifications that are within the approved licence conditions, safety analysis and operational limits and conditions, still having significant margins and no effect on the safety system settings and which do not require a change in the safety related operating procedures.

"*No effect on safety*" means any modifications that present no hazard and have no impact on safety.

3.7. An application for Category A modification shall comprises of the following:

a) Letter of Intent;
b) Safety Analysis Report for Modification[1];
c) Integrated Management System for Modification;
d) Any other information as agreed to as deemed necessary.

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

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

3.10. Modification of the Category A require review and approval from the Reactor Manager and safety committee, and shall not be implemented before approval has been obtained from the AELB.

3.11. The Category B and Category C modification shall be documented together with the justification for the proposed safety category. These modifications shall require approval from the Reactor Manager and the safety committee, together with written notification to the AELB **at least one month** prior to the implementation of such projects. Records of this modification may be reviewed by the AELB to ensure that there are no disagreements in the interpretation of the criteria for approval.

[1] Typical information which is required for the content of the safety analysis report for a modification is presented in **Appendix II**.

Modifications with a Major Effect on Safety

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

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

3.14. The management system for the project shall cover the responsibilities, duties and competencies of the operating personnel, the main contractors and others involved in the project.

3.15. The safety analysis report for the modification project shall be reviewed by the reactor manager with respect to safety, operability and compatibility with other associated experimental facility in the research reactor and with reactor systems, structure and component.

3.16. If the proposed modification will affect the operating licence or the licence documentation, an appropriate licence amendment process shall be applied.

3.17. The operating procedures, including emergency procedures, shall be reviewed as a result of the modification, and made subject to AELB approval as appropriate.

Modifications with Minor Safety Significance

3.18. Some modifications are considered to have minor safety significance. Such modifications include small modifications to structures, systems or components. Research reactors are, by their nature, often used for repetitive sample irradiations or for repetitive experiments with minor modifications. Criteria shall be defined for modifications having only minor changes from the original design.

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

Modifications with no Effect on Safety

3.20. Any proposed change before categorizing it as a modification with no effect on safety shall be carefully considered. Such consideration shall be based on a description of the modification, together with an assessment of its implications, and these shall be submitted to the Reactor Manager for approval.

3.21. Records of all such approvals shall be retained, together with the related documentation.

3.22. The safety committee(s) shall also **reviewed quarterly** the records of modifications and experiments with no effect on safety, in order to ensure that there are no disagreements in the interpretation of the criteria for approval.

4. PHASES OF A MODIFICATION PROJECT

General

4.1. This section provides detailed recommendations for the various phases of a typical modification project. These recommendations shall be followed for a project within Category A. *Figure 1* shows a flow chart for a project phase, together with the interface between the operating organization and AELB throughout the execution of the project. Other organizations could also be involved in the modification project, e.g. a design organization or sub-contractors.

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

4.3. Each phase of the project shall be clearly defined and shall be understood by all personnel involved. In particular, the transition points/hold points between phases shall be formally acknowledged and recorded.

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

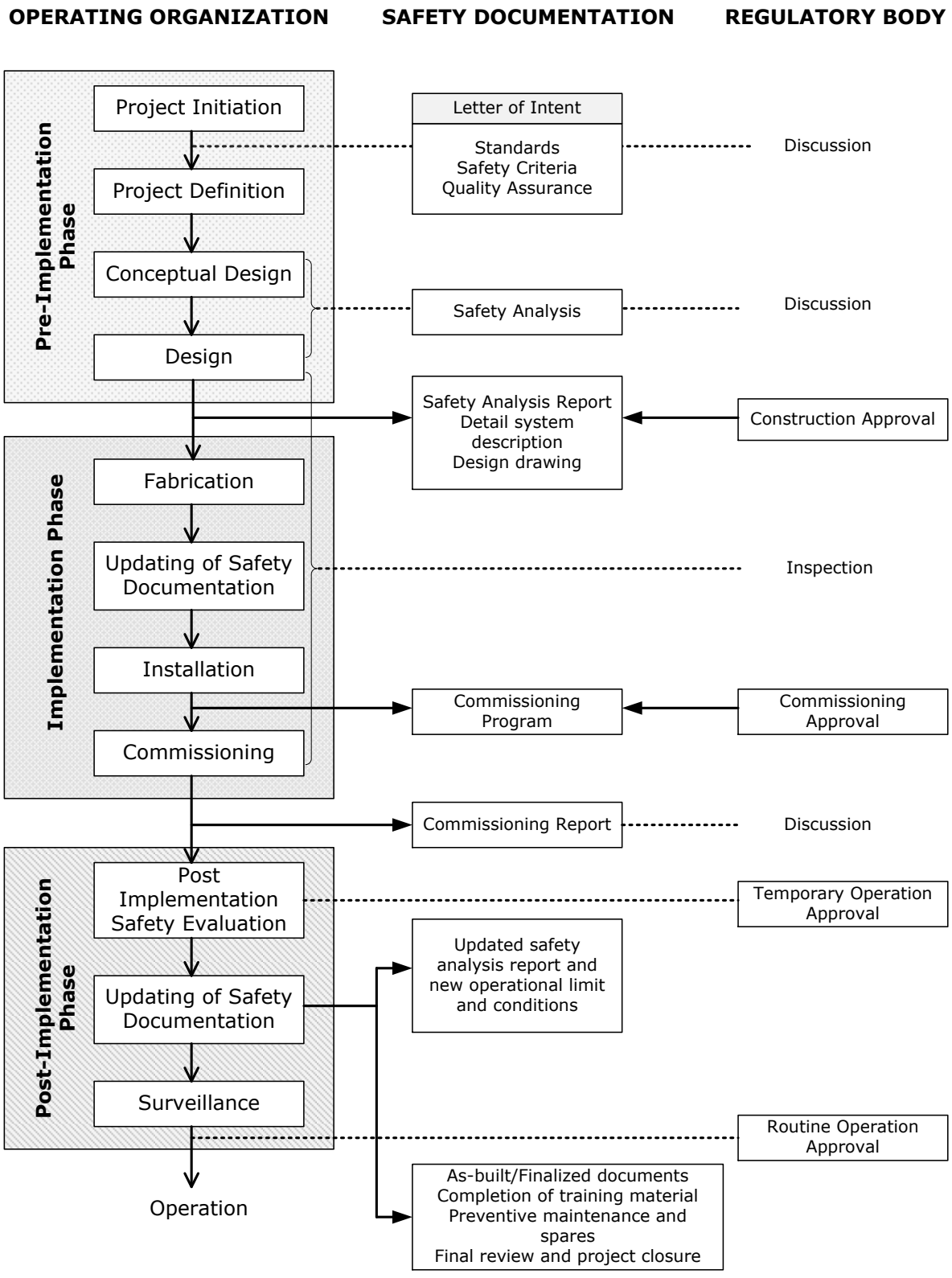

Figure 1: Typical modification phases of Category A modification

Project Initiation

4.5. The need for a modification can arise from different groups of persons, such as the reactor management, the AELB, experimenters or equipment suppliers. Modifications can involve changes to safety system, safety related items, operational limits and conditions, procedures, documentation, or operating conditions for the reactor as well as for experiments. Whatever the reason for a modification, the general concept shall be discussed by the reactor management and AELB at early stages of the project. It may also be appropriate to include other groups, such as the safety committee(s), experimenters, equipment suppliers and independent consultants.

Project Definition

4.6. The project definition stage involves development of the specific objectives and the scope of the proposed modification 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 shall also be developed at this stage.

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

Categorization and Selection of Safety Codes and Standards

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

4.9. The applicability of relevant existing safety codes and national and international standards to the structures, systems and components shall be evaluated, and in some cases, development of some additional codes and standards may be necessary.

Data collection

4.10. The use of relevant technical data and information on performance and material properties and process characteristics as input in the design stage is essential to ensure the quality and safety of modifications.

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

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

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

Pre-design appraisal

4.14. Depending on the safety category of the modification, the pre-design appraisal shall be discussed with the AELB and, if applicable, the safety codes and design standards that have been selected for the project shall be submitted to the AELB for assessment and review, and the associated time schedule shall be discussed with the AELB at the pre-design stage.

4.15. The pre-design appraisal may lead to a decision not to execute the modification.

Design

4.16. At the design stage, the selected option shall be developed into a fully documented and justified design for the modification. Thus, project plans, specifications, design assessments, safety analyses, detailed drawings for manufacture and the installation of the modification and all associated documentation shall be prepared at this stage. Requirements for commissioning, post-implementation safety evaluation and surveillance shall also be determined at the design stage.

4.17. Management system criteria for design control shall be established and implemented, covering all aspects of the design, including inspection and testing methods, and construction. Measures shall 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 shall also be provided for verification of the adequacy of design. This verification shall be performed by qualified individuals other than those who developed the original design.

4.18. Detailed safety analysis[2] shall be carried out to the extent necessary for the potential hazards. The analyses shall be capable of demonstrating that the design is safe and, in particular, of showing that:

a) Any new system or component complies with all relevant safety standards and that it will function safely for all operational states.
b) New systems will not adversely affect the safety characteristics of other items important to safety under any operational states, or the safety relevant characteristics of the reactor.

[2] Care shall be taken that up-to-date safety documentation and data are used in these analyses.

c) The failure of the new system would not result in any new event scenario with significantly increased risks (different failure modes may have to be considered).

d) The modification can be carried out without significantly increasing the dose to staff and members of the public; this shall be determined in accordance with the principle of optimization of protection, or with the risk of an accident.

e) The modification can be carried out without adversely affecting the safety of reactor operation.

f) Any new hazards introduced by the modification can be safely managed at any stage of the project.

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

4.20. 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 direct effects on the reactor, but also the effect on items important to safety, such as systems for accident prevention and for mitigation of the consequences of accidents.

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

4.22. Attention shall be paid to the review and updating, as necessary, of the documentation covering the design, operational limits and conditions, operating

procedures, and other safety documentation, to be used as a basis for approval for normal operation of the modified research reactor.

4.23. Testing of modified equipment or system prior to their installation in the reactor shall be considered. Tests shall be planned as part of the design and the commissioning of the modification.

4.24. The output from the design stage shall also include the following:

a) A statement of the objectives to be met.
b) Details of the structure of the organization set-up for the project and the responsibilities of the parties involved.
c) A description of the activities, techniques and procedures to be employed, including those for the implementation programme.
d) A safety evaluation of the specific procedures and techniques to be used, including for decommissioning, dismantling and removal of major reactor components.
e) A description of the expected state of the reactor at the various phases of the project.
f) The necessary design calculations, drawings and specifications for the complete project.
g) The training programme designed to enable staff to cope with anticipated operational occurrences during the implementation of the project.
h) Procedures for the modified state of the reactor, including any new or temporary emergency procedures[3] and the associated training programme.
i) A plan for commissioning to verify that the design objectives have been achieved.
j) An outline of the preliminary decommissioning plan.

[3] The temporary procedures established may subject to approval and exercised in cases where potentially hazardous situation have been identified in connection with the installation of modified system at research reactor. These procedures shall be formally withdrawn once the installation is completed.

k) A special surveillance programme, including ageing management and in-service inspection requirements, where necessary.

l) An overview of the safety related spare parts that shall be available before implementation of the modification project.

Fabrication

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

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

4.27. The project manager shall also ensure that the suppliers involved have an appropriate management system.

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

Installation

4.29. Measures shall be established for the control of the installation of equipment, and any potential hazards, for example, radiation, chemical, fire, electrical and industrial hazards, shall be taken into consideration.

4.30. The installation of the modification shall not commence until all approvals have been obtained and the relevant staff involved in the installation have been trained satisfactorily.

Management

4.31. Management of the installation stage of the project shall cover at least the following:

a) Clear identification of all responsibilities, including those relating to management system procedures and radiation protection.

b) Frequent meetings to inform on progress and exchange information with all staff (i.e. technical, operational and health physics staff) involved in or affected by the project.

c) Clear procedures with respect to the control (i.e. reporting, assessment and disposition) of deviations from approved methods and specifications, or from expected behaviour.

d) Clear procedures to ensure that no foreign objects, e.g. assembly or installation tools and equipment, have been left in the area around the modification.

e) Measurement and registration of all characteristics of the system as built; this is required for updating relevant technical documents, drawings and procedures

f) Training and provision of information to operating personnel and external personnel with respect to the conduct of the modification, methods to be used, safety aspects and safe working practices.

g) Contingencies in the project plans to accommodate unforeseen events and operational deviations that may require a revision of the working practices and the project planning.

Safety Aspects

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

4.33. If temporary equipment has to be installed, the external and internal events that have been taken into account for the research reactor shall be taken into account for the design and installation of temporary equipment.

4.34. Specific safety topics that shall be considered for the installation stage are related to:

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

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

Commissioning

4.36. Commissioning of an approved modification project, which may include pre-installation tests of equipment shall be aimed at demonstrating the functionality and safety of the project.

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

4.38. The safety of a modification that is to be implemented shall be verified through a commissioning programme involving tests and checks, and measurements and evaluations prior to and during implementation of the modification.

4.39. The adequacy of the commissioning programme for each modification shall be reviewed with respect to the following objectives:

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

d) Provision of additional information and data from commissioning, in order to update the safety documentation, the technical documentation and the operating procedures;

e) Provision of opportunities for familiarization and training of operating and maintenance personnel;

f) Adjustment of the reactor systems affected by the modification for optimum performance.

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

4.41. The need for formal approval of the commissioning results and permission for operation with the modified system shall be considered at this stage.

Post-Implementation Safety Evaluation and Approval for Temporary Operation

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

4.43. Some project, however, may require a certain period of operation before sufficient information on their effect on operation, reliability and safety of the reactor can be obtained and evaluated. In these cases, a temporary operation period may be required.

For such cases, a Temporary Operation Approval shall be obtained prior to such operations.

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

Updating of Safety Documentation

4.45. Revision of the safety documentation and the safety analysis report shall be carried out as appropriate, to include the as-built description of the modification, and to take into account the results of the commissioning process. The time schedule for the revision of the documentation shall be made subject to approval by the reactor manager, in accordance with the regulatory requirements.

4.46. If the safety documentation has been revised, the approval and distribution of the documentation shall be carried out in accordance with the approved procedures on the basis of the safety significance of the modification. This could require involvement of the safety committee(s) and review and approval by the AELB, as appropriate.

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

Special Surveillance and Approval for Routine Operation

4.48. The justification for certain modifications may be dependent on technical or material characteristics that may be affected in long term reactor operation by irradiation embrittlement, corrosion or other ageing effects.

4.49. In cases where such effects cannot be predicted with sufficient accuracy from previous experience or by analysis, a safety surveillance programme shall be defined for

monitoring the behaviour of the relevant characteristics. Any special surveillance requirements determined at the design stage shall be implemented.

4.50. The results of such surveillance shall be a pre-requisite for the issuance of approval for routine operation.

5. SAFETY CONSIDERATION FOR THE DESIGN OF MODIFICATION

General Considerations

5.1. The design of a modification shall demonstrate that:

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

5.2. The design of a modification shall be such as to minimize additional demands on the reactor protection system.

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

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

Specific Considerations

Reactivity

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

5.6. 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 shall be treated as a separate modification with a major effect on safety and shall be implemented before the originally proposed modification is implemented.

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

Radiation Protection

5.8. A modification shall not significantly affect the radiation protection programme for the research reactor. The original design will typically have been based on a combination of shielding, ventilation filtration and decay to reduce radioactive releases, with associated monitoring instrumentation for radiation and airborne radioactive substances,

for all operational states and for accident conditions. If the modification would otherwise affect the radiation protection measures, then additional measures shall be taken to reduce the dose to site personnel and the public during the implementation of a modification project to levels as low as reasonably achievable (principle of optimization of protection). Such measures may include the removal of sources that generate high radiation fields, the provision of additional shielding and/or the provision of remote handling devices.

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

5.10. The potential for an uncontrolled release of radioactive substances 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 the installation stage, for all operational states (i.e. normal operation and anticipated operational occurrences) and for removal, storage and shipment of modified systems.

Safety Devices

5.11. Whenever possible, 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).

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

Heat Generation and Cooling

5.13. Special consideration shall be given to the possibility of a modification affecting the capability for heat removal from the reactor core.

5.14. A dominant cause of failure for many irradiation experiments is related to either excessive heat generation or insufficient cooling. Thus, adequate heat removal under all conditions considered in the design of the modification and of the reactor itself shall be one of the main aspects addressed in the safety analysis for the modification.

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

Pressure

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

5.17. Special precautions shall be taken in the design for irradiating material, including their enclosures. Such material can readily decompose or otherwise change state, or its chemical reactivity may be enhanced, producing an overpressure, or gases that may be flammable and/or explosive. It shall be ensured that pressures within the enclosures and chemical concentrations of the target material do not endanger the reactor.

Selection of Materials

5.18. In the design of modification, the selection of materials shall take into account material compatibility, corrosion, changing of material properties due to irradiation (e.g.

creep, embrittlement, radiolytic decomposition), including transmutation of material, differential thermal expansion and resistance, ageing effects and ease of decontamination, dismantling and final disposal.

Flux Perturbations

5.19. Consideration shall be given to the effects of interactions of neutrons from a modified system with core components, fuel or other experiments. Perturbations in the neutron flux shall be evaluated, especially in the vicinity of safety related devices (e.g. neutron detectors). The effects on the power distribution in fuel assemblies and on the controllability of reactivity changes shall be carefully assessed.

Protection Against External and Internal Hazards

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

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

Mechanical Interaction of Modified System and the Reactor

5.22. The possible vibration of modified components due to coolant flow shall be considered. Particular consideration shall be given to avoiding vibrations at resonance frequency.

Testability and Ageing Management

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

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

6. SECURITY AND SAFEGUARDS REQUIREMENTS

General Considerations

6.1. Modifications of systems for protection of the site and installation against sabotage and unauthorized removal of fissile material and radioactive material should be carried out in accordance with the requirements of the relevant national security authorities and the guidance provided in publications in the IAEA Nuclear Security Series.

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

6.3. The operating organization shall provide the information on security and safeguards to AELB prior to the commencement of modification activities, regardless of whether these activities involve nuclear material.

6.4. The operating organization dealing with nuclear material and single use technology is subject to the safeguards agreement and any protocols agreed and shall submit to the AELB the information and data necessary for compliance with the undertakings by Malaysia arising from such instruments.

6.5. The operating organization conducting activities or practices utilizing nuclear material or radioactive material is primarily responsible for ensuring the security and physical protection of such materials pursuant to applicable regulation and license conditions.

6.6. The design of the proposed modification shall be adequate to protect the installation from the malicious act in order to eliminate the danger to life, property and the environment.

6.7. All measures shall be taken prior to any particular modification to ensure the security and protection of the nuclear installation to prevent loss, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving radioactive material and nuclear material or their associated facilities.

6.8. Procedures for the implementation and fulfilment of safeguards requirements for any modification involving nuclear materials shall be in place prior to project implementation.

Specific Requirements

Security

6.9. The operating organization involve in modification shall establish requirements for the physical protection of nuclear material and radioactive materials, including:

a) a categorization of material based on an assessment of damage that could result from theft or diversion of a certain type and quantity of material from authorized uses or sabotage of a facility utilizing that material;
b) a system of inspection and monitoring to verify compliance with applicable physical protection requirements;
c) protection measures necessary for different categories of material; and
d) protection measures necessary or associated installation.

6.10. The proposed security measures during the entire phase of the modification to prevent or mitigate the effects of accidental releases of radioactive material to the environment, the health and safety of persons shall be submitted to AELB prior to implementation of modification project.

6.11. Periodic security review shall confirm the modification activity will not tolerate the security of the nuclear installation.

Safeguards

6.12. The operating organization involve in modification shall establish requirements for the accounting of nuclear material including a system of accounting for and control of nuclear material (SSAC).

6.13. The operating organization shall also establish record for radioactive material inventory.

6.14. The operating organization shall provide, upon request to the AELB:

a) safeguards information;
b) physical access;
c) facilitating the performance of inspectors in their tasks; and
d) rendering services requested by inspectors.

6.15. The SSAC shall ensure the effective conducts of safeguards in Malaysia by establishing and implementing:

a) A system for the measurement of nuclear material;
b) A system for the evaluation of measurement accuracy;
c) Procedures for reviewing measurement differences;
d) Procedures for carrying out physical inventories;
e) A system for evaluation of unmeasured inventories;
f) A system of records and reports for tracking nuclear material inventory and flows;
g) Procedures for ensuring that accounting procedures and arrangements are being operated correctly; and
h) Procedure for reporting to the IAEA

APPENDIX 1

CHECKLIST FOR CATEGORIZATION OF A MODIFICATION AT A RESEARCH REACTOR

Form to be completed by the designated Project Manager
Part 1 – Description of the modification
Describe the modification project *Please describe the modification project to be undertaken.*

<Go to Part 2>

Part 2 – Safety Screening

Screening question *(Tick the appropriate box)*

No.	Question	Answer		Justification
		Yes	No	
1.	Does the proposed modification involve a change to, or an effect on, a structure, system and component that could affect its design function or its ability to perform its design function as described in the SAR?	☐	☐	
2.	Does the proposed modification involved a change to a procedure that could affect how the design functions of structure, system or and component described in the SAR are performed or controlled?	☐	☐	
3.	Does the proposed modification involve revising or replacing an evaluation methodology described in the SAR, used in establishing the design bases or used in the SAR?	☐	☐	
4.	Does the proposed modification involve a test, or activity not described in the SAR, where a structure, system or component is utilized or controlled in a manner that is outside the reference bounds of the design for that structure, system or component, or the modification is inconsistent with analyses or descriptions in the SAR?	☐	☐	
5.	Does the proposed change require a change to any of the following (*other than an editorial or typographic change*): Licence, SAR, Operational limits and conditions, Safety related operating procedures?	☐	☐	

Results of safety screening *(Tick the appropriate box)*

A	***If at least one question above has been answered "YES"*** Safety Evaluation (**Part 3**) is required and Category A modification is recommended.	☐
B	***If all questions above has been answered "NO"*** If the proposed modification involved safety classification SSCs, Category B modification is recommended. Safety evaluation (**Part 3**) is not required.	☐
C	***If all questions above has been answered "NO"*** If the proposed modification involved non-safety classification SSCs, Category C modification is recommended. Safety evaluation (**Part 3**) is not required.	☐

Part 3 – Safety Evaluation

Evaluation question *(Tick the appropriate box)*

No.	Question	Answer		Justification
		Yes	No	
Effect in relation to accidents and malfunctions previously evaluated in SAR				
1.	Could the proposed modification affect the frequency of occurrences of design basis accident (DBA) previously evaluated in SAR?	☐	☐	
2.	Could the proposed modification affect the consequences of DBA previously evaluated in SAR?	☐	☐	
3.	Could the proposed modification affect the likelihood of occurrences of malfunction of SSCs important to safety previously evaluated in SAR?	☐	☐	
4.	Could the proposed modification affect the consequences of malfunctions of SSCs important to safety previously evaluated in SAR?	☐	☐	
Potential for occurrences of a new type of event not previously evaluated				
5.	Could the proposed modification create a possibility for an accident of a different type than any previously evaluated in the SAR?	☐	☐	
6.	Could the proposed modification create a possibility for a malfunction of SSCs important to safety with a different result than any previously evaluated in the SAR?	☐	☐	
Impact on fission product barriers as described in the SAR				
7.	Could the proposed change result in a design basis limit for a fission product barrier as describe in the SAR being exceeded or altered?	☐	☐	
Impact on evaluation methodologies described in the SAR				
8.	Does the proposed change result in a deviation from a method of evaluation described in the SAR used in establishing the design basis or in the safety analysis?	☐	☐	
9.	Does the proposed change require a change to the SAR (*other than editorial or typographic change*) that impacts the safety case in a way not considered in Question 1-8?	☐	☐	

Part 3 – Safety Evaluation

Evaluation question *(Tick the appropriate box)*

No.	Question	Answer		Justification
		Yes	No	
10.	Does the proposed change require a change to the OLC (*other than editorial or typographic change*)?	☐	☐	
11.	Does the proposed change require a change to the licensing basis documentations (*other than editorial or typographic change*)?	☐	☐	
12.	Does the proposed change require a change to the reactor procedures (*other than editorial or typographic change*)?	☐	☐	

Part 4 – Safety Categorization			
Category Requested *(Tick the appropriate box)*	☐ *Category A*	☐ *Category B*	☐ *Category C*
Justification			
Prepared by (Designated Project Manager)			

Name:		**Signature:**		**Date:**	

Part 5 – Safety Re-categorization			
Category Requested *(Tick the appropriate box)*	☐ *Category A*	☐ *Category B*	☐ *Category C*
Justification			
Prepared by (AELB)			

Name:		**Signature:**		**Date:**	

APPENDIX 2

EXAMPLE OF THE CONTENT OF THE SAFETY ANALYSIS REPORT FOR A MODIFICATION OF RESEARCH REACTOR

The following lists the typical information to be provided in the safety analysis report for modification project, as follows:

a) A description of the purpose of modification;
b) A justification for the necessity of the modification;
c) A description of the structure of the organization set up for the project and the responsibility and duties of the involved groups and personnel;
d) The requirement and criteria for design;
e) A list of new or modified safety devices connected to the reactor;
f) Revised safety analysis that considers each credible failure mode of the modified SSCs as a postulated initiating event for a new event scenario;
g) Revised operational limits and conditions based on the results of the safety analysis;
h) Revised radiation protection program which take into consideration the modified SSCs and the relevant activities of the modification project, including its normal operation;
i) A description of the need for the disposal of radioactive waste generated in connection with the modification project;
j) A description of the manufacturing and installation processes involved;
k) A description of the commissioning process;
l) A description of the training program designed to enable the reactor operating personnel to cope with unusual operation during the implementation of the project;
m) The preparation of all documentation, including any new or temporary emergency procedures and the associated staff training program;
n) Quality Assurance Program that covers different stages of the modification project;
o) A list of the relevant documentation that needs to be updated;
p) A special surveillance program if this is necessary for design verification;

q) Schedules for implementation phases of the modification.

The topics that are not relevant shall be indicated with the remark “Not Applicable”

REFERENCES

1) International Atomic Energy Agency. *Fundamental Safety Principles*, Safety Fundamental No. SF-1 (2006)

2) International Atomic Energy Agency. *Safety of Research Reactors*, Safety Requirements No. NS-R-4 (2005)

3) International Atomic Energy Agency. *Safety in the Utilization and Modification of Research Reactors*, Specific Safety Guides No. SSG-24 (2012)

4) Atomic Energy Licensing Board. *Standard for Modification of Research Reactors*, LEM/TEK/53 (2009)

CONTRIBUTORS FOR DRAFTING AND REVIEW

Date	Status of Review	Contributor
4 December 2009	0	Nuclear Installation Division of AELB
29 December 2015	1	Mohd. Pauzi Mohd. Sobari - AELB Ibrahim Muhamad - AELB Nik Mohd. Faiz Khairuddin - AELB Abd. Aziz Sadri - AELB Ahmad Tarmizi Ab. Rahman - AELB Nur Adlina Elias - AELB Mohamad Izam Azahari Yusuf - AELB Nurul Sareeza Azidin - AELB Nabilah Syafikah Mohd. Yusof - AELB Najihah Mat Lazim - AELB Ridha Roslan - AELB