IAEA Safety Standards

for protecting people and the environment

Maintenance, Periodic Testing and Inspection of Research Reactors

Safety Guide

No. NS-G-4.2

IAEA

International Atomic Energy Agency

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MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

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SAFETY GUIDE

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FOREWORD

by Mohamed ElBaradei
Director General

The IAEA's Statute authorizes the Agency to establish safety standards to protect health and minimize danger to life and property — standards which the IAEA must use in its own operations, and which a State can apply by means of its regulatory provisions for nuclear and radiation safety. A comprehensive body of safety standards under regular review, together with the IAEA's assistance in their application, has become a key element in a global safety regime.

In the mid-1990s, a major overhaul of the IAEA's safety standards programme was initiated, with a revised oversight committee structure and a systematic approach to updating the entire corpus of standards. The new standards that have resulted are of a high calibre and reflect best practices in Member States. With the assistance of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its safety standards.

Safety standards are only effective, however, if they are properly applied in practice. The IAEA's safety services — which range in scope from engineering safety, operational safety, and radiation, transport and waste safety to regulatory matters and safety culture in organizations — assist Member States in applying the standards and appraise their effectiveness. These safety services enable valuable insights to be shared and I continue to urge all Member States to make use of them.

Regulating nuclear and radiation safety is a national responsibility, and many Member States have decided to adopt the IAEA's safety standards for use in their national regulations. For the Contracting Parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by designers, manufacturers and operators around the world to enhance nuclear and radiation safety in power generation, medicine, industry, agriculture, research and education.

The IAEA takes seriously the enduring challenge for users and regulators everywhere: that of ensuring a high level of safety in the use of nuclear materials and radiation sources around the world. Their continuing utilization for the benefit of humankind must be managed in a safe manner, and the IAEA safety standards are designed to facilitate the achievement of that goal.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was developed under the IAEA programme for safety standards for research reactors, which covers all the important areas of research reactor safety. It supplements and elaborates upon the safety requirements for the maintenance, periodic testing and inspection of research reactors that are established in paras 7.56–7.64 of the IAEA Safety Requirements publication on the Safety of Research Reactors [1].

1.2. The safety of research reactors requires provisions in the design to facilitate maintenance and repair and for appropriate functional testing and inspection. During the operational and utilization phase of a research reactor's lifetime, maintenance, periodic testing and inspection[1] are required to ensure the adequacy of the safety status of the reactor and compliance with the operational limits and conditions (OLCs). To help achieve these objectives, Ref. [1] establishes general requirements regarding maintenance, periodic testing and inspection to ensure that the safety level is not reduced during reactor operation and maintenance. However, it does not provide guidance on how to fulfil these requirements or how to conduct maintenance.

OBJECTIVE

1.3. The primary objective of this Safety Guide is to provide practical guidance on fulfilling the requirements established in Ref. [1], paras 6.43, 6.45–6.47 and 7.56–7.64. This Safety Guide thus provides recommendations for research reactor operating organizations to assist them in preparing and implementing programmes of maintenance, periodic testing and inspection.

1.4. This Safety Guide is intended for use primarily by operating organizations, regulatory bodies and other organizations involved in the operation of a research reactor. While the intention is not to recommend ways

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[1] Some organizations use the terms 'surveillance' or 'surveillance testing' for periodic testing. In addition, the context of 'inspection', as in the title of this Safety Guide, is that of 'in-service inspection' in some organizations. For clarification of these terms, see para. 3.1 and the Glossary of this Safety Guide, and para. 2.11 of Ref. [2].

to make the operation of a research reactor more effective or more efficient, it provides guidelines for maintenance, periodic testing and inspection to ensure safety, which will undoubtedly contribute to effectiveness and efficiency.

1.5. The establishment of a programme of maintenance, periodic testing and inspection is generally a legal operational safety requirement for facility licensing. However, the scope and format of a programme to meet the requirement will depend on the national practices of each State. The approach adopted in the preparation of this Safety Guide is to consider a broad range of international practices and to present a consensus. The Safety Guide includes:

— Activities relating to preventive and corrective maintenance of structures, systems and components (SSCs), as recommended by designers, constructors, manufacturers and support groups and as adopted by operating organizations at the facilities;
— Activities relating to periodic testing intended to ensure that operation remains within the established OLCs;
— Activities relating to inspections of SSCs initiated by the operating organization to determine whether they are acceptable for continued safe operation.

SCOPE

1.6. The recommendations and guidance provided in this Safety Guide are intended to be applicable to most types of research reactor having a limited potential for causing hazard to the public. This Safety Guide describes the safety objectives, the tasks that should be accomplished to meet these objectives, and the activities necessary to perform these tasks.

1.7. In formulating the recommendations in this Safety Guide, the IAEA Safety Guide on Maintenance, Surveillance and In-Service Inspection for Nuclear Power Plants [2] has been consulted. Where appropriate, in consideration of the differences in hazard potential and complexity of systems between nuclear power plants and research reactors, certain provisions of Ref. [2] have been adopted.

1.8. This Safety Guide deals with maintenance, periodic testing and inspection for all types of heterogeneous, thermal spectrum research reactor having a power rating of up to several tens of megawatts. Research reactors of higher power, specialized reactors (e.g. homogeneous reactors, fast spectrum reactors) and reactors having specialized facilities (e.g. hot or cold neutron sources, high pressure and high temperature loops) may require additional guidance. The guidance for power reactors, as provided in Ref. [2], may be more suitable for these reactors.

1.9. Low risk research reactors having a power rating of up to several tens of kilowatts and critical assemblies may need a less comprehensive maintenance, periodic testing and inspection programme than that outlined here. While all recommendations in this Safety Guide should be considered, some may not be applicable to these low power reactors. For these reasons, the recommendations in this Safety Guide should be graded[2] for their applicability to a particular research reactor (see Ref. [1], paras 1.11–1.14). Grading may be of assistance in determining the appropriate frequency for maintenance, periodic testing and inspection. It should be based on the complexity of the activity and the importance to safety of the systems and equipment concerned.

STRUCTURE

1.10. This Safety Guide consists of 12 sections, an appendix and three annexes. Section 2 covers the management system for maintenance, periodic testing and inspection. Section 3 presents an overview of maintenance, periodic testing and inspection, and describes the interrelationships of the three activities and their common terminology. Section 4 discusses design considerations with regard to the ability to maintain, test and inspect research reactors and experiments. Section 5 presents recommendations and guidance for the preparation of the programme for maintenance, periodic testing and inspection. Sections 6 to 9 develop the main concepts of this programme. Sections 10, 11 and 12 discuss maintenance facilities, procurement and storage of spare parts, and inspection methods. The Appendix explains the relationships between terms used in this Safety Guide, and the three annexes provide examples of maintenance activities, periodic testing activities and a work permit.

[2] The recommendations should be graded, for example, by considering — using sound engineering judgement — the safety and operational importance of the topic, and the maturity and complexity of the area involved.

2. MANAGEMENT SYSTEM FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION

GENERAL

2.1. A documented management system that integrates safety, health, environmental, security, quality and economic objectives for the research reactor project should be in place. The documentation for the management system should describe the system that controls the development and implementation of all aspects of the reactor project, including maintenance, periodic testing and inspection. Approval of the management system (or parts thereof) by the regulatory body may be required. The management system should cover four functional categories: management responsibility; resource management; process implementation; and measurement, assessment and improvement. Generally:

- Management responsibility includes providing the means and management support needed to achieve the organization's objectives.
- Resource management includes measures needed to ensure that resources essential to the implementation of strategy and the achievement of the organization's objectives are identified and made available.
- Process implementation includes those actions and tasks needed to achieve quality.
- Measurement, assessment and improvement provide an indication of the effectiveness of management processes and work performance.

Further requirements for the management system are established in Ref. [1], paras 4.5–4.13, and further guidance is provided in Refs [3, 4].

2.2. As part of the integrated management system, a management system for maintenance, periodic testing and inspection should be established and put into effect by the operating organization early in the research reactor project. The management system should apply to all items, services and processes important to safety and should include the means of establishing controls over maintenance, periodic testing and inspection activities to provide confidence that they are performed according to established requirements. In establishing the management system, a graded approach based on the relative importance to safety of each item or process should be used.

2.3. The objective of the management system as applied to maintenance, periodic testing and inspection is to ensure that the facility meets the requirements for safety as derived from:

— The regulatory body's requirements;
— Design requirements and assumptions;
— The safety analysis report (SAR);
— The OLCs;
— Administrative requirements of the reactor management[3].

2.4. The management system should support the development, implementation and enhancement of a strong safety culture in all aspects of the maintenance, periodic testing and inspection programme.

MANAGEMENT RESPONSIBILITY

2.5. The maintenance, periodic testing and inspection of the SSCs of the reactor should be considered at the design stage of the reactor, and programmes for maintenance, periodic testing and inspection should be developed at the pre-operational stages. Pertinent information from designers, manufacturers and other operating organizations should be used.

2.6. Successful implementation of the programme for maintenance, periodic testing and inspection requires the following:

— Planning and prioritization of work;
— Availability of qualified personnel with suitable skills;
— Procedures;
— Availability of spare parts;
— Addressing all relevant regulatory requirements;
— Addressing the requirements derived from the OLCs;
— Availability of special tools and equipment;
— A satisfactory working environment, including isolation of SSCs, worker protection and consideration of radiation hazards;

[3] The reactor management comprises members of the operating organization to whom the responsibility and the authority for directing the operation of the research reactor facility have been assigned.

— Performing and documenting the required maintenance, periodic testing and inspection.

2.7. The activities for maintenance, periodic testing and inspection should be performed and recorded in accordance with written procedures and instructions.

2.8. Documents such as the procedures, specifications and drawings of the maintenance, periodic testing and inspection programme should be prepared, reviewed, updated, approved, issued, validated as required, and archived.

2.9. Records essential to the performance and verification of activities for maintenance, periodic testing and inspection should be controlled through a system for their identification, approval, review, filing, retrieval and disposal.

RESOURCE MANAGEMENT

2.10. Maintenance, including corrective maintenance (the repair and restoration of defective items), is normally carried out using a work control system. In cases where the defective item affects the safe and reliable operation of the research reactor, the deficiency should be brought to the attention of the operating staff and, where appropriate, the management of the operating organization.

2.11. Equipment and items used for maintenance, periodic testing and inspection should be identified and controlled to ensure their proper use.

2.12. The frequency and severity of failures of SSCs should be recorded and analysed to identify the causes of the failures and to look for common mode failures. This information should be used as input to the preventive maintenance programme.

2.13. Plant maintenance work should be monitored and trends should be evaluated to identify necessary improvements.

2.14. The management of the operating organization should participate in the maintenance process by:

— Having frequent personal contact with maintenance personnel, including the observation of work in progress;

— Establishing and implementing a set of performance indicators for maintenance;
— Participating in evaluations of the maintenance process;
— Providing feedback derived from maintenance performance indicators for use in operations.

2.15. Facilities and equipment for maintenance, periodic testing and inspection should be adequate to ensure that all maintenance, periodic testing and inspection can be performed effectively during the time periods allotted.

2.16. Personnel who are not working directly for the research reactor facility and personnel of contracting organizations who perform maintenance, periodic testing and inspections on SSCs should be appropriately trained and qualified for the work they are to perform. Such personnel should receive general employee training and specific training in appropriate procedures and practices. Adequate time should be provided for this training. Experienced and qualified personnel may be allowed to bypass training by proving proficiency. Contractors should perform maintenance work under the same controls and to the same work standards as facility maintenance personnel. Facility supervisors should review the work of contractor personnel during preparation for the work, at the job site during performance of the work, and during post-maintenance acceptance testing and inspection.

2.17. Before the commencement of operation of a research reactor, an in-service inspection programme should be prepared for implementation during the operating lifetime of the facility for the detection of safety significant deterioration. Pre-operational inspection data should be available to serve as baseline data.

2.18. The scope and frequency of periodic tests should be specified and should be consistent with the OLCs and regulatory requirements. The recording and presentation of test results should permit easy comparison with the results of previous tests and should permit the detection of any changes since previous tests and any deviations from the reference values measured earlier.

2.19. The operating organization should have the responsibility for preparing and issuing specifications and procedures for maintenance, periodic testing and inspection. The reactor manager[4] should be an active participant in executing and evaluating the work in maintenance, periodic testing and inspection. The detailed responsibilities of the reactor manager are presented in para. 6.15 of this Safety Guide.

2.20. The competence requirements for staff performing work should be determined and personnel should be competent to perform their assigned work. Training should be provided when necessary.

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

2.22. The hardware and software necessary for work to be carried out in a safe manner and for requirements to be met should be determined, provided and maintained.

PROCESS IMPLEMENTATION

2.23. The activities and interfaces between different groups involved in maintenance, periodic testing and inspection should be planned, controlled and managed to ensure effective communication and the clear assignment of responsibility.

2.24. Maintenance, periodic testing and inspection should have a nominated person responsible and accountable for developing and documenting the process, monitoring the performance of the process, ensuring that the staff are competent, and evaluating the impact of the process upon safety. This person is usually the reactor manager or a maintenance supervisor acting on behalf of the reactor manager.

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

2.25. Inspection, testing, verification and validation activities should be completed before the implementation of maintenance, periodic testing and inspection procedures or before putting into operation the SSCs that have undergone maintenance, periodic testing and inspection.

2.26. Valid monitoring and measurement should be performed to provide evidence of conformity to requirements and satisfactory performance in service.

2.27. Suppliers should be evaluated and selected on the basis of specified criteria.

2.28. Equipment used for monitoring, data collection, and inspections and tests should be calibrated and documented.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

2.29. Measures should be established for assessments to determine whether, and for review and verification to ensure that, maintenance, periodic testing and inspection activities are accomplished as specified in the appropriate procedure. These measures should include:

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

2.30. Effective implementation of the management system for maintenance, periodic testing and inspection should be assessed by qualified personnel who are not directly involved in performing these activities.

2.31. Audits should be performed to determine the adequacy and effectiveness of, and adherence to, all aspects of the management system during maintenance, periodic testing and inspection activities. The audits should pay particular attention to the interfaces and transfers of responsibilities that occur between maintenance and operation groups. The need for auditing by an independent organization should be given due consideration.

2.32. Suitable methods should be applied for monitoring the effectiveness of the programme for maintenance, periodic testing and inspection. The following performance indicators should be considered:

- Availability of safety systems;
- Availability of the reactor for utilization;
- Radiation exposure of personnel conducting maintenance activities;
- Injuries and accidents due to the failure of SSCs;
- Injuries and accidents to personnel conducting maintenance;
- Backlog of maintenance, testing and inspection;
- Assessment results in maintenance, testing and inspection areas.

2.33. An organizational unit should be established with the responsibility to conduct independent assessments of the maintenance, periodic testing and inspection programme on behalf of the operating organization. This unit may be the safety committee as described in para. 7.18 of Ref. [1].

2.34. The operating organization should evaluate the results of the independent assessments and should take any necessary actions to make improvements.

3. OVERVIEW OF MAINTENANCE, PERIODIC TESTING AND INSPECTION

GENERAL

3.1. The objective of maintenance, periodic testing and inspection is to ensure that the SSCs function in accordance with the design intents and requirements, and in compliance with the SAR and the OLCs, to ensure the long term safety of the reactor. The programme for maintenance, periodic testing and inspection should meet the requirements for safety as derived from:

- The SAR;
- The OLCs;
- Regulatory body requirements;
- Reactor management requirements;
- Manufacturers’ recommendations.

All activities for maintenance, periodic testing and inspection should be conducted while maintaining control over the reactor at all times and without reducing or jeopardizing the safety of the reactor. Although maintenance, periodic testing and inspection may be included in one programme and may be performed by the same operating personnel[5], this Safety Guide draws a clear distinction between these three activities. These distinctions and the applicable terminology relating to maintenance, testing and inspection are defined in the Glossary and are illustrated in the Appendix.

3.2. Maintenance may include tests similar to those performed under periodic testing (namely inspection, operability checks and calibration). While these tests are primarily intended to verify that the maintenance has been properly completed, such a test when performed may be considered to satisfy a requirement for periodic testing if it satisfies the frequency requirement.

3.3. Periodic testing includes tests performed to ensure compliance with the OLCs and therefore to verify the safety status of the reactor.

3.4. Inspection, while an activity inherent in all maintenance and periodic testing, is an examination of SSCs for deterioration to determine whether they are acceptable for continued operation or whether remedial measures should be taken. As used in this Safety Guide, inspection also refers to specific, non-routine examination for assessing ageing effects in SSCs. Inspection is sometimes referred to as in-service inspection.

INTERRELATIONSHIP BETWEEN MAINTENANCE, PERIODIC TESTING AND INSPECTION

3.5. Maintenance, periodic testing and inspection have a common objective, as stated in para. 3.1. Maintenance should always be followed by testing. Periodic testing or inspection should be compared with acceptance criteria for the SSC being tested or inspected. If the results fall outside the criteria, corrective action (i.e. maintenance), such as adjustment, repair or replacement, should be initiated. Testing or inspection should be repeated after the corrective action is completed to ensure that the results are restored to acceptable values. A common database should be established in order to share

[5] The operating personnel comprise the reactor manager, the shift supervisors, the operators, the maintenance personnel and the radiation protection personnel.

data and evaluations among the organizations involved in the planning and implementation of activities for maintenance, periodic testing and inspection.

3.6. Testing consists of periodic testing, post-maintenance testing and inspection testing. The purpose of all testing is to confirm that the SSCs continue to meet the design intent as expressed in the SAR and the OLCs. In this Safety Guide, these three types of testing are considered separately.

MAINTENANCE

3.7. There are several possible approaches to maintenance, which can broadly be divided into two categories: preventive maintenance (also referred to as routine or scheduled maintenance) and corrective (or remedial) maintenance. Most maintenance activities are performed while the reactor is shut down. However, maintenance may be performed while the reactor is in operation, provided that the OLCs are maintained, including the limiting conditions of operation.

Preventive maintenance

3.8. Preventive maintenance should consist of regularly scheduled inspections, testing, servicing, overhauls and replacement activities. Its purpose is to enhance the reliability of equipment, to detect and prevent incipient failures, and to ensure the continuing capability of the reactor's SSCs to perform their intended functions. A list of typical preventive maintenance activities is presented in Annex I.

3.9. Preventive maintenance should be performed on SSCs:

— As specified by designers or manufacturers;
— As specified by law and in regulatory requirements;
— As determined by the reactor management on the basis of safety reviews and previous operational experience or for other reasons, such as to meet insurance stipulations.

3.10. Manufacturers' instructions on preventive maintenance may be modified to reflect experience. However, care should be exercised during this process, and the manufacturer should be consulted where necessary.

3.11. Preventive maintenance includes periodic, predictive and planned maintenance activities as follows:

- Periodic maintenance activities should be accomplished on a routine basis and may include inspections, alignments or calibrations, overhauls and replacement of SSCs.
- Predictive maintenance activities should involve continuous or periodic monitoring, where possible, to predict failure of SSCs.
- Planned maintenance activities should be performed prior to the degradation or failure of SSCs and may be initiated on the basis of the results of predictive or periodic maintenance or for the reason stated in para. 3.12.

3.12. Defective SSCs identified during preventive maintenance should undergo proper, timely and adequate repair or replacement.

3.13. In order to predict failures of SSCs, data relating to failures, including root causes, should be collected and stored. These data, usually in the form of reports, should be analysed and used as inputs to the programme developed for preventive maintenance.

Corrective maintenance

3.14. Corrective maintenance (sometimes referred to as remedial maintenance) consists of repair and/or replacement activities not occurring on a regular schedule. The preventive maintenance programme will reduce the need for corrective maintenance and may result in extended availability of SSCs and cost reductions. However, the need for corrective actions cannot be totally eliminated. Adequate resources, such as human resources, spare parts and funds, should be allocated for corrective maintenance.

3.15. If a maintenance activity necessitates a change in an SSC or to the original design, procedures for implementation of a modification should be followed. Further guidance in this regard is given in Ref. [5].

3.16. The operating organization should make adequate provisions for dealing with urgent requirements for corrective maintenance. For prompt action, an on-call system of qualified individuals or maintenance organizations may be necessary.

3.17. Following maintenance or repair activities, pertinent SSCs should be inspected and, where necessary, recalibrated, tested and approved for operation by the responsible personnel. Reference [1] requires that "The results of inspection, periodic testing and maintenance shall be [assessed] by properly qualified personnel, who…shall verify compliance with the OLCs" ([1], para. 7.63).

PERIODIC TESTING

3.18. Periodic testing should be carried out to maintain and improve the availability of equipment, to ensure compliance with the OLCs, and to detect and correct abnormal conditions before they can give rise to significant consequences for safety. The abnormal conditions include not only deficiencies in the performance of SSCs and software, but also trends within the accepted limits that indicate that the performance of one or more of the SSCs is deviating from the design intent.

3.19. The performance of periodic testing often fulfils the surveillance requirements that are incorporated into the OLCs of the reactor operating licence in most Member States.

3.20. Periodic testing, which is usually performed at fixed time intervals, also includes repetitive tests carried out at variable time intervals in conjunction with specific tasks (e.g. pre-operational instrument and control system checks, load testing of an overhead crane before a major lifting operation, testing related to a new core configuration).

3.21. Periodic testing should include operability checks (qualitative testing) and calibration checks (qualitative and quantitative testing).

3.22. Operability checks should be made to provide information on the ability of an instrument system or channel to relay correct signals and on the functioning of systems important to safety.

3.23. Calibration checks of instruments should be carried out to confirm that a known input to an instrument or channel gives an output within specified limits.

INSPECTION

3.24. On a predetermined schedule, the operating organization should examine the SSCs for deterioration and to evaluate the effects on them of ageing mechanisms to determine whether they are acceptable for continued safe operation or whether remedial measures should be taken. Emphasis should be placed on the evaluation of SSCs important to safety, particularly embedded piping, tanks and areas normally restricted from view.

3.25. Routine inspection of SSCs should include several kinds of activity, such as:

(a) Observation of the condition of equipment (e.g. leaks, noise, vibration), which is normally done during periodic walk-downs of the reactor facilities. For some systems, devices such as telescopes and binoculars may be needed for inspections.
(b) Measurement of process variables and operational parameters either by stationary or by portable equipment.
(c) On-line or off-line monitoring.
(d) Sampling for chemical or radiochemical analysis.
(e) Response time measurements of safety systems (e.g. control rod release time, control rod drop time).
(f) Calculations (e.g. hot channel factor, burnup) or measurements (e.g. instrumented fuel elements[6]) performed to verify compliance with the OLCs.

3.26. Inspection results should be evaluated using baseline data collected during the pre-service inspection and subsequent examinations. The degradation anticipated at the time of the next inspection should be considered in the evaluation. The results of the evaluation should be added to the baseline data.

3.27. Non-destructive testing and non-destructive inspection techniques, discussed in Section 12 of this Safety Guide, should be used together with measurements and chemical analysis.

[6] The nuclear fuel elements are the elements containing fissionable nuclear material that are used in the core of a research reactor for the purpose of generating neutrons.

4. DESIGN CONSIDERATIONS

4.1. This section provides guidance to designers of new research reactors, modifications[7] to existing reactors and new experiments, and is intended to ensure that the needs of the operating organization with regard to maintenance, periodic testing and inspection are considered in the design.

4.2. The design for maintainability, testability and inspectability should be based on the principle that radiation exposure of personnel performing maintenance, periodic testing and inspection should be kept as low as reasonably achievable. This may be achieved through design features that minimize human involvement in the maintenance, periodic testing and inspection of reactor systems, particularly those systems that are located in radiation areas.

DESIGN FOR MAINTAINABILITY

4.3. To facilitate maintenance, the following items should be addressed in the design stage of the reactor:

(a) Appropriate accessibility to SSCs;
(b) Adequate shielding of SSCs;
(c) Remote handling;
(d) Post-irradiation radiation levels of SSCs;
(e) Decontamination of SSCs.

4.4. Appropriate accessibility should be achieved by providing sufficient space around SSCs to facilitate good working conditions and convenience in working on, removing and replacing them. This should include space for any additional equipment for handling material that may be needed. The width and height of doors, corridors, elevators and hatches should be given special attention.

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[7] Modification is the deliberate changing of or addition to an existing reactor configuration, with possible implications for safety, intended to permit the continuation of the reactor's operation. It may involve safety systems, safety related items or systems, procedures, documentation or operating conditions.

4.5. The reactor design should make provision for adequate shielding of radioactive components during maintenance. One means of achieving adequate shielding may be by the segregation of radioactive and non-radioactive components into separate rooms. For example, the regulating valves of the purification system for cleanup water may be located in a corridor with the minimum necessary length of piping, while the filters and resin vessels (which retain radioactive material) are located in a closed, shielded space.

4.6. Adequate local shielding should be considered also for equipment that is located in normally inaccessible rooms, to facilitate maintenance during shutdown periods (e.g. for changing the filters and resins).

4.7. Remote handling facilities are generally necessary for handling irradiated fuel elements and other irradiated SSCs. These facilities also include inspection equipment such as underwater television cameras and remotely controlled manipulating and cutting equipment.

4.8. Provision should be made for decontamination tasks to be carried out locally, at the place of work.

4.9. The research reactor facility should make provisions for mechanical, electrical and electronic workshops, properly equipped, to handle all SSCs of the reactor systems, including contaminated and activated equipment and components. Further guidance is provided in Section 10.

DESIGN FOR TESTABILITY

4.10. Provisions should be incorporated into the reactor design for:

(a) Facilitating appropriate functional testing and inspection of all items important to safety to ensure that these items will perform their safety functions when necessary (this is particularly important for passive components and for systems whose ability to function is not normally verified by routine operations);
(b) Performing tests and inspections that represent real conditions as closely as possible;
(c) Self-testing circuits in electrical and electronic systems where possible and appropriate.

4.11. Designing for appropriate functional testing means that all systems, devices, instruments and logic circuits should incorporate, where possible, built-in features to facilitate quick and easy testing of the performance of their safety functions.

4.12. Testing under real conditions means that functional checks should be performed by exposing the sensors of the systems to actual process variables, rather than to simulated variables (e.g. by using a neutron source to test an electronic shutdown channel). The behaviour of safety systems should be tested from input signal to final safety functions.

4.13. Self-testing circuits may be of two types:

(a) Those that continuously monitor important circuit parameters and actuate an indicator, alarm or safety function when the parameter is out of specification;
(b) Those that are activated only during a functional check of the system.

4.14. Where self-testing circuits are not incorporated into the systems, design for testing should also provide the means to test circuit parameters of safety related equipment (e.g. voltage and stability) by using externally connected testing devices. Self-testing circuits should be subject to regular recalibration.

4.15. Tests for systems located in radiation areas should be designed to minimize radiation exposure of personnel. Remote testing, shielding and appropriate scheduling can significantly reduce radiation exposure.

4.16. Where safety systems have to meet numerical reliability targets, the design should permit the meeting of such targets to be demonstrated by tests.

DESIGN FOR INSPECTABILITY

4.17. The reactor should be designed to facilitate in-service inspections aimed at detecting corrosion, erosion, fatigue or ageing effects on SSCs. For this purpose, the following items should be considered:

(a) The provision of adequate clearance to permit access for personnel and equipment and to facilitate the use of the necessary methods and techniques;
(b) The need to minimize radiation exposure of personnel;

(c) The ease of performance of operations associated with the repair or replacement of systems or components;
(d) The availability of decontamination facilities.

4.18. Other design considerations for inspectability include aspects such as the selection of material, weld configuration, surface finish and the buildup of crud or corrosion products.

5. PROGRAMME FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION

GENERAL

5.1. Reference [1] requires that “There shall be documented programmes based on the SAR for the inspection, periodic testing and maintenance of the reactor equipment, especially all items important to safety” ([1], para. 7.57). Inspections, periodic testing and maintenance conducted on a programmatic basis should be performed following a prepared plan and procedures. This plan should include experimental devices and may be presented in one or more documents. In this Safety Guide, these plans are considered as a single programme.

5.2. The programme should be established early in the research reactor project, should be implemented during commissioning before the commencement of routine operation, and should be subject to continuing development and improvement throughout the lifetime of the reactor. Special attention should be given to the collection of baseline data for comparison with observations made later in the lifetime of the facility.

5.3. The programme for maintenance, periodic testing and inspection should cover all administrative and technical measures necessary for the performance of maintenance, periodic testing and inspection. The measures include service, overhaul and repair, replacement of parts, testing, calibration and inspection.

5.4. The following should be available for the preparation of the programme for maintenance, periodic testing and inspection:

(a) The SAR;
(b) The OLCs;
(c) Documentation on the management systems;
(d) Piping and instrumentation diagrams;
(e) Process diagrams;
(f) Schematic and detailed drawings (including as-built drawings);
(g) Specifications of SSCs;
(h) Manufacturers' information (e.g. descriptions, specifications, and operating and service manuals);
(i) Failure data (where available);
(j) Information on maintenance practices from other reactors.

5.5. Activities for maintenance, periodic testing and inspection, if not properly interfaced with one another and the operation of the reactor, could have an adverse effect on safety. These activities should be planned in the context of the management system (see Section 2).

CONTENT OF THE PROGRAMME

5.6. The programme should be written so as to enable the objectives and methods of maintenance, periodic testing and inspection to be understood for the purposes of review, assessment and implementation and to allow management control and coordination. The programme should cover the following:

(a) General description;
(b) Management systems;
(c) Organization and responsibilities;
(d) Selection, training and qualification of maintenance personnel;
(e) SSCs included in the programme;
(f) Administrative and technical procedures;
(g) Administrative controls;
(h) Scheduling;
(i) Review and verification of the programme;
(j) Documentation;
(k) Review of results;
(l) Maintenance facilities;
(m) Procurement and storage of spare parts.

These elements of the programme are discussed in the following sections.

General description

5.7. A general description should state the overall objectives, specifications and scope of the programme.

Management systems

5.8. The programme should detail the management system measures that are incorporated in the activities for maintenance, periodic testing and inspection. The management system is discussed in Section 2.

Organization and responsibilities

5.9. The programme should describe the organizational structure and define the responsibilities for maintenance, periodic testing and inspection within the operating organization and the reactor facility. Organization and responsibilities are discussed in Section 6.

Selection, training and qualification of maintenance personnel

5.10. The programme should specify the qualifications and training of the personnel performing maintenance, periodic testing and inspection. Selection, training and qualification of these personnel are discussed in Section 7.

SSCs included in the programme

5.11. The maintenance, periodic testing and inspection programme should include a list of all SSCs subject to maintenance, periodic testing and inspection. This list should include all SSCs that are important to safety. A brief description of the preventive maintenance, periodic testing or inspection performed on each item should be included in the list. Annex II provides an example of SSCs to be included in the list.

Technical procedures and administrative controls

5.12. Procedures constitute an important part of the written programme. The programme should include a list of all procedures for maintenance, periodic testing and inspection. In some Member States, the procedures themselves are collected in a separate document.

5.13. When general procedures not specific to the maintenance activities (e.g. administrative procedures or radiation protection procedures) are used in conjunction with the procedures for maintenance, periodic testing and inspection, they should be properly referenced. Further guidance on procedures for maintenance, periodic testing and inspection is provided in Section 8.

5.14. In addition to a listing of the procedures for maintenance, periodic testing and inspection for each SSC, the written programme should also provide, in a separate section or in administrative procedures, detailed guidance on the administrative aspects of the work. This guidance should include a description of the sequential steps (e.g. work permit, work execution, work control, testing, return to operational state and record keeping) involved in the performance of the tasks. Further guidance on these administrative controls for maintenance, periodic testing and inspection is provided in Section 9.

Scheduling

5.15. The programme should state the frequency of preventive maintenance, periodic testing and inspection. The intervals between successive periodic activities are usually set in terms of time frames with a range to allow for flexibility. The frequency of periodic testing of items important to safety should be included in the surveillance requirements section of the OLCs.

5.16. Reference [1] requires that "The frequency of inspection, periodic testing and maintenance of individual SSCs shall be adjusted on the basis of experience and shall be such as to ensure adequate reliability" ([1], para. 7.60). Consideration should be given to:

(a) The relative importance to safety of individual SSCs;
(b) The likelihood of their failure to function as intended;
(c) The requirements established in the OLCs.

In addition, the frequency of inspection, periodic testing and maintenance of individual SSCs should also follow, where appropriate, the recommendations of the designer and manufacturer, and should be adjusted in the light of experience gained by the operating organization. Due consideration should also be given, where necessary, to the schedule for reactor operation.

Review and verification of the programme

5.17. The programme should include requirements for review and verification of the programme, including review of procedures, prior to implementation. The review of the programme and procedures should be based on the guidance on the management system provided in Section 2.

Documentation

5.18. The programme should specify the required documentation and how to archive the maintenance, periodic testing and inspection records. The required documents should be issued, approved, reviewed and maintained according to the guidance on the management system provided in Section 2.

5.19. Typical maintenance, periodic testing and inspection documents associated with the programme are:

(a) Management system documents;
(b) Procedures;
(c) Work permits;
(d) Supporting documentation (e.g. drawings, specifications);
(e) Work completion reports;
(f) Results of periodic testing;
(g) Inspection results;
(h) Maintenance records.

5.20. The programme should require reports for all maintenance, periodic testing and inspection. When maintenance, periodic testing and inspection are performed on items important to safety, the reports should include the following:

(a) Description of the work completed;
(b) Names of work leader and participants;
(c) Date of execution;
(d) Reason for the work;
(e) Defects found and remedial actions taken;
(f) Resources used (person-hours, materials and spare parts);
(g) Procedures used;
(h) Test results;
(i) Accumulated radiation exposures for workers;
(j) Experience gained in executing the work;

(k) Status of the equipment;
(l) Recommendations for future actions.

5.21. The mandatory retention period for these records and reports should be based on the management system and should be specified in the records management programme.

Review of results

5.22. Reference [1] requires that "The results of inspection, periodic testing and maintenance shall be [assessed] by properly qualified personnel, who shall verify that the activities have been accomplished as specified in the appropriate procedure and shall verify compliance with the OLCs" ([1], para. 7.63).

Maintenance facilities

5.23. The on-site facilities dedicated to maintenance tasks should be briefly described in the programme. The description may cover the following:

(a) Workshops;
(b) Decontamination facilities;
(c) Facilities for the maintenance of radioactive items;
(d) Lifting and handling facilities;
(e) Special facilities and tools;
(f) Storage facilities.

Further guidance on maintenance facilities is provided in Section 10.

Procurement and storage of spare parts

5.24. The programme should describe the procurement process and should identify the items and quantities of spare parts and materials to be held at all times. Storage conditions and storage time limits should also be specified in the programme. Further guidance is provided in Section 2 and Section 11.

ADDITIONAL NON-ROUTINE MAINTENANCE, TESTING AND INSPECTION

5.25. In routine operation, the major requirements for maintenance, testing and inspection of the research reactor should be met through the programme for preventive maintenance, periodic testing and inspection However, unforeseen factors (e.g. obsolescence, new technology, unforeseen failure mechanisms, premature failures) will arise that will call for special maintenance, testing and inspection that is not addressed in the programme.

5.26. The general status of the research reactor can be improved if special non-routine maintenance, testing and inspection for specific objectives is established in addition to the regular programme. From time to time, this may be requested by the regulatory body or initiated by the operating organization to assess particular aspects of the safety status of SSCs (e.g. prior to modifications for upgrading or to assess ageing effects).

5.27. Over the lifetime of a research reactor, SSCs are subjected to high stresses and severe environmental conditions such as high temperatures and high radiation levels. These conditions may lead to changes in the properties of materials (ageing effects)[8] that may result in unexpected failures. Prevention of ageing related failures should be given special attention.

5.28. To the extent that the in-service inspection programme does not already address them, special inspections should be scheduled for the purpose of determining the conditions of SSCs subject to corrosion, erosion, fatigue or ageing effects. These inspections constitute a major activity in the operation of the reactor and are routinely scheduled in many reactor facilities. Examples of such inspections are:

(a) Examination of the reactor tank, pool liner or cooling systems;
(b) Examination of reactor internals;
(c) Examination of the inner and, where possible, outer surfaces of the beam tube;
(d) General examination of pipes (particularly embedded pipes), pumps and valves;
(e) Examination of spent fuel pools and liquid storage tanks;
(f) Examination of electrical cabinets, cables, switchgear and transformers;
(g) Examination of systems for confinement, containment and ventilation.

[8] Further information on ageing effects may be found in INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Research Reactor Ageing, IAEA-TECDOC-792, IAEA, Vienna (1995).

5.29. Such inspections usually require that the reactor be shut down and occasionally necessitate a total unloading of the core and draining of the coolant. All vulnerable components of the reactor should be inspected. Some components may be inspected during operation or during routine shutdowns and may give indications of problems that may be extrapolated to other components. The timing and scope of major inspections may be influenced by these results.

5.30. The decision to perform a non-routine inspection (or routine in-service inspection) should be made well before the predicted time of failure of the SSC. The scheduling should be based on conservative assumptions of the deterioration rate.

6. ORGANIZATION AND RESPONSIBILITIES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION

ORGANIZATIONAL STRUCTURE[9]

6.1. The organizational structure for maintenance, periodic testing and inspection will vary according to national practices and type of reactor. Management should establish a maintenance group of operating personnel with specific responsibility for maintenance of the reactor to implement the programme for maintenance, periodic testing and inspection. At some research reactors, the operation group may be trained to perform maintenance tasks, periodic testing and inspection, fulfilling the role of a maintenance group. At others, either a central maintenance department within the operating organization or outside contractors may perform these tasks under the supervision of a maintenance supervisor. These different sources of maintenance personnel can be successfully used in combination.

6.2. While overall responsibility for maintenance rests with the operating organization, direct responsibility for implementing the programmes for maintenance, periodic testing and inspection should be delegated to an individual. In this Safety Guide, this individual is referred to as the

[9] Further guidance on the overall organization, not restricted to the area of maintenance, periodic testing and inspection, is provided in a Safety Guide in preparation.

‘maintenance supervisor’. In some cases, the reactor manager may also serve as the maintenance supervisor.

6.3. The main hub of the maintenance, periodic testing and inspection group should be established at the beginning of a research reactor project, and this group should remain in close contact with the design, construction and commissioning groups.

6.4. The maintenance group may be divided into sections (e.g. mechanical, electrical, instrumentation and control), each of which is led by a section head. In smaller organizations, an intermediate position between the maintenance supervisor and the maintenance technicians may be unnecessary. For example, the reactor supervisor may be in charge of maintenance of instrumentation and control systems, while the reactor facility engineer may be in charge of maintenance of mechanical and electrical systems. The authorized reactor operators may perform the maintenance, assisted occasionally by outside experts. The maintenance group may also engage experts (e.g. electricians, welders, metallurgists and experts in pump repair and in non-destructive testing and examination) from outside the maintenance group or from outside the operating organization.

6.5. The organizational structure for maintenance, periodic testing and inspection should also include radiation protection personnel, who “shall work in cooperation with the group that operates the reactor, but they shall have reporting lines to the operating organization that are independent of the reactor management” ([1], para. 7.98).

6.6. It is common at many facilities to undertake a large amount of maintenance and inspection work during a shutdown period that lasts for a period of a week or more. Much maintenance and inspection work can only be performed during this period and this leads to a peak in demand for resources. The organization for maintenance and inspection should be well structured and adequately staffed to meet this peak in demand.

6.7. Independent verification that the activities of maintenance, periodic testing and inspection have been completed in compliance with the requirements for the management system should be carried out by persons from the operating organization who have not been directly involved in the activity being verified.

COORDINATION AND INTERFACES

6.8. Effective coordination should be established:

(a) Among different sections of the maintenance group (mechanical, electrical, instrumentation and control, and civil engineering);
(b) Among the groups for operations, radiation protection, and maintenance, periodic testing and inspection;
(c) Among the facility groups and contractors.

Interface control

6.9. For all activities in maintenance, periodic testing and inspection, an interface control system or procedure should be in place that provides a clear definition of the responsibilities of all organizational units participating in the activities. In particular, the interface between the operating organization and contractors should be clearly specified, with clear arrangements for maintaining configuration control to ensure the safety of the facility during and after the contracted work.

6.10. Interfaces should be addressed in the management system.

RESPONSIBILITIES

Operating organization

6.11. Reference [1] requires that "It shall be the responsibility of the operating organization to ensure that…[the] research reactor is being operated and maintained in accordance with the safety requirements by suitably qualified and experienced personnel" ([1], para. 7.10(f)). Although the operating organization may delegate or subcontract the execution of some tasks to other organizations, it cannot delegate its responsibility for safety. In carrying out its responsibilities, the operating organization should ensure that:

(a) A management system has been established and implemented;
(b) Procedures have been established and implemented to control and perform maintenance, periodic testing and inspection of the reactor;
(c) Persons with responsibilities relating to maintenance and periodic testing are properly trained, and a training and retraining programme is

established, implemented, updated and periodically reviewed to verify its effectiveness;

(d) Adequate facilities and services are available during maintenance, periodic testing and inspection;

(e) A safety culture[10] prevails in the organization, and the attitude of the staff and the operating environment are conducive to safe maintenance, periodic testing and inspection;

(f) Operational experience, including information feedback from operating experience at other, similar facilities, is carefully examined to detect any precursor signs of tendencies adverse to safety, so that corrective actions can be taken before serious conditions arise, and to prevent recurrences of events;

(g) Sufficient authority and resources are provided to management to allow it to implement effectively the programmes for maintenance, periodic testing and inspection;

(h) The completion of activities for maintenance, periodic testing and inspection relevant to the safety of personnel and of the reactor takes priority over operational or production demands.

Regulatory body

6.12. The regulatory body should carry out the following major regulatory responsibilities with respect to maintenance, periodic testing and inspection of the research reactor:

(a) Reviewing and assessing documents relating to maintenance, periodic testing and inspection, such as documents on the respective programmes;

(b) Reviewing, assessing and approving those parts of the programme for maintenance, periodic testing and inspection that are related to the OLCs and the changes to them;

(c) Ensuring adequate control of maintenance, periodic testing and inspection (e.g. by ensuring that requirements are incorporated into the operating licence through the OLCs);

(d) Conducting inspections to ensure conformance with the requirements for maintenance, periodic testing and inspection set by the OLCs and applicable regulations, codes and standards;

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[10] Further guidance on this topic is provided in Ref. [6].

(e) Reviewing information concerning maintenance related safety incidents (e.g. violation of safety limits or non-conformance with limiting conditions for safe operation).

Safety committee

6.13. The safety committee ([1], para. 7.25) should review and advise the operating organization and reactor manager on:

(a) Safety issues arising in the maintenance, periodic testing and inspection of the reactor;
(b) Programmes for maintenance, periodic testing and inspection;
(c) Procedures for maintenance, periodic testing and inspection;
(d) Results and findings of maintenance, periodic testing and inspection.

The safety committee may also have the responsibility for conducting independent assessments of the programme for maintenance, periodic testing and inspection.

Reactor manager

6.14. Reference [1] requires that "The decision to carry out maintenance work on installed equipment, to remove equipment from operation for maintenance purposes, or to reinstall equipment after maintenance…shall be the overall responsibility of the reactor manager…[and] shall be in accordance with the objective of maintaining the level of safety of the reactor as specified in the OLCs" ([1], para. 7.59). The reactor manager should therefore have responsibility for all aspects of maintenance, periodic testing and inspection. There should be a clearly defined structure of authorization for the performance of the work. The responsibility for coordinating the work may be delegated by the reactor manager to a maintenance supervisor.

6.15. The reactor manager should be responsible for:

(a) Preparation of the programme for maintenance, periodic testing and inspection and its approval and implementation after review by the safety committee;
(b) Preparation of implementing procedures for programmes for maintenance, periodic testing and inspection;
(c) Approval of work permits (see also para. 9.4(d));
(d) Training and retraining of the maintenance personnel;

(e) Ensuring that only suitable, qualified, experienced and trained personnel undertake and supervise activities in maintenance, periodic testing and inspection;
(f) Defining, in writing, the responsibilities and duties of the maintenance group members and their lines of communication;
(g) Initiation of the process of approval and implementation of system modifications originated on the basis of maintenance activities;
(h) Review and correction of deficiencies;
(i) Interface control;
(j) Having frequent personal contact with the personnel for maintenance, periodic testing and inspection, including the observation of work in progress;
(k) Participation in evaluations of the process for maintenance, periodic testing and inspection;
(l) Establishing and implementing a set of performance indicators;
(m) Providing feedback for operations derived from performance indicators.

6.16. The reactor manager should have the additional responsibilities listed in para. 6.17. Alternatively, the reactor manager may delegate these responsibilities to a maintenance supervisor or others.

Maintenance supervisor

6.17. If the responsibility for coordinating the work has been delegated by the reactor manager to a maintenance supervisor or others, the responsibilities should include some or all of the following:

(a) Implementing the programme for maintenance, periodic testing and inspection in accordance with the management system and the guidelines issued by the reactor manager;
(b) Reviewing the maintenance, testing and inspection results and assessing the impact of any deficiencies against the specified expectations for performance and availability;
(c) Making suggestions or recommendations for improvements to the programme for maintenance, periodic testing and inspection, including changes to equipment, procedures or schedules;
(d) Promptly reporting deficiencies revealed during the work that may necessitate further investigation;
(e) Ensuring the availability and use of procedures for maintenance, periodic testing and inspection;
(f) Supervising the maintenance personnel;

(g) Ensuring that the necessary tools and equipment are available and in a suitable condition for use;
(h) Reviewing and approving records and reports;
(i) Procuring spare parts in accordance with specifications and the management system;
(j) Contributing to the preparation of maintenance, periodic testing and inspection procedures and updating them on the basis of experience with available facilities, equipment and tools;
(k) Planning and allocating resources in accordance with the overall requirements for the facility;
(l) Supervising the progress and quality of work to ensure that procedures are followed, and preparing reports and records;
(m) Coordinating activities with other groups;
(n) Considering proposals by maintenance technicians and craftspersons;
(o) Reporting the status of the work to the reactor manager;
(p) Certifying satisfactory completion of the work.

Outside contractors

6.18. The operating organization may delegate to other organizations some activities of maintenance, periodic testing and inspection, but it is required to retain overall responsibility for such delegated work and should perform all the necessary administrative and supervisory functions in mobilizing the outside resources.

6.19. Contractors should be subject to the same standards as facility staff, especially in the areas of competence, adherence to procedures and evaluation of performance. Suitable steps should be taken to ensure that contractors conform to the technical standards and the safety culture of the operating organization.

6.20. Activities performed by contractors should be controlled by means of management systems that cover the required quality of their work, the training and qualification of contractor personnel, radiation protection, adherence to procedures, understanding of facility systems, and administrative procedures for normal and emergency conditions. Contractor personnel should be made aware of their responsibilities in relation to the safety of the facility and the equipment they maintain.

Maintenance technicians and craftspersons

6.21. The responsibilities of the maintenance technicians and craftspersons should be:

(a) Performing maintenance, periodic testing and inspection in accordance with approved written procedures;
(b) Suggesting new procedures or changes to existing procedures to enhance safety, improve efficiency and reduce the radiation exposure of workers.

7. SELECTION, TRAINING AND QUALIFICATION OF PERSONNEL[11]

7.1. Maintenance personnel[12] should be selected on the basis of the competences necessary to perform the tasks. When establishing the maintenance group, it is desirable to incorporate members of the design, construction and commissioning groups, if available. Typical qualifications for maintenance personnel for research reactors are presented in Table 1. It should be possible to substitute long term experience for formal qualification. Maintenance personnel at all levels should be periodically evaluated for their performance and requalified to ensure their professional competence.

7.2. In some Member States, the individuals who perform maintenance, periodic testing and inspections of instrumentation and control systems, safety systems, shutdown systems and protection systems require authorization or licensing by a competent authority. For this reason, these individuals should be selected for their ability to be authorized or licensed.

7.3. In addition to the skills of the trade, all maintenance personnel should receive training in:

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[11] Further guidance on the selection and training of personnel, not restricted to maintenance, periodic testing and inspection, is provided in a Safety Guide in preparation.

[12] In the context of this Safety Guide, 'maintenance personnel' are the operating personnel responsible for maintenance, periodic testing and inspection.

TABLE 1. TYPICAL QUALIFICATIONS FOR MAINTENANCE PERSONNEL

Maintenance supervisor	College degree in physical sciences, engineering or equivalent
Section head	Technician's qualification in relevant technology acquired at an educational institution or by industrial training. Depending on the size and activity of the organization, an appropriate college degree may be desirable
Technician	Technician's qualification in relevant technology acquired at an educational institution or by industrial training
Craftsperson	Craftsperson's qualification in relevant craft, acquired at an educational institution or by industrial training

(a) Physical principles relating to nuclear reactors;
(b) Radiation protection;
(c) Principles of systems important to safety;
(d) Specific knowledge of systems and equipment relevant to their duties;
(e) Nuclear and industrial safety;
(f) Management system requirements applicable to their duties;
(g) Emergency procedures;
(h) Maintenance procedures;
(i) Periodic testing procedures;
(j) Inspection procedures;
(k) Regulatory requirements.

The level of training in the above subjects should be appropriate for the duties assigned to each individual. Personnel should have achieved competence in these subjects before being allowed to work independently. The maintenance personnel should be retrained to preserve and enhance their competence.

7.4. All maintenance personnel should be made aware of the importance to safety of the tasks that they perform and the potential consequences of technical, procedural or human errors. Experience of faults and hazards caused by errors at other nuclear facilities should be reviewed and incorporated into the personnel training programmes, as appropriate.

7.5. Contract maintenance personnel should be given training that is equivalent to that provided to personnel employed by the operating organization. For short term contractors, most of the training identified in para. 7.3 may be replaced by supervision by a member of the maintenance group (see also paras 9.8 and 9.9).

7.6. Training programmes and schedules should be prepared for each category of maintenance worker on the basis of the topics outlined in para. 7.3.

7.7. Maintenance personnel should be provided with opportunities to deepen the specific knowledge necessary to perform their duties.

8. PROCEDURES

8.1. In order to implement the programme for maintenance, periodic testing and inspection, the operating organization should ensure that administrative controls and work controls are established. These controls usually take the form of administrative procedures and maintenance procedures that include all requirements for performing activities in the research reactor facility. These procedures should be prepared, reviewed, validated, issued and modified in accordance with the requirements of the management system. A mechanism should be established to enable users of the procedures to feed back suggestions for their improvement.

8.2. Temporary changes to procedures should be properly controlled and should be subject to review and approval. Where appropriate, temporary changes should be promptly incorporated into permanent procedures to limit the number and duration of temporary procedures.

8.3. A Safety Guide in preparation on operational limits and conditions and operating procedures for research reactors will provide guidance on the preparation of procedures, including their format and content and the steps in the preparation of a procedure.

8.4. Administrative controls are discussed in Section 9.

ADMINISTRATIVE PROCEDURES

8.5. The factors to be taken into account in developing administrative procedures for maintenance, periodic testing and inspection should include:

(a) The use of written procedures for maintenance, periodic testing and inspection;
(b) The use of work permits (see paras 9.2–9.5);
(c) Radiation protection considerations;
(d) Control of the system configuration;
(e) Calibration of tools and equipment;
(f) Industrial safety and fire hazard controls;
(g) The use of interlocks and keys;
(h) Nomenclature, location and labelling of equipment;
(i) Housekeeping;
(j) Planning of work during maintenance shutdowns;
(k) Equipment requalification and return of the reactor to an operational state.

PROCEDURES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION

8.6. Maintenance, periodic testing and inspections should be conducted by following approved procedures that are prepared in accordance with the requirements of the management system. These requirements should cover the process for the review and approval of maintenance procedures that could affect reactor safety. These procedures should include written instructions for performing the following:

(a) Maintenance of SSCs that could affect the safety of the reactor;
(b) Periodic inspections, calibrations and tests of SSCs that are important to safety;
(c) Periodic testing and inspection (surveillance) of the reactor and its auxiliary systems during periods of extended shutdown.

Checklists may be useful for all these activities.

8.7. In the preparation of procedures for maintenance, periodic testing and inspection, attention should be paid to the possible consequences of the use of the procedures for safety systems and for reactor operation ([1], para. 7.57). Some procedures may be performed during reactor operation with no impact on the safety of the reactor; others may necessitate shutting down the reactor. It should therefore be confirmed that these procedures do not cause any action to be taken that reduces reactor safety such that the OLCs are violated. Care should be exercised to avoid the introduction of common cause failures through maintenance activities (e.g. the systematic incorrect resetting of alarm settings or safety system settings).

8.8. In the preparation of procedures for maintenance, periodic testing and inspection, consideration should be given to radiation protection to keep radiation doses as low as reasonably achievable.

8.9. Procedures for maintenance, periodic testing and inspection should clearly delineate any change from the normal operating configuration of the reactor and should make provision for restoration to the normal configuration before the resumption of operation.

8.10. The procedure should require that final acceptance be given (including signature) by an individual qualified to assess the results of the activities for maintenance, periodic testing or inspection that were performed under the procedure. The procedure should state the acceptance criteria.

8.11. Special procedures should be prepared to control contractor maintenance work. These procedures should include prerequisites for the work and specifications for supervision of the contractor, contractor qualifications and work coordination.

8.12. Procedures should include provisions for resolving non-conformance with the OLCs.

8.13. A special procedure should be prepared to control the replacement of items in safety systems and safety related systems. This procedure should specify how to ensure that identical spare parts are used or, in the case of using equivalent alternatives, how to substantiate the equivalence (e.g. by form, fit or function) so that the safety of the reactor is not compromised.

8.14. Special procedures regarding inspection for and prevention of ageing effects should be developed and implemented. This topic is discussed in paras 5.26–5.30.

9. ADMINISTRATIVE CONTROLS

9.1. Administrative controls should be developed that take into account the interfaces between the maintenance of the facility, operation of the facility and radiation protection. The following elements should be explicitly covered:

(a) The demarcation between those performing maintenance and those directly responsible for operation of the facility (e.g. the shift supervisor);
(b) Ensuring that the operating personnel have information about the status of the research reactor at all times during maintenance activities;
(c) Establishment of a work permit system and the designation of individuals who are authorized to issue and cancel work permits for maintenance, equipment isolation, live testing and access control;
(d) Provision of direct positive indication of equipment that is out of service, including provisions to prevent unintentional return to service;
(e) Ensuring that SSCs are inspected and tested after maintenance before being declared functional and reinstated for normal operation;
(f) Return to operational status.

WORK AUTHORIZATION (WORK PERMIT)

9.2. In addition to the written procedures for maintenance, periodic testing and inspection, a system of work permits should be used for all maintenance activities. The purpose of the work permit is to ensure that the work is conducted with the knowledge and permission of the person in operational control of the reactor (e.g. the shift supervisor) and that both the safety of personnel and the safety of the reactor are ensured. The work permit system should be used to authorize the work, to signify the completion of the work and to specify requirements for return to service. Although some routine activities (e.g. checking of the reactor system before each startup) may be performed under a 'continuous' work permit, the operating personnel should still be notified of every routine activity before it begins.

9.3. A work permit generally consists of a standard form that summarizes the work to be done, the requirements for hazard elimination and the safety precautions to be taken, and that bears the signatures of the responsible personnel. The work permit may include the following:

(a) Work request;

(b) Work requirements, including those for safety and security;
(c) Radiation protection requirements;
(d) Work approval;
(e) Notification of personnel in the control room;
(f) Work completion certificate.

An example of a work permit form is included as Annex III.

9.4. The performance of a maintenance task should be controlled by following sequential steps (refer to the example of the work permit form in Annex III):

(a) Any member of the operating organization may initiate a request for maintenance, periodic testing or inspection. The maintenance supervisor should consider the request and, if agreed, initiate a work permit identifying the SSC and the task to be performed. (In using the sample form in Annex III, this corresponds to the completion of part A.)
(b) The maintenance supervisor should be responsible for determining the most important requirements relating to the task requested and for assembling all the documents necessary to perform the job (e.g. procedures, drawings and manuals). The requirements should remove as many hazards as practicable (e.g. by means of electrical isolation or isolation from gas or liquid supplies). Hazards that cannot be removed should be clearly identified and appropriate instructions should be given (e.g. for clothing or breathing equipment). Any decision regarding isolation of the equipment or the system to be maintained should be taken at this stage and the relevant isolation procedures or instructions should be specified. (In using the sample form in Annex III, this corresponds to the completion of part B by the maintenance supervisor.)
(c) The radiation protection supervisor should consider the task to be performed. The main radiation protection measures to be taken in performing the task should be specified. These measures generally consist of the following:

    — Monitoring and mapping of radiation fields in the work area;
    — Monitoring and mapping of contaminated surfaces in the work area;
    — Use of equipment and procedures for decontaminating items of equipment;
    — Maintaining control points at the entrances to the work area, including the provision of protective clothing, gloves and breathing equipment;
    — Monitoring people and equipment leaving the work area;

- Giving advice to maintenance personnel on dose levels and work times, and providing assistance in controlling them;
- Collecting data on radiation exposure of personnel.

(In using the sample form in Annex III, this corresponds to the completion of part C by the radiation protection supervisor.)

(d) Since the reactor manager has responsibility for all aspects of maintenance, the reactor manager should review the tasks to be performed and, if necessary, add further requirements or instructions. It should also be the reactor manager's responsibility to schedule the beginning of the work. (In using the sample form in Annex III, this corresponds to the completion of part D by the reactor manager.)

(e) Since all maintenance tasks should be coordinated with the control room personnel and the shift supervisor, the shift supervisor should review the task of maintenance, periodic testing or inspection. The shift supervisor should also be responsible for isolation of the equipment or system. A method to mark isolated components should be used by the operating personnel. One way of doing this is by placing isolation tags on the isolated equipment and on remote operation actuators. (In using the sample form in Annex III, this corresponds to the completion of part E by the reactor supervisor.)

(f) A work completion certification should be issued once the following conditions have been fulfilled:

- The maintenance work has been completed;
- All necessary adjustments, recalibrations and verifications have been accomplished;
- The system has been restored to its required status;
- A functional test has been performed.

(In using the sample form in Annex III, this corresponds to the completion of part F.)

9.5. The maintenance supervisor should issue the work completion certificate mentioned in para. 9.4(f) above after the shift supervisor has certified the restoration of equipment to a normal state. Acceptance by the reactor manager should be required. This should include a note in the reactor operating log that maintenance has been completed and that the reactor configuration has been verified.

WORK COORDINATION

9.6. Arrangements for the coordination of maintenance activities with other groups in the reactor facility are important and should be specified in writing. It should usually be the responsibility of the maintenance supervisor to coordinate maintenance with all other groups, such as the operation group, the radiation protection group (operating personnel who have specific responsibility for radiation protection), experimenters and contractors.

9.7. During the execution of major maintenance, the reactor manager and the shift supervisor should be kept informed of the progress of work.

WORK PERFORMED BY CONTRACTORS

9.8. Administrative control should be established to supervise maintenance performed by contractors, who may have had inadequate training in radiation protection and other topics relevant to the facility. A record should be maintained of contract personnel engaged in performing maintenance. This record should include information on the type of work, days or hours employed, radiation doses received and identities of the workers.

9.9. Work carried out by contractors should be verified as being done in accordance with written procedures and the requirements of the management system. This verification may be done by a member of the operating organization designated to act as supervising officer of the contractor.

10. MAINTENANCE FACILITIES

WORKSHOP FACILITIES

10.1. The operating organization should provide suitable workshop facilities with sufficient space and equipment to carry out maintenance activities. The availability and intended use of off-site facilities and the need to deal with radioactive SSCs of the facility should be taken into consideration. The requirements for maintenance of experimental devices should be considered.

10.2. On-site workshops should be provided for the maintenance of mechanical, electrical, and instrumentation and control equipment.

FACILITIES FOR MAINTENANCE OF RADIOACTIVE ITEMS

10.3. For the maintenance of radioactive or contaminated SSCs, the workshop, whether on or off the site, should be designated and marked as a supervised or controlled area, as appropriate. Dedicated tool stores may be appropriate and their use should be controlled. Off-site facilities should be used only if they can be decontaminated upon completion of the maintenance.

10.4. It may be impractical or impossible to remove a contaminated or radioactive item from the reactor building, making it necessary to supplement the permanent arrangements by use of a temporary facility erected around the SSC or machine tool for the maintenance work to be done locally. Whichever type of facility is provided, consideration should be given to the following:

(a) Access control rooms and changing rooms;
(b) Arrangements for proper ventilation;
(c) Treatment, handling and disposal of liquid and solid radioactive waste;
(d) Radiation protection;
(e) Shielding and remote handling;
(f) Storage facilities for radioactive items;
(g) Decontamination requirements.

DECONTAMINATION FACILITIES

10.5. A local facility should be provided for removing radioactive contamination from SSCs, tools or equipment prior to maintenance or their transfer to another location. This facility may include arrangements for the following:

(a) Access control rooms and changing rooms;
(b) Arrangements for proper ventilation;
(c) Treatment, handling and disposal of liquid and solid radioactive waste;
(d) Radiation protection;
(e) Decontamination tanks, special equipment and tools needed for decontamination, with account taken of the largest item anticipated;

(f) Adequate supplies of electrical power, steam, hot water, compressed air and chemical decontamination agents;
(g) Adequate lifting and handling facilities;
(h) Protective equipment for personnel.

LIFTING AND HANDLING FACILITIES

10.6. Lifting and handling facilities should be provided in the design of the reactor. It should be the responsibility of the maintenance group to maintain all lifting and handling facilities in good order. Space should be left around equipment for performing these activities and to keep access routes clear. The capacities of lifting and handling facilities should be clearly indicated on the equipment.

10.7. The failure of lifting facilities associated with reactor systems may have serious consequences. Lifting devices should therefore be subject to preventive maintenance and periodic testing (inspections, tests and servicing), which should be incorporated into the programme for maintenance, periodic testing and inspection in accordance with existing national regulations. Cautionary notices and mechanical and electrical inhibits should be utilized to limit the movements of loads over specified areas. Trained personnel should perform all operations involving lifting and rigging.

SPECIAL EQUIPMENT AND TOOLS

10.8. Reference [1] requires that "Equipment and items used for periodic testing and maintenance shall be identified and controlled to ensure their proper use" ([1], para. 7.61). Measurement devices used for the periodic testing of fuel surveillance should be calibrated against standards prior to first use and as specified in the facility calibration programme.

10.9. Special equipment and tools that may reduce radiation exposure and improve safety should be provided by the operating organization. Examples of these are:

(a) Long handled tools;
(b) Remote handling manipulators;
(c) Remotely operated equipment for non-destructive testing;

(d) Remote viewing equipment such as binoculars, mirrors, telescopes, closed circuit television, remotely operated cameras and underwater telescopes;
(e) Special lighting equipment, including underwater light fixtures;
(f) Special communication systems (e.g. for use with respiratory protection masks);
(g) Containers for contaminated items;
(h) Shielded containers and transport equipment for irradiated items;
(i) Portable shielding;
(j) Clothing and equipment for radiation protection;
(k) Materials and equipment for controlling and containing radioactive contamination (e.g. plastic sheets and tents, paper floor covering, strippable coating material and vacuum cleaners equipped with filters).

MOCK-UPS AND MODELS

10.10. Simulations, mock-ups and models of particular sections of the research reactor facility may serve for:

(a) Rehearsing work to be carried out in high radiation areas or highly contaminated areas;
(b) Preparing and validating procedures;
(c) Developing and improving tools;
(d) Gaining experience with tools and protective equipment;
(e) Training and qualifying personnel;
(f) Confirming estimates for work duration for the purpose of making dose estimates.

11. PROCUREMENT AND STORAGE

PROCUREMENT

11.1. The procurement and storage of spare parts and components should meet the requirements of the management system. The certification of suppliers of materials used in the reactor should also conform to the management system.

11.2. The operating organization should arrange for purchasing appropriate quantities of spare parts and components for the reactor. In some organizations the maintenance group may have direct responsibility for procurement and storage. When this responsibility rests with another group, the maintenance group should ensure that it receives adequate supplies of spare parts and components that meet the same technical and quality specifications and standards as the installed research reactor items. The maintenance group should ensure that the spare parts are stored appropriately.

11.3. The minimum shelf quantities and quantities on order should be determined according to the maintenance experience, the procurement time and the shelf life of each item.

RECEIPT

11.4. Upon receipt, purchased items should be inspected against the purchase specifications and in accordance with the management system.

STORAGE

11.5. Spare parts and components should be stored in appropriate environmental conditions to prevent deterioration. The stored items should be subjected to regular examinations for the detection of deterioration.

11.6. Access to stored items and equipment that are part of SSCs important to safety should be restricted.

11.7. A method of identifying and cataloguing spare parts and materials should form an integral part of the management system for the reactor.

11.8. Items with limited shelf life should be clearly identified and should be discarded upon reaching the end of their shelf life. Usage rates of parts that deteriorate in storage should be determined to prevent unnecessary waste.

12. TESTING AND INSPECTION METHODS AND TECHNIQUES

12.1. Many methods and techniques may be used in the programme for maintenance, periodic testing and inspection. They range from the well known methods of dimensional and electrical measurements and chemical analysis to the more sophisticated methods of non-destructive examination of the surfaces and volume of structures. Regardless of the methods or techniques employed, the method selected should be qualified for the examination to be done. The work should be done according to appropriate procedures by personnel who are qualified to use the methods and techniques employed. Similarly, the results should be evaluated by qualified personnel and compared with baseline data to detect changes.

12.2. Many of the examinations to be done in the testing and inspection programme involve the methods and techniques of non-destructive testing and non-destructive examination. A brief description of some of these techniques is given here. More detailed information on the techniques and their application is available in Section 10 of Ref. [2] and in Ref. [7].

VISUAL EXAMINATION

12.3. Visual examination provides information on the general condition of SSCs to be examined, including such conditions as scratches, wear, cracks, corrosion or erosion of the surface, and evidence of leakage. Optical aids such as television cameras, underwater telescopes, binoculars and mirrors may be useful for this activity.

SURFACE EXAMINATION

12.4. A surface examination is undertaken to delineate or verify the presence of surface or near-surface flaws or discontinuities. It may be conducted by techniques that use a liquid penetrant, an eddy current or magnetic particles.

VOLUMETRIC EXAMINATION

12.5. A volumetric examination is undertaken for the purpose of indicating the presence, depth or size of a surface-breaking or subsurface flaw or discontinuity, and usually involves radiographic, ultrasonic or eddy current techniques.

12.6. Radiographic techniques, employing penetrating radiation such as X rays, gamma rays or thermal neutrons, may be utilized with appropriate image recording devices, not only to detect the presence of flaws, but also to establish their size.

12.7. An appropriate ultrasonic testing method is commonly used to establish the length and depth of flaws.

12.8. Eddy current examination as well as ultrasonic testing is normally applied to tubing and tubular configurations to establish the existence and depth of flaws.

12.9. Inspections and testing using the techniques described in paras 12.4–12.8 should be performed by specialists who are specially qualified to use the techniques and to interpret the results.

OTHER TESTING TECHNIQUES

12.10. Other testing techniques, such as hydrostatic testing of pressure equipment and helium leak testing, may be used as appropriate. Computer based systems should also be subjected to appropriate testing after maintenance.

Appendix

RELATIONSHIPS BETWEEN TERMS USED

A.1. The relationships between terms used in this Safety Guide and activities relating to the respective parts of the maintenance and testing programme are indicated in Fig. A.1.

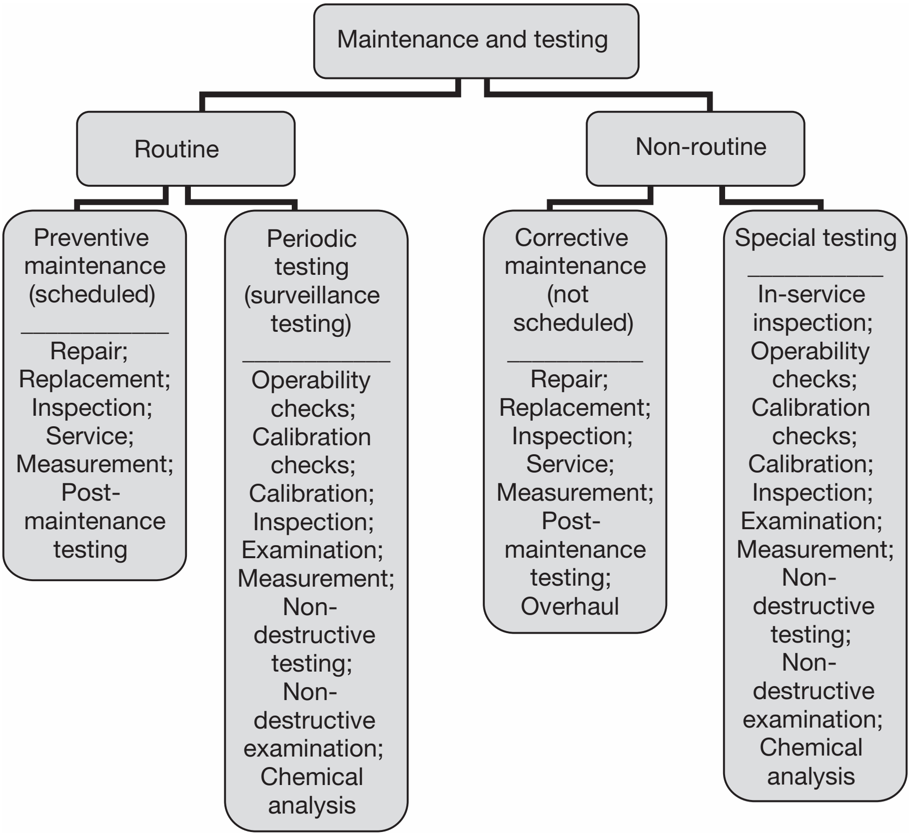

FIG. A.1. Relationships between terms used and activities relating to the respective parts of the maintenance and testing programme.

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[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of Non-Destructive Testing and In-Service Inspection to Research Reactors, IAEA-TECDOC-1263, IAEA, Vienna (2001).

Annex I

EXAMPLES OF PREVENTIVE MAINTENANCE ACTIVITIES

The following are examples of preventive maintenance activities and their application to selected common equipment.

I–1. PREVENTIVE MAINTENANCE ACTIVITIES

(a) Walk-down inspections (looking for leaks, oil spills, vibration, hot spots, unusual noise, etc.);
(b) Measurement of operational parameters (e.g. current, temperature);
(c) Monitoring of conditions;
(d) Lubrication;
(e) Filter replacement;
(f) Chemistry control;
(g) Cleaning/preserving;
(h) Internal inspections;
(i) Calibrations/alignments/alignment checks;
(j) Oil checks and changes;
(k) Testing of equipment and instrumentation;
(l) Replacement of parts before their predicted failure age;
(m) Overhauls;
(n) Replenishment of consumable materials (e.g. corrosion inhibitors);
(o) Surface treatment and painting.

I–2. APPLICATION OF PREVENTIVE MAINTENANCE TO SPECIFIC EQUIPMENT

Valves

(a) Visual inspection;
(b) Lubrication;
(c) Cleaning/preserving;
(d) Replacement of parts.

Rotating equipment (pumps, compressors, etc.)

(a) Visual inspection;
(b) Balancing of rotating assemblies;
(c) Greasing of couplings;
(d) Measurements of electrical current;
(e) Checks of protection circuits (for overload, vibration, overheating);
(f) Replacement of equipment internals.

Heat exchangers

(a) Internal inspections;
(b) Tube cleaning;
(c) Back-flushing;
(d) Tube sealing/plugging.

Electrical distribution

(a) Visual inspections;
(b) Cleaning of switchgear, distribution panels;
(c) Replacement of filters (for motor air intakes, ventilation, instrument cabinets);
(d) Impedance measurements.

Instrumentation and control systems

(a) Calibrations;
(b) Operational checks, verification tests for output signals;
(c) Replacement of relays, fuses, contacts.

Confinement

(a) Leak tests;
(b) Replacement of seals;
(c) Cleaning of filters.

Annex II

EXAMPLES OF PERIODIC TESTING ACTIVITIES

II–1. Requirements for periodic testing (surveillance requirements) are generally established on parameters of SSCs for which safety limits, safety system settings and limiting conditions for safe operation have been specified. These surveillance requirements generally include three types of surveillance test, namely operability checks, calibrations and inspections. The term inspection as used here refers to an inspection activity or action called for by a periodic test. It is not to be confused with the major in-service inspection programme. Table II–1 shows a number of reactor parameters and SSCs that are usually subject to periodic testing, as well as the type of test that is applied.

TABLE II–1. EXAMPLES OF PERIODIC TESTING ACTIVITIES

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculation
Reactivity limits			
Core excess reactivity			+
Reactivity worth of control rods			+
Shutdown margin[b]			+
Protection and shutdown systems			
Overpower shutdown	+	+	
Startup channel	+	+	
Log count rate channel	+	+	
Period safety channel	+	+	
Flux level safety channels	+	+	
Power/flow mismatch scram[c]	+		
Safety channel–heat balance comparison		+	
Reduced flow shutdown	+	+	
Primary pump failure shutdown	+		
Reduced core pressure difference shutdown	+	+	
Loss of electrical power shutdown	+		

TABLE II–1. EXAMPLES OF PERIODIC TESTING ACTIVITIES (cont.)

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculation
Protection and shutdown systems (cont.)			
Radiation monitors (operation, alarm, shutdown)	+	+	
Control rods release time			+
Control rods drop time			+
Manual shutdown switch	+		
Magnet power key switch	+		
Coolant temperature rundown[d]	+	+	
Pool level shutdown	+	+	
Pool level rundown	+	+	
Bridge unlocked shutdown	+		
Experiments shutdown	+		
Instrumentation and control			
Linear level channel	+	+	
Large servo error (deviation interlock)	+		
Air radiation monitor (Ar-41)	+	+	+
Airborne particulate monitor	+	+	+
Exhaust air radiation monitor	+	+	+
Fission product monitor	+	+	+
Liquid waste activity monitor	+	+	+
Confinement and ventilation			
Confinement pressure			+
Confinement/containment isolation logic	+		
Changeover to emergency mode operation	+		
– Ventilation system turned off			
– Ventilation dumpers closed			
– Emergency system turned on			

TABLE II–1. EXAMPLES OF PERIODIC TESTING ACTIVITIES (cont.)

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculation
Coolant systems			
Primary coolant pH		+	+
Primary coolant conductivity		+	+
Primary coolant chemistry analysis			+
Primary coolant activity content			+
Secondary coolant chemistry			+
Miscellaneous			
Emergency core cooling	+	+	
Fuel burnup			+
Emergency power supply	+		
Fire extinguishers	+		
Reflector elements' condition			+
Core visual inspection			+
Fuel storage pool system			
– Level	+		
Auxiliary systems			
– Compressed air	+		
– Cover gas	+		
– Shield cooling system	+		

[a] A periodic testing activity, not necessarily part of the in-service inspection programme.

[b] The shutdown margin is the negative reactivity provided in addition to the negative reactivity necessary to maintain the reactor in a subcritical condition without a time limit, with the most reactive control device removed from the core and with all experiments that can be moved or changed during operation in their most reactive condition.

[c] In forced flow operation mode only.

[d] Rundown means automatic insertion of control elements.

Annex III

EXAMPLE OF A WORK PERMIT FORM

WORK PERMIT PRIOR APPROVAL REQUIRED BEFORE ANY WORK IS INITIATED		
A. WORK REQUEST (initiator)		
Requested by:	Date:	
Equipment identification:		
Job description:		
B. WORK REQUIREMENTS (maintenance supervisor)		
Name and title of personnel required:		
Special requirements:		
Attached procedures, drawings, manuals, etc.:		
Isolation requirements:		
	Date:	Signature:
C. RADIATION PROTECTION (radiation protection supervisor)		
Area dose rate:	Expected work time:	Number of workers:
Radiation protection measures to be used:		
	Date:	Signature:
D. WORK APPROVAL (reactor manager)		
Additional instructions:		
Beginning of work on (date and time):		
	Date:	Signature:
E. CONTROL ROOM NOTIFICATION (shift supervisor)		
The equipment has been isolated (if required):		
	Date:	Signature:
F. WORK COMPLETION CERTIFICATION		
Maintenance supervisor	Date:	Signature:
Reactor manager	Date:	Signature:
Shift supervisor	Date:	Signature:

GLOSSARY

audit. A documented activity performed to determine by investigation, examination and evaluation of objective evidence the adequacy of, and adherence to, established procedures, instructions, specifications, codes, standards, administrative or operational programmes and other applicable documents, and the effectiveness of their implementation.

authorization. The granting by a regulatory body or other governmental body of written permission for an operator to perform specified activities.

- Authorization could include, for example, licensing, certification, registration, etc.
- The term authorization is also sometimes used to describe the document granting such permission.
- Authorization is normally a more formal process than approval.

calibration (of an instrument, system or channel). A measurement of, or adjustment to, an instrument, component or system to ensure that its accuracy or response is acceptable.

channel. An arrangement of interconnected components within a system that initiates a single output. A channel loses its identity where single output signals are combined with signals from other channels (e.g. from a monitoring channel or a safety actuation channel).

confinement. Prevention or control of releases of radioactive material to the environment in operation or in accidents.

construction. The process of manufacturing and assembling the components of a facility, the carrying out of civil works, the installation of components and equipment and the performance of associated tests.

containment. Methods or physical structures designed to prevent or control the release and the dispersion of radioactive substances.

inspection. An examination, observation, measurement or test undertaken to assess structures, systems and components and materials, as well as operational activities, technical processes, organizational processes, procedures and personnel competence.

maintenance. The organized activity, both administrative and technical, of keeping structures, systems and components in good operating condition, including both preventive and corrective (or repair) aspects.

monitoring. Continuous or periodic measurement of radiological or other parameters or determination of the status of a system, structure or component. Sampling may be involved as a preliminary step to measurement.

normal operation. Operation within specified operational limits and conditions.

operability check. Test to verify that a system or component is capable of performing its intended function.

operating organization. An organization applying for authorization or authorized to operate an authorized facility and responsible for its safety.

operation. All activities performed to achieve the purpose for which an authorized facility was constructed. (For a research reactor, this includes maintenance, refuelling and other associated activities.)

operational limits and conditions. A set of rules setting forth parameter limits, the functional capability and the performance levels of equipment and personnel approved by the regulatory body for safe operation of an authorized facility.

periodic testing. Inspections, operability checks and calibrations carried out on parameter values, structures, systems and components to verify compliance with operational limits and conditions and to ensure adequacy of the safety status of the reactor.

protection system. System that monitors the operation of a reactor and which, on sensing an abnormal condition, automatically initiates actions to prevent an unsafe or potentially unsafe condition. (It encompasses all electrical and mechanical devices and circuitry involved in generating those signals associated with the protective function, from sensors to actuation device input terminals.)

research reactor[1]**.** A nuclear reactor used mainly for the generation and utilization of neutron flux and ionizing radiation for research and certain other purposes.

(nuclear) safety. The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards.

safety analysis report. A document provided by the applicant to the regulatory body in support of an application for authorization, containing information concerning the nuclear facility, its design, the safety analysis and provisions to minimize the risk to operating personnel, the public and the environment.

safety limits. Limits on operational parameters within which an authorized facility has been shown to be safe. Safety limits are operational limits and conditions beyond those for normal operation.

safety system[2]**.** A system important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents.

shutdown system. A safety system to execute the shutdown of the reactor by rapid reactivity reduction, actuated either manually or on the receipt of a signal from the protection system.

surveillance testing. Periodic testing to verify that structures, systems and components continue to function or are capable of performing their functions when called upon to do so.

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[1] For the purposes of this Safety Guide, the term research reactor also includes associated experimental facilities and critical assemblies.

[2] Safety systems can be of the active or passive type. Active systems or components are those that will initiate their assigned functions upon receiving an input signal from the protection system or manually. Passive systems or components are those that do not need an input signal to initiate their assigned functions. There is a recognized degree of passivity for safety systems that allows for a definition (not universally recognized) of three categories. The highest category is the one in which all the components needed for safety are passive.

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