IAEA Safety Standards

for protecting people and the environment

Maintenance, Periodic Testing and Inspection of Research Reactors

Specific Safety Guide

No. SSG-81

IAEA
International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

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

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

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

https://www.iaea.org/resources/safety-standards

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

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

RELATED PUBLICATIONS

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

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

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

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

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

MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

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

IAEA SAFETY STANDARDS SERIES No. SSG-81

MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

SPECIFIC SAFETY GUIDE

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FOREWORD

by Rafael Mariano Grossi
Director General

The IAEA's Statute authorizes it to "establish…standards of safety for protection of health and minimization of danger to life and property". These are standards that the IAEA must apply to its own operations, and that States can apply through their national regulations.

The IAEA started its safety standards programme in 1958 and there have been many developments since. As Director General, I am committed to ensuring that the IAEA maintains and improves upon this integrated, comprehensive and consistent set of up to date, user friendly and fit for purpose safety standards of high quality. Their proper application in the use of nuclear science and technology should offer a high level of protection for people and the environment across the world and provide the confidence necessary to allow for the ongoing use of nuclear technology for the benefit of all.

Safety is a national responsibility underpinned by a number of international conventions. The IAEA safety standards form a basis for these legal instruments and serve as a global reference to help parties meet their obligations. While safety standards are not legally binding on Member States, they are widely applied. They have become an indispensable reference point and a common denominator for the vast majority of Member States that have adopted these standards for use in national regulations to enhance safety in nuclear power generation, research reactors and fuel cycle facilities as well as in nuclear applications in medicine, industry, agriculture and research.

The IAEA safety standards are based on the practical experience of its Member States and produced through international consensus. The involvement of the members of the Safety Standards Committees, the Nuclear Security Guidance Committee and the Commission on Safety Standards is particularly important, and I am grateful to all those who contribute their knowledge and expertise to this endeavour.

The IAEA also uses these safety standards when it assists Member States through its review missions and advisory services. This helps Member States in the application of the standards and enables valuable experience and insight to be shared. Feedback from these missions and services, and lessons identified from events and experience in the use and application of the safety standards, are taken into account during their periodic revision.

I believe the IAEA safety standards and their application make an invaluable contribution to ensuring a high level of safety in the use of nuclear technology. I encourage all Member States to promote and apply these standards, and to work with the IAEA to uphold their quality now and in the future.

THE IAEA SAFETY STANDARDS

BACKGROUND

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

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

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

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

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

Safety Fundamentals

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

Safety Requirements

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

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it

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

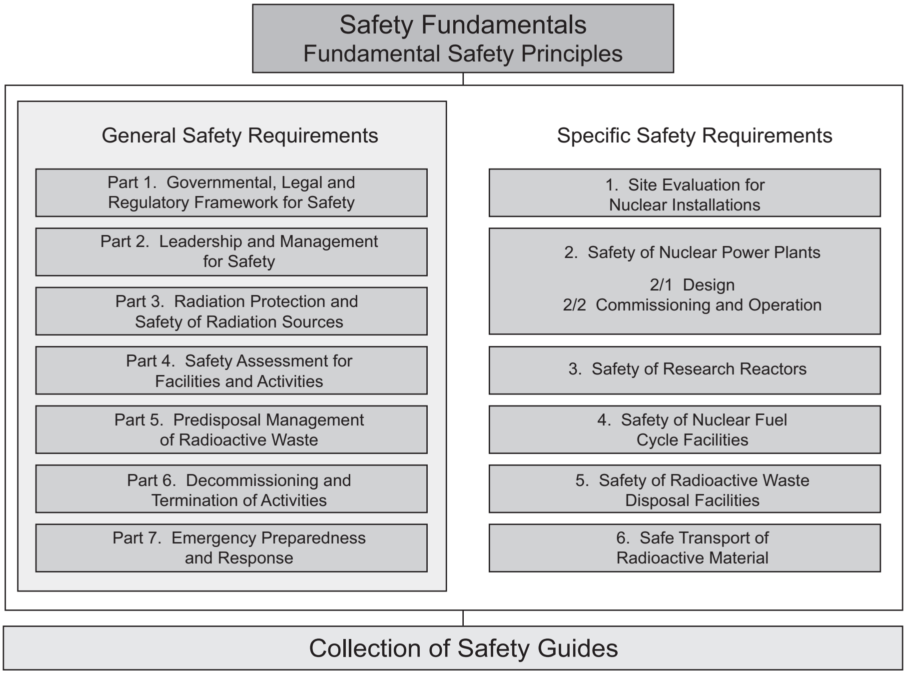

FIG. 1. The long term structure of the IAEA Safety Standards Series.

is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

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

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

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

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

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

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

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five Safety Standards Committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

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

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards.

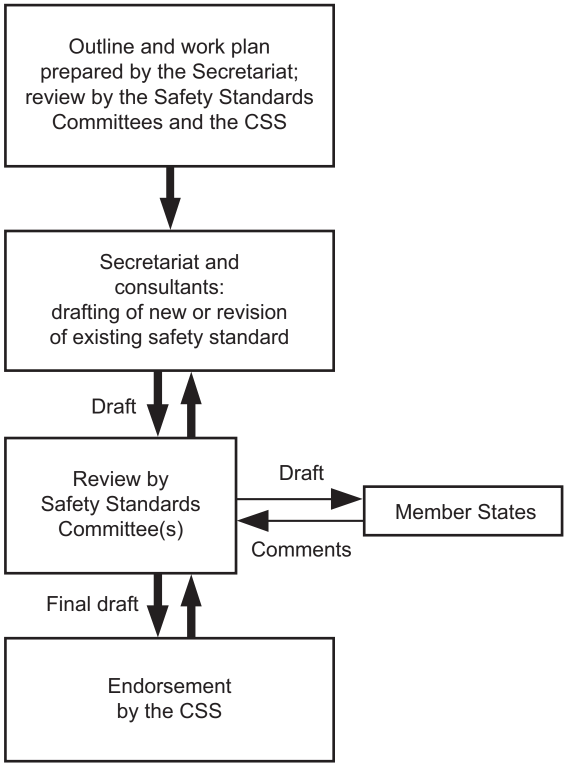

FIG. 2. The process for developing a new safety standard or revising an existing standard.

It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

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

INTERPRETATION OF THE TEXT

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

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

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

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

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Requirements for the safety of research reactors, with particular emphasis on their design and operation, are established in IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors [1].

1.2. This Safety Guide provides recommendations on the maintenance, periodic testing and inspection of research reactors.[1]

1.3. This Safety Guide was developed in parallel with seven other Safety Guides on the safety of research reactors, as follows:

(a) IAEA Safety Standards Series No. SSG-80, Commissioning of Research Reactors [2];
(b) IAEA Safety Standards Series No. SSG-82, Core Management and Fuel Handling for Research Reactors [3];
(c) IAEA Safety Standards Series No. SSG-83, Operational Limits and Conditions and Operating Procedures for Research Reactors [4];
(d) IAEA Safety Standards Series No. SSG-84, The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors [5];
(e) IAEA Safety Standards Series No. SSG-85, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors [6];
(f) IAEA Safety Standards Series No. SSG-10 (Rev. 1), Ageing Management for Research Reactors [7];
(g) IAEA Safety Standards Series No. SSG-37 (Rev. 1), Instrumentation and Control Systems and Software Important to Safety for Research Reactors [8].

1.4. Additional recommendations on the safety of research reactors are provided in IAEA Safety Standards Series Nos SSG-20 (Rev. 1), Safety Assessment for

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[1] Some organizations use the terms ‘surveillance’ or ‘surveillance testing’ for periodic testing. In addition, ‘inspection’, as in the title of this Safety Guide, is equivalent to ‘in-service inspection’ in some organizations. Periodic testing includes inspections, operability checks and calibrations performed on parameter values and on structures, systems and components to verify compliance with operational limits and conditions and to ensure adequacy of the safety status of the research reactor.

Research Reactors and Preparation of the Safety Analysis Report [9], and SSG-24 (Rev. 1), Safety in the Utilization and Modification of Research Reactors [10].

1.5. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Nuclear Safety and Security Glossary [11].

1.6. This Safety Guide supersedes IAEA Safety Standards Series No. NS-G-4.2, Maintenance, Periodic Testing and Inspection of Research Reactors[2].

OBJECTIVE

1.7. The objective of this Safety Guide is to provide recommendations on maintenance, periodic testing and inspection of research reactors, to meet the relevant requirements established in SSR-3 [1], in particular Requirements 31 and 77.

1.8. The recommendations provided in this Safety Guide are aimed at operating organizations of research reactors, regulatory bodies and other organizations involved in a research reactor project.

SCOPE

1.9. This Safety Guide is primarily intended for use for heterogeneous, thermal spectrum research reactors that have a power rating of up to several tens of megawatts. For research reactors of higher power, specialized reactors (e.g. fast spectrum reactors) and reactors that have specialized facilities (e.g. hot or cold neutron sources, high pressure and high temperature loops), additional guidance may be needed. For such research reactors, the recommendations provided in IAEA Safety Standards Series No. SSG-74, Maintenance, Testing, Surveillance and Inspection in Nuclear Power Plants [12], might be more suitable. Homogeneous reactors and accelerator driven systems are outside the scope of this publication.

1.10. Some research reactors, critical assemblies and subcritical assemblies with a low hazard potential might need a less comprehensive programme for maintenance, periodic testing and inspection. While all recommendations in this Safety Guide are to be considered, some might not be applicable to such research

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[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Maintenance, Periodic Testing and Inspection of Research Reactors, IAEA Safety Standards Series No. NS-G-4.2, IAEA, Vienna (2006).

reactors, critical assemblies and subcritical assemblies (see Requirement 12 and paras 2.15–2.17 of SSR-3 [1], as well as IAEA Safety Standards Series No. SSG-22 (Rev. 1), Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors [13]).

1.11. In this Safety Guide, subcritical assemblies will be mentioned separately only if a specific recommendation is not relevant for, or is applicable only to, subcritical assemblies.

1.12. The establishment of programmes for maintenance, periodic testing and inspection is normally a regulatory requirement for the authorization of a research reactor. However, the scope and format of programmes to meet this 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 considers the following:

(a) Preventive maintenance and corrective maintenance of the structures, systems and components (SSCs) of a research reactor, in accordance with the recommendations of designers, constructors, manufacturers and support groups, and as adopted by operating organizations;
(b) Periodic testing intended to ensure that the operation of a research reactor remains within the established operational limits and conditions (OLCs);
(c) Inspections of SSCs initiated by the operating organization to determine whether they are acceptable for continued safe operation of the research reactor.

STRUCTURE

1.13. Section 2 provides recommendations on the management system for a research reactor as it relates to maintenance, periodic testing and inspection. Section 3 provides recommendations on maintenance, periodic testing and inspection, and the interrelationships of the three activities and their common terminology. Section 4 provides recommendations on design considerations with regard to the ability to maintain, test and inspect research reactors and experiments. Section 5 provides recommendations on the preparation of the programmes for maintenance, periodic testing and inspection, and Sections 6–9 provide recommendations on the main concepts of these programmes. Sections 10, 11 and 12 provide recommendations on maintenance facilities, on procurement, receipt and storage of spare parts, components and materials, and on testing and inspection methods, respectively. The Appendix explains the relationships between terms used in this Safety Guide, and the three annexes provide examples of preventive maintenance activities, periodic testing activities and a work permit.

2. APPLICATION OF THE MANAGEMENT SYSTEM TO THE MAINTENANCE, PERIODIC TESTING AND INSPECTION OF A RESEARCH REACTOR

2.1. A management system that integrates safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements for the research reactor project is required to be developed (see Requirement 4 of SSR-3 [1]). The documentation of the management system should describe the system that controls the planning and implementation of all activities at the research reactor, including maintenance, periodic testing and inspection. Approval of the management system (or parts thereof) by the regulatory body may be required (see para. 4.12 of SSR-3 [1]).

2.2. In accordance with paras 4.13–4.20 of SSR-3 [1], the management system is required to cover four functional categories, as follows:

(a) Management responsibility: includes providing the means and management support needed to achieve the organization's objectives (see paras 2.12 and 2.13 of this Safety Guide);
(b) Resource management: includes the 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 (see paras 2.14–2.20 of this Safety Guide);
(c) Process implementation: includes those actions and tasks needed to achieve the goals of the organization (see paras 2.21–2.28 of this Safety Guide);
(d) Measurement, assessment and improvement of the management system: includes activities conducted to evaluate the effectiveness of management processes and work performance (see paras 2.29–2.37 of this Safety Guide).

General requirements for the management system are established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [14]. Specific recommendations are provided in IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installations [15].

2.3. As part of the management system, the arrangements for the management of maintenance, periodic testing and inspection of the research reactor should be established and implemented by the operating organization early in the research reactor project. These arrangements 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. This should provide confidence that these activities are performed in accordance with established codes, standards, specifications, procedures and administrative controls, as required by para. 4.16 of SSR-3 [1].

2.4. In establishing the management system, a graded approach in accordance with the relative importance to safety of each item or process is required to be used (see para. 4.7 of SSR-3 [1]).

2.5. The objective of the management system as applied to maintenance, periodic testing and inspection should be to ensure that the facility meets the following:

(a) Regulatory requirements;
(b) Design requirements and assumptions;
(c) The safety analysis report (see Requirement 1 of SSR-3 [1]);
(d) The OLCs for the research reactor (see Requirement 71 of SSR-3 [1]);
(e) Administrative requirements associated with the management of the research reactor.

2.6. The management system is required to support the development, implementation and enhancement of a strong safety culture (see paras 1.5(b) and 4.9 of GSR Part 2 [14]). This safety culture should be applied in all aspects of the programmes for maintenance, periodic testing and inspection.

2.7. The maintenance, periodic testing and inspection of the SSCs of the research reactor are required to be considered during the design stage (see Section 4), and programmes for maintenance, periodic testing and inspection should be developed during the pre-operational stages. Pertinent information from designers, manufacturers and other operating organizations should be used.

2.8. Successful implementation of the management system should ensure that the programmes for maintenance, periodic testing and inspection include the following:

(a) Planning and prioritizing work;
(b) Addressing regulatory requirements;
(c) Ensuring compliance with the OLCs;

(d) Ensuring the availability of sufficient qualified personnel with suitable skills;
(e) Implementing appropriate procedures for maintenance, periodic testing and inspection;
(f) Ensuring the availability of spare parts;
(g) Ensuring the availability of special instruments and equipment;
(h) Ensuring a satisfactory working environment, including isolation of SSCs, worker protection and consideration of radiation hazards;
(i) Performing and documenting the necessary maintenance, periodic testing and inspection activities.

2.9. Paragraph 7.69 of SSR-3 [1] states that "All maintenance, periodic testing and inspection of systems or items important to safety shall be performed by following approved written procedures." In addition, the results of maintenance, periodic testing and inspection are required to be recorded in accordance with written procedures (see para. 7.95 of SSR-3 [1]).

2.10. Documents such as the procedures, specifications and drawings associated with the programmes for maintenance, periodic testing and inspection should be prepared, reviewed, updated, approved, issued, validated and archived in accordance with the management system for the research reactor.

2.11. Records essential to the performance and verification of activities for maintenance, periodic testing and inspection are required to be controlled through a system for their identification, approval, issue, validation, review, filing, retrieval and disposal (see Requirement 8 of GSR Part 2 [14]).

MANAGEMENT RESPONSIBILITY FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF A RESEARCH REACTOR

2.12. The operating organization should prepare and issue specifications and procedures for maintenance, periodic testing and inspection. The reactor manager[3] should be an active participant in executing and evaluating the work done in maintenance, periodic testing and inspection. The responsibilities of the reactor manager are described in paras 6.17–6.20.

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

2.13. The management of the operating organization should participate in the programmes for maintenance, periodic testing and inspection by means of the following:

(a) Scheduling and tracking maintenance activities to ensure that all maintenance specified in the OLCs and by the regulatory body is performed;
(b) Having frequent contact with maintenance personnel, including observation of work in progress;
(c) Supervising contractor personnel who perform maintenance, periodic testing and inspection;
(d) Establishing and implementing a set of performance indicators for maintenance, periodic testing and inspection;
(e) Participating in evaluations of the programmes for maintenance, periodic testing and inspection;
(f) Providing feedback derived from maintenance performance indicators for use in the operation of the research reactor.

RESOURCE MANAGEMENT FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF A RESEARCH REACTOR

2.14. Paragraph 4.15(c) of SSR-3 [1] states that "The management system shall ensure that: ...The equipment, tools, materials, hardware and software necessary to conduct the work in a safe manner are identified, provided, checked, and verified and maintained."

2.15. Maintenance, including corrective maintenance (the repair and restoration of defective items), is normally performed using a work control system (see Section 9). If the defective item affects the safe and reliable operation of the research reactor, the deficiency should be brought to the attention of the operating personnel and, where appropriate, the management of the operating organization.

2.16. The equipment, tools, materials, hardware and software necessary to conduct maintenance, periodic testing and inspection are required to be identified and controlled to ensure their proper use (see para. 7.73 of SSR-3 [1]).

2.17. The facilities, tools, materials, hardware and software necessary to perform 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.

2.18. In accordance with para. 7.28 of SSR-3 [1], the competence requirements for personnel performing maintenance, periodic testing and inspection are required to be determined. Training is required to be provided (see paras 7.29 and 7.30 of SSR-3 [1]) to ensure that personnel are competent to perform their assigned work.

2.19. Paragraph 4.15(b) of SSR-3 [1] states:

> "The management system shall ensure that: …External personnel (including suppliers and experimenters) are adequately trained and qualified and perform their activities under the same controls and to the same standards as the reactor personnel".

These external personnel should receive the same general training provided to operating personnel, as well as specific training in maintenance, periodic testing and inspection procedures and practices. Adequate time should be provided for this training. Experienced and qualified personnel may be allowed to forgo such training by proving their proficiency. Research reactor 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.

2.20. Paragraph 4.15(a) of SSR-3 [1] states:

> "The management system shall ensure that: …Suppliers, manufacturers and designers of structures, systems and components important to safety have an effective integrated management system in place, with audits to confirm its effectiveness".

Arrangements should be made with vendors and suppliers to ensure that the regulatory body is provided with any information it has requested.

PROCESS IMPLEMENTATION FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF A RESEARCH REACTOR

2.21. 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 clear assignment of responsibility.

2.22. The operating organization should nominate a person to be responsible and accountable for developing and documenting the programmes for maintenance, periodic testing and inspection; monitoring the performance of these programmes; ensuring that the personnel are competent; and evaluating the impact of the programmes on safety. This person is usually the reactor manager or a maintenance supervisor acting on behalf of the reactor manager.

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

2.24. Inspection, testing, verification and validation activities should be included in the procedures for maintenance, periodic testing and inspection, as necessary. These activities should be completed before putting into operation any SSCs that have undergone maintenance, periodic testing and inspection.

2.25. Appropriate monitoring and measurement should be performed on SSCs important to safety (see annex I to SSR-3 [1]) to provide evidence of conformity to design requirements and satisfactory performance in service.

2.26. Paragraph 4.19 of SSR-3 [1] states that "Suppliers shall be evaluated and selected on the basis of specified criteria." Such criteria should be developed and documented within the operating organization's procurement process and form part of the management system for the research reactor.

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

2.28. The scope and frequency of periodic testing (see Section 5) 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.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT OF THE MANAGEMENT SYSTEM FOR A RESEARCH REACTOR

2.29. Paragraph 4.20 of SSR-3 [1] states:

> "The effectiveness of the management system shall be regularly measured and assessed through independent assessments and self-assessments.

Weaknesses in processes shall be identified and corrected. The operating organization shall evaluate the results of such assessments and shall determine and take the necessary actions for continuous improvements.”

2.30. Assessment measures, including review and verification, should be established to ensure that maintenance, periodic testing and inspection activities are performed as specified in the appropriate procedures. These measures should include the following:

(a) Review of maintenance, periodic testing and inspection procedures;
(b) Verification by means of inspection, witnessing and surveillance;
(c) Review and verification of maintenance, periodic testing and inspection records, results and reports, including those on the status of non-conformance and corrective actions;
(d) Verification of the adequacy and timeliness of corrective actions.

2.31. The effective implementation of the management system in relation to maintenance, periodic testing and inspection should be assessed by qualified personnel who are not directly involved in performing these activities.

2.32. Audits should be performed to determine the adequacy and effectiveness of, and adherence to, the management system in relation to maintenance, periodic testing and inspection. The audits should pay particular attention to the interfaces and transfers of responsibilities that occur between the maintenance group (see Section 6) and the operations group. The need for auditing of the management system by an independent organization should be given due consideration.

2.33. 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. The frequency of maintenance, periodic testing and inspection of individual SSCs is required to be adjusted on the basis of such experience to ensure adequate reliability (see para. 7.72 of SSR-3 [1]).

2.34. Paragraph 7.76 of SSR-3 [1] states that “The safety committee and the regulatory body shall be informed of any non-conformance that is significant to safety. An assessment shall be made of the impact of the non-conformance on the maintenance programme.” Near misses should also be recorded and analysed.

2.35. Maintenance, periodic testing and inspection activities should be monitored, and trends should be evaluated to identify any necessary improvements to the performance of these activities.

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

(a) Availability of safety systems;
(b) Availability of the research reactor for utilization;
(c) Occupational exposure of personnel conducting maintenance activities;
(d) The occurrence and nature of any injuries and accidents due to the failure of SSCs;
(e) The occurrence and nature of any injuries and accidents to personnel during maintenance, periodic testing and inspection activities;
(f) Any backlog of maintenance, periodic testing and inspection activities;
(g) Assessment results of maintenance, periodic testing and inspection areas.

2.37. An organizational unit should be established with the responsibility of conducting independent assessments of the programmes for maintenance, periodic testing and inspection on behalf of the operating organization. Such an assessment could be performed by the reactor safety committee, as described in para. 7.19 of SSR-3 [1].

3. OVERVIEW OF MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

3.1. The objectives of maintenance, periodic testing and inspection are to ensure that the SSCs of the research reactor function in accordance with the design intent and in compliance with the OLCs, and to ensure compliance with the safety analysis report (see paras 7.68 and 7.38 of SSR-3 [1], respectively). The programmes for maintenance, periodic testing and inspection should, as far as reasonably practicable, include those SSCs (mobile or permanently installed) that could be necessary in response to design extension conditions. The programme should meet the expectations for safety as derived from the following:

(a) The safety analysis report;
(b) The OLCs;
(c) Regulatory body requirements;
(d) Reactor management[4] requirements;
(e) Designer and manufacturer recommendations;
(f) Operating experience.

3.2. All maintenance, periodic testing and inspection should be conducted while maintaining control over the research reactor at all times and without reducing or jeopardizing the safety of the reactor.

INTERRELATIONSHIP BETWEEN MAINTENANCE, PERIODIC TESTING AND INSPECTION

3.3. Although maintenance, periodic testing and inspection may be included in a single programme at a research reactor and may be performed by the same personnel, 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 IAEA Nuclear Safety and Security Glossary [11] and are described in the Appendix.

3.4. Maintenance may include tests similar to those performed under periodic testing (i.e. inspections, operability checks and calibrations). While these tests are primarily intended to verify that the maintenance has been properly completed, such a test — when performed — may also be considered to satisfy conditions for periodic testing, provided the frequency of testing is consistent with that programme.

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

3.6. Inspection, while inherent in all maintenance and periodic testing, is an examination of SSCs for deterioration to determine whether they are acceptable

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

for continued operation or whether remedial measures should be taken. In this Safety Guide, inspection also refers to specific, non-routine examination for assessing ageing effects on SSCs. Inspection is sometimes referred to as in-service inspection.

3.7. Maintenance, periodic testing and inspection have common objectives, as stated in para. 3.1. Maintenance should always be followed by testing. The results of periodic testing and inspection should be compared with acceptance criteria for the SSC being tested or inspected. If the results fall outside the acceptance 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 has been completed to ensure that the acceptance criteria are met. A common database should be established to share data and evaluations among the organizations involved in the planning and implementation of maintenance, periodic testing and inspection at a research reactor.

3.8. 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 safety analysis report and the OLCs. In this Safety Guide, these three types of testing are considered separately.

MAINTENANCE OF RESEARCH REACTORS

3.9. 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 research 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 for safe operation (see para. 7.37 of SSR-3 [1]).

Preventive maintenance

3.10. 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 research reactor's SSCs to perform their intended functions. A list of typical preventive maintenance activities is presented in Annex I.

3.11. Preventive maintenance should be performed on SSCs, as follows:

(a) As specified by designers and/or manufacturers;
(b) In accordance with regulatory requirements;
(c) As determined by the reactor management (e.g. on the basis of safety reviews or operating experience or for other reasons, such as to meet insurance stipulations).

3.12. Manufacturer 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.

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

(a) Periodic maintenance activities should be accomplished on a routine basis and may include inspections, alignments, calibrations, overhauls or replacements of SSCs.
(b) Predictive maintenance activities should involve continuous or periodic monitoring, where possible, to predict the failure of SSCs.
(c) Planned maintenance activities should be performed prior to the degradation or failure of SSCs and may be initiated on the basis of experience, the results of predictive or periodic maintenance, or the recommendations of designers and manufacturers, or for the reason stated in para. 3.14.

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

3.15. To predict failures of SSCs, data relating to failures, including root causes, should be collected and stored (see also paras 2.33 and 2.35). These data, usually in the form of reports, should be analysed and used as inputs to the preventive maintenance programme.

Corrective maintenance

3.16. Corrective maintenance consists of repair and/or replacement activities to restore the capabilities of failed SSCs to perform their intended functions. The preventive maintenance programme will reduce the need for corrective maintenance and might result in extended availability of SSCs and cost reductions. However, the need for corrective maintenance cannot be totally eliminated. In accordance with para. 7.9(j) of SSR-3 [1], adequate resources, such as human resources, spare parts and funds, are required to be allocated for corrective maintenance.

3.17. If a maintenance activity necessitates a change to an SSC or to the original design, procedures for the implementation of a modification should be followed. Further recommendations are provided in SSG-24 (Rev. 1) [10].

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

3.19. Paragraph 7.75 of SSR-3 [1] states:

> "Properly qualified personnel, who shall verify that the activities have been accomplished as specified in the appropriate procedure and shall verify compliance with the operational limits and conditions, shall assess the results of maintenance, periodic testing and inspection."

3.20. Following maintenance or repair activities, any potentially affected SSCs should be inspected and, where necessary, recalibrated and tested for approval for operation by the maintenance supervisor.

3.21. The use of risk informed maintenance strategies should be considered in order to provide a reasonable balance between corrective maintenance and preventive maintenance and to facilitate proactive maintenance rather than exclusively corrective maintenance. The reasons for corrective maintenance should be evaluated, and — if appropriate — the preventive maintenance programme should be revised accordingly.

PERIODIC TESTING OF RESEARCH REACTORS

3.22. Periodic testing should be performed to maintain and improve the availability of equipment, to ensure compliance with the OLCs, and to detect and correct abnormal conditions before they can affect the safety of the research reactor. The abnormal conditions include not only deficiencies in the performance of SSCs and software but also trends within the acceptance criteria that indicate that the performance of one or more SSCs is deviating from the design intent.

3.23. The performance of periodic testing often fulfils the surveillance requirements that form part of the OLCs in the authorization for the operation of the research reactor issued by the regulatory body.

3.24. Periodic testing, which is usually performed at fixed time intervals, also includes repetitive tests performed 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 relating to a new core configuration).

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

3.26. 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.

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

INSPECTION OF RESEARCH REACTORS

3.28. The operating organization should inspect SSCs for deterioration in accordance with a predetermined schedule. These inspections should evaluate the effects of ageing mechanisms on SSCs to determine whether the SSCs 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.

3.29. Routine inspection of SSCs should include the following:

(a) Observation of the condition of equipment (e.g. leaks, noise, vibration), normally performed during periodic walkdowns of the research reactor. For the inspection of some systems, devices such as cameras, telescopes and binoculars may be needed.
(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, activation of emergency ventilation as applicable).
(f) Calculations (e.g. hot channel factors, fuel burnup as applicable) or measurements (e.g. using instrumented fuel elements as applicable) to verify compliance with the OLCs.

3.30. Inspection results should be evaluated using baseline data collected during the pre-service inspections (and revised as appropriate during subsequent inspections). 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.

3.31. Non-destructive testing and non-destructive inspection techniques, discussed in Section 12, should be used together with measurements and chemical analysis.

4. DESIGN CONSIDERATIONS FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

4.1. Requirement 31 of SSR-3 [1] states:

> "**Items important to safety for a research reactor facility shall be designed to be calibrated, tested, maintained, repaired or replaced, inspected and monitored as required to ensure their capability of performing their functions and to maintain their integrity in all conditions specified in their design basis.**"

4.2. The design of a research reactor should consider maintainability, testability and inspectability while ensuring that the radiation exposure of personnel performing maintenance, periodic testing and inspection is kept as low as reasonably achievable. This may be achieved through design features that minimize human involvement in maintenance, periodic testing and inspection of reactor systems, particularly those systems located in areas in which there is a significant radiation hazard.

DESIGN OF A RESEARCH REACTOR FOR MAINTAINABILITY

4.3. To facilitate maintenance of a research reactor, 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 levels of radiation from SSCs;
(e) Decontamination of SSCs.

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

4.5. The design of the research reactor is required to make provision for adequate shielding of radioactive components during maintenance (see para. 6.100 of SSR-3 [1]). One means of achieving this might 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 might 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. To facilitate maintenance during shutdown periods (e.g. for changing filters and resins), adequate local shielding should also be considered for equipment that is located in normally inaccessible rooms.

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 cameras and remotely controlled manipulating and cutting equipment and cleaning systems.

4.8. Paragraph 6.101 of SSR-3 [1] states that “Provision shall be made for appropriate decontamination facilities for both personnel and equipment and for handling the radioactive waste arising from decontamination activities.” In a research reactor, arrangements should be made for decontamination tasks to be performed locally (i.e. close to where the maintenance work is performed). Following major outages or situations involving significant contamination, external services could be used if available.

4.9. The research reactor should include provisions for mechanical, electrical and electronic workshops that are properly equipped to handle all relevant SSCs, including contaminated and activated equipment and components. Further recommendations are provided in Section 10.

DESIGN OF A RESEARCH REACTOR FOR TESTABILITY

4.10. Paragraph 6.86 of SSR-3 [1] states:

> "Items important to safety shall be designed to allow for appropriate functional testing to ensure that these items will perform their safety functions with the required reliability and shall be arranged so that they can be adequately tested and maintained as appropriate, before commissioning and at regular intervals thereafter, in accordance with their importance to safety."

This is particularly important for passive components and for systems whose ability to function is not normally verified by routine operations.

4.11. In addition, para. 6.87 of SSR-3 [1] states:

> "Important factors that shall be considered are the ease of performing the tests and inspections, the degree to which the tests and inspections represent real conditions, and the need to maintain the performance of the safety function during tests. Where possible and appropriate, self-testing circuits shall be installed in electrical and electronic systems."

4.12. Design 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.

4.13. 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.

4.14. Self-testing circuits may be of two types, as follows:

(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.

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

4.15. Tests for systems located in areas in which there is a significant radiation hazard should be designed to ensure that the radiation exposure of personnel is as low as reasonably achievable. Remote testing, shielding and appropriate scheduling can significantly reduce occupational exposures.

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 OF A RESEARCH REACTOR FOR INSPECTABILITY

4.17. The research 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 should be considered:

(a) The provision of adequate access for personnel and equipment, to facilitate the use of the necessary inspection methods and techniques;
(b) The need to optimize protection and safety;
(c) The ease of performance of operations associated with the repair or replacement of systems or components;
(d) The provision of adequate lighting and ventilation and access to utilities (e.g. electricity) needed to perform the inspections;
(e) The availability of decontamination facilities (see para. 4.8).

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

5. PROGRAMMES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

5.1. Requirement 77 of SSR-3 [1] states that "**The operating organization for a research reactor facility shall ensure that effective programmes for maintenance, periodic testing and inspection are established and implemented.**"

5.2. Maintenance, periodic testing and inspection conducted on a programmatic basis should be performed following a prepared plan and procedures. This plan should include experimental devices and equipment necessary for response to design extension conditions and may be presented in one or more documents.

5.3. The programmes for maintenance, periodic testing and inspection should be established early in the research reactor project and should be implemented during commissioning, before the commencement of routine operation.

5.4. Paragraph 7.69 of SSR-3 [1] states that "The maintenance, periodic testing and inspection programmes shall be reviewed at regular intervals to incorporate lessons learned from experience." Consequently, the programmes should be subject to continuing development and improvement throughout the lifetime of the research reactor. Special attention should be given to the collection of baseline data for comparison with observations made later in the lifetime of the research reactor.

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

5.6. Paragraph 7.68 of SSR-3 [1] states:

> "Maintenance...periodic testing and inspection shall be conducted to ensure that structures, systems and components are able to function in accordance with the design intent, in compliance with the operational limits and conditions."

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

(a) The safety analysis report;
(b) The OLCs and any other applicable regulatory requirements;
(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) Information from manufacturers (e.g. descriptions, specifications, operating manuals and service manuals);
(i) Failure data (where available);
(j) Information on maintenance practices from other reactors;
(k) Pre-service inspection data and reports.

CONTENT OF THE PROGRAMMES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

5.8. The programmes should be documented so as to enable the objectives and methods of maintenance, periodic testing and inspection of the research reactor to be clearly understood in order to facilitate the implementation, review and assessment of the programmes and to allow management control and coordination. The programme documentation should cover the following:

(a) General description;
(b) Management system;
(c) Organizational structure and responsibilities;
(d) Selection, training and qualification of maintenance personnel;
(e) SSCs included in the programmes;
(f) Technical and administrative procedures;
(g) Administrative controls;
(h) Scheduling of maintenance, periodic testing and inspection;
(i) Review and verification of the programmes;
(j) Documents and records associated with the programmes;
(k) Review of results of maintenance, periodic testing and inspection;
(l) Maintenance facilities at the research reactor;
(m) Procurement and storage of spare parts;
(n) Interface with the ageing management programme (see SSG-10 (Rev. 1) [7]).

These elements of the programmes are described in paras 5.9–5.29.

General description

5.9. The general description should state the overall objectives, specifications and scope of the programmes for maintenance, periodic testing and inspection of the research reactor.

Management system

5.10. The programme documentation should detail the management system measures relevant to maintenance, periodic testing and inspection. Recommendations on the management system are provided in Section 2.

Organizational structure and responsibilities

5.11. The programme documentation should describe the organizational structure and define the responsibilities for maintenance, periodic testing and inspection within the operating organization of the research reactor. Recommendations on the organizational structure and responsibilities are provided in Section 6.

Selection, training and qualification of maintenance personnel

5.12. The programme documentation should specify the necessary qualifications and training of personnel performing maintenance, periodic testing and inspection. Recommendations on the selection, training and qualification of these personnel are provided in Section 7.

Structures, systems and components included in the programmes for maintenance, periodic testing and inspection

5.13. The programme documentation should include a list of all SSCs subject to maintenance, periodic testing and inspection. This list should include all SSCs 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 examples of SSCs to be included in the list.

Technical and administrative procedures and administrative controls

5.14. Procedures constitute an important part of the programme documentation, which 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.

5.15. Where other procedures (e.g. administrative procedures, radiation protection procedures) are used in conjunction with the procedures for maintenance, periodic testing and inspection, they should be properly referenced. Further recommendations on procedures for maintenance, periodic testing and inspection are provided in Section 8.

5.16. In addition to a list of the procedures for maintenance, periodic testing and inspection for each SSC, the programme documentation 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, record keeping) involved in the performance of tasks. Further recommendations on these administrative controls for maintenance, periodic testing and inspection are provided in Section 9.

Scheduling of maintenance, periodic testing and inspection

5.17. The programme documentation 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 or operating hours, with a range to allow for flexibility. The frequency of periodic testing of items important to safety should be included in the surveillance requirements of the OLCs.

5.18. Paragraph 7.72 of SSR-3 [1] states that "The frequency of maintenance, periodic testing and inspection of individual structures, systems, and components shall be adjusted on the basis of experience and shall be such as to ensure adequate reliability". When adjusting the frequency of maintenance, periodic testing and inspections, consideration should be given to the following:

(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;
(d) The recommendations of manufacturers and vendors.

5.19. Routine in-service inspection should be performed well before the predicted time of failure of SSCs. The scheduling should be prepared using conservative assumptions regarding the deterioration rate. The data collected in the ageing management programme may be used for this evaluation.

5.20. The frequency of maintenance, periodic testing and inspection of individual SSCs should also be consistent with the recommendations of the designer and manufacturer and should be adjusted in the light of experience gained by the operating organization, including operating experience from other facilities. Due consideration should also be given, where necessary, to the schedule for reactor operation.

Review and verification of the programmes for maintenance, periodic testing and inspection

5.21. The programmes should include arrangements for review and verification, including a review of procedures prior to implementation. The review of the programmes and procedures should be in accordance with the management system (see Section 2).

Documents and records associated with the programmes for maintenance, periodic testing and inspection

5.22. The documentation should specify the documents needed to implement the programmes; the records of maintenance, periodic testing and inspection produced by the programmes; and how this documentation is to be archived. The documents should be issued, approved, reviewed and maintained in accordance with the management system (see Section 2).

5.23. Typical documents associated with the programmes for maintenance, periodic testing and inspection are as follows:

(a) Management system documents;
(b) Plans and 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.

5.24. The programmes should include the need for records of 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 personnel in charge of the work and participating in the work;
(c) Date of execution;
(d) Reason for the work;
(e) Defects found and remedial actions taken;
(f) Resources used (e.g. personnel hours, materials, spare parts);
(g) Procedures, drawings and checklists used;
(h) Test results;
(i) Radiation doses received by personnel;
(j) Experience gained in executing the work;
(k) Status of the equipment;
(l) Recommendations for future actions.

5.25. The retention period for these records and reports should be in accordance with the management system (see Section 2).

Review of results of maintenance, periodic testing and inspection

5.26. The results of the maintenance, periodic testing and inspection activities should be assessed by qualified personnel (see para. 7.75 of SSR-3 [1]) who are not directly involved in performing these activities.

Maintenance facilities at the research reactor

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

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

Further recommendations on maintenance facilities are provided in Section 10.

Procurement and storage of spare parts

5.28. The programme documentation should describe the procurement process to support maintenance, periodic testing and inspection 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 recommendations are provided in Section 2 and Section 11.

Interface with the ageing management programme

5.29. In accordance with para. 7.120 of SSR-3 [1], the ageing management programme and the programmes for maintenance, periodic testing and inspection are required to be coordinated and consistent. Ageing related inspections may be performed during routine maintenance activities. The ageing management programme should be considered when developing or revising maintenance plans. The programmes for maintenance, periodic testing and inspection should be evaluated and, if necessary, updated on the basis of the findings of the ageing management programme. Recommendations on ageing management for research reactors are provided in SSG-10 (Rev. 1) [7].

NON-ROUTINE MAINTENANCE, TESTING AND INSPECTION OF RESEARCH REACTORS

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

5.31. The operating organization of the research reactor should establish arrangements for special non-routine maintenance, testing and inspection for specific objectives in addition to the regular programmes. Occasionally, this might be requested by the regulatory body or initiated by the operating organization to assess specific aspects of the safety status of SSCs (e.g. prior to modifications for upgrading or to assess ageing effects).

5.32. 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) that may result in unexpected failures. In accordance with Requirement 86 of SSR-3 [1], prevention of ageing related failures is required to be addressed through a formal ageing management programme. Recommendations on ageing management are provided in SSG-10 (Rev. 1) [7].

5.33. Special inspections should be scheduled, as appropriate, in coordination with the ageing management programme (see SSG-10 (Rev. 1) [7]) to determine the conditions of SSCs subject to corrosion, erosion, fatigue or other ageing effects. These inspections constitute a major activity in the operation of the reactor and are routinely scheduled in many research reactors. Examples of such inspections, as applicable to the design of the research reactor, are as follows:

(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 tubes;
(d) General examination of pipes (in particular embedded pipes), pumps and valves;
(e) Examination of spent fuel pools and tanks for storing liquids;
(f) Examination of electrical cabinets, cables, switchgear and transformers;
(g) Examination of systems for confinement, containment and ventilation.

5.34. Some components may be inspected during operation or during routine shutdowns and might give indications of problems that can be extrapolated to other components. The timing and scope of major inspections might be influenced by these results. To perform the inspections described in para. 5.33, it is usually necessary to shut down the research reactor and occasionally it is necessary to unload the core and drain the coolant. All susceptible components of the reactor should be inspected.

5.35. Where possible, a non-routine inspection should be made well before the predicted time of failure of the SSC. The scheduling should be prepared using conservative assumptions regarding the deterioration rate. The data collected in the ageing management programme may be used for this evaluation.

6. ORGANIZATIONAL STRUCTURE AND RESPONSIBILITIES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

ORGANIZATIONAL STRUCTURE FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

6.1. The organizational structure for maintenance, periodic testing and inspection of a research reactor will vary in accordance with national practices and the type of reactor. The reactor management is required to establish a maintenance group of operating personnel with specific responsibility for the implementation of the programmes for maintenance, periodic testing and inspection (see para. 7.22 of SSR-3 [1]). At some research reactors, critical assemblies and subcritical assemblies with low hazard potential, the operations group may be trained to perform maintenance tasks, periodic testing and inspection, thereby fulfilling the role of a maintenance group. In such cases, the functional independence of the persons authorizing, supervising and performing these activities should be ensured. At other research reactors, 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 maintenance personnel may be used in combination. Further guidance on the organizational structure of research reactors is provided in SSG-84 [5].

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

6.3. The maintenance group should be established at the beginning of a research reactor project, and this group should remain in close contact with the designers, the construction group and the commissioning group.

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 operating organizations, an intermediate position between the maintenance supervisor and the maintenance personnel might 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. Authorized reactor operators may perform the maintenance, assisted occasionally by outside experts, particularly for critical and subcritical facilities. The maintenance group may also engage experts (e.g. electricians, welders, metallurgists, experts in pump repair or in non-destructive testing and examination) from outside the maintenance group or from outside the operating organization.

6.5. The operating organization is also required to establish a radiation protection group (see para. 7.23 of SSR-3 [1]). This group should implement the radiation protection activities relating to maintenance, periodic testing and inspection. Paragraph 7.108 of SSR-3 [1] states that "The radiation protection programme…shall have sufficient independence and resources to be able to advise on and enforce radiation protection regulations, standards and procedures, and safe working practices." The organizational structure of a research reactor should promote cooperation between the radiation protection group and the maintenance group to ensure that maintenance procedures take due account of radiation protection and to provide direct radiation protection assistance when needed.

6.6. At many research reactors, a large amount of maintenance, testing and inspection is performed during a shutdown period that lasts for a period of a week or more. This results in a peak in demand for resources. The organization for maintenance, testing and inspection should be structured and staffed to meet this peak in demand.

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

COORDINATION AND INTERFACES IN MAINTENANCE, PERIODIC TESTING AND INSPECTION OF A RESEARCH REACTOR

6.8. Effective coordination should be established among the following:

(a) Different sections of the maintenance group (e.g. mechanical, electrical, instrumentation and control, civil engineering);
(b) The operations group, the radiation protection group, the maintenance, periodic testing and inspection group, and the ageing management group (if the ageing management programme is implemented by a separate group);
(c) The facility groups and contractors.

Interface control

6.9. An interface control system or procedure should be established that clearly defines the responsibilities of all groups that participate in maintenance, periodic testing and inspection activities. In particular, the interface between the operating organization and contractors should be clearly defined, with clear arrangements for maintaining configuration control to ensure the safety of the facility during and after the contracted work.

6.10. Adequate arrangements should be established for effective coordination in planning and implementing maintenance, periodic testing and inspection work on SSCs to manage the interface between safety and nuclear security (including physical security and computer security), as described in para. 9.1(g).

6.11. Interfaces should be addressed in the management system.

RESPONSIBILITIES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

Operating organization

6.12. Paragraph 7.9(h) of SSR-3 [1] states:

> "It shall be the responsibility of the operating organization to ensure…: The research reactor is operated and maintained in accordance with the safety requirements by suitably qualified and experienced personnel certified by the relevant authorities."

6.13. Although the operating organization may delegate or subcontract the execution of some tasks to other organizations, it cannot delegate its responsibility for safety (see para. 7.3 of SSR-3 [1]). In performing its responsibilities, in accordance with para. 7.9 of SSR-3 [1], the operating organization is required to ensure the following:

(a) A management system has been established and implemented (see Section 2).
(b) Procedures have been established and implemented to control and perform maintenance, periodic testing and inspection of the research reactor.
(c) Persons with responsibilities relating to maintenance, periodic testing and inspection are properly trained, and a training and retraining programme

has been established and implemented, which is updated and periodically reviewed to verify its effectiveness.
(d) Adequate facilities and services are available during maintenance, periodic testing and inspection.
(e) A strong safety culture (see Requirement 12 of GSR Part 2 [14]) has been fostered in the organization to ensure that the attitude of the personnel and the operating environment are conducive to safe maintenance, periodic testing and inspection.
(f) A programme to examine feedback from operating experience, including from other 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 the reactor management to allow it to effectively implement the programmes for maintenance, periodic testing and inspection.

6.14. In accordance with Requirement 3 of SSR-3 [1], the operating organization is required to ensure that the completion of maintenance, periodic testing and inspection activities relevant to the safety of personnel and to the safety of the reactor take priority over operational or production demands.

Regulatory body

6.15. The regulatory body has the following 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 (see paras 3.10, 3.11 and 4.3 of SSR-3 [1]);
(b) Reviewing, assessing and approving those parts of the programmes for maintenance, periodic testing and inspection that are related to the OLCs and the changes to them (see para. 7.33 of SSR-3 [1]);
(c) Ensuring that OLCs for maintenance, periodic testing and inspection reflect the conditions imposed by the regulatory body in the operating licence (see para. 7.34 of SSR-3 [1]);
(d) Conducting regulatory inspections (see para. 3.14 of SSR-3 [1]) to verify that maintenance, periodic testing and inspection activities are in conformance with the OLCs and applicable regulations, codes and standards;
(e) Reviewing information concerning any maintenance related events that are significant to safety (e.g. a violation of safety limits; see para. 7.35 of SSR-3 [1]) or a non-conformance with limiting conditions for safe operation (see para. 7.37 of SSR-3 [1])), as required by para. 7.76 of SSR-3 [1].

Reactor safety committee

6.16. Paragraph 7.26 of SSR-3 [1] states that “The reactor safety committee (or advisory group) shall advise the reactor manager on the safety aspects of the day to day operation and utilization of the reactor.” With regard to maintenance, periodic testing and inspection, the reactor safety committee should review and advise the operating organization and reactor manager on the following:

(a) Safety issues arising in the maintenance, periodic testing and inspection of the research 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 reactor safety committee may also be made responsible for conducting independent assessments of the programmes for maintenance, periodic testing and inspection.

Reactor manager

6.17. Requirement 69 of SSR-3 [1] states:

> “**The reactor manager shall have overall responsibility for all aspects of operation, training, maintenance, periodic testing, inspection, utilization and modification of the reactor. Discharge of this responsibility shall be the primary duty of the reactor manager.**”

6.18. Paragraph 7.71 of SSR-3 [1] states:

> “The decision to carry out maintenance work on installed equipment, to remove equipment from operation for maintenance purposes or to reinstall equipment after maintenance:
>
> (a) Shall be the responsibility of the reactor manager;
> (b) Shall be in accordance with the objective of maintaining the level of safety of the reactor as specified in the operational limits and conditions.”

The reactor manager should have overall responsibility for all aspects of maintenance, periodic testing and inspection and should ensure that there are clearly defined arrangements for the approval of maintenance, periodic testing and inspection activities. The responsibility for coordinating the work may be delegated by the reactor manager to the maintenance supervisor.

6.19. The reactor manager should be responsible for the following:

(a) Preparing the programmes for maintenance, periodic testing and inspection and ensuring their approval and implementation after review by the reactor safety committee;
(b) Preparing procedures to implement the programmes for maintenance, periodic testing and inspection;
(c) Approving work permits (see also para. 9.4(d));
(d) Training and retraining the maintenance personnel;
(e) Ensuring that only suitable, qualified, experienced and trained personnel undertake and supervise maintenance, periodic testing and inspection activities;
(f) Defining, in writing, the responsibilities and duties of the maintenance group members and their lines of communication;
(g) Initiating the approval and implementation of system modifications originated on the basis of maintenance, testing and inspection activities;
(h) Reviewing and correcting deficiencies revealed during the work;
(i) Coordinating and managing interfaces (see paras 6.8–6.11);
(j) Having frequent contact with the personnel performing maintenance, periodic testing and inspection of the research reactor, including the observation of work in progress;
(k) Participating in evaluations of the programmes for maintenance, periodic testing and inspection;
(l) Establishing and implementing a set of safety performance indicators to monitor and enhance the programmes for maintenance, periodic testing and inspection, and providing feedback for operations derived from these performance indicators.

6.20. The reactor manager may delegate the responsibilities listed in para. 6.19 to a maintenance supervisor or other responsible person.

Maintenance supervisor

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

(a) Implementing the programmes for maintenance, periodic testing and inspection in accordance with the management system and any instructions issued by the reactor manager;
(b) Reviewing the results of maintenance, periodic testing and inspection and assessing the impact of any deficiencies against the specified acceptance criteria;
(c) Recommending improvements to the programmes for maintenance, periodic testing and inspection, including changes to equipment, procedures or schedules;
(d) Promptly reporting to the reactor manager any deficiencies revealed during the work that 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 records and reports for approval;
(i) Procuring spare parts in accordance with specifications and the management system;
(j) Contributing to the preparation of procedures for maintenance, periodic testing and inspection, and updating these procedures on the basis of the experience gained from using the available facilities, equipment and tools;
(k) Planning and allocating resources in accordance with the management system;
(l) Supervising the work to ensure that procedures are followed;
(m) Preparing reports and records of maintenance, periodic testing and inspection;
(n) Coordinating maintenance, periodic testing and inspection activities with other groups;
(o) Considering proposals by maintenance personnel;
(p) Reporting the status of the work to the reactor manager;
(q) Certifying satisfactory completion of the work.

Contractors

6.22. The operating organization may delegate some maintenance, periodic testing and inspection activities to other organizations, but is required to retain overall responsibility for the safety of these activities (see paras 7.3 and 7.98 of SSR-3 [1]) and is required to perform all the necessary administrative and supervisory functions to ensure this (see para. 7.1 of SSR-3 [1]).

6.23. Contractors are required to be subject to the same standards as facility personnel (see para. 4.15(b) of SSR-3 [1]), 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.

6.24. Activities performed by contractors should be controlled by means of a management system that specifies the quality of their work, the training and qualifications 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, as well as the need for appropriate management of sensitive information (see para. 9.1).

Maintenance personnel

6.25. The responsibilities of the maintenance personnel should be as follows:

(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 optimize protection and safety.

7. SELECTION, TRAINING AND QUALIFICATION OF MAINTENANCE PERSONNEL AT A RESEARCH REACTOR

7.1. Maintenance personnel 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. The competence of maintenance personnel is required to be periodically evaluated (see para. 7.30 of SSR-3 [1]), and maintenance personnel should be requalified to ensure their continuing professional competence.

7.2. In accordance with para. 7.28 of SSR-3 [1], certain individuals who perform maintenance, periodic testing and/or inspections (e.g. of instrumentation and control systems, safety systems, shutdown systems or protection systems) might require authorization by a competent authority. In some research reactors, critical assemblies and subcritical assemblies with a low hazard potential, some of the maintenance, periodic testing and inspection activities may be performed by the operating personnel. In such cases, the functional independence of the persons authorizing, supervising and performing these activities should be ensured.

TABLE 1. TYPICAL QUALIFICATIONS FOR MAINTENANCE PERSONNEL AT RESEARCH REACTORS

Maintenance supervisor	College degree in physical sciences, engineering or equivalent
Section head (see para. 6.4)	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 might be desirable
Technician	Qualification in relevant technology acquired at an educational institution or by industrial training
Personnel with specific manual skills	Qualification in relevant manual skills, acquired at an educational institution or by industrial training

7.3. In addition to training in their specific skills, all maintenance personnel should receive training in the following:

(a) Principles of operation of research reactors;
(b) Radiation protection;
(c) Principles of SSCs important to safety;
(d) Specific knowledge of systems and equipment relevant to their duties;
(e) Nuclear safety and non-radiation-related 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;
(l) Safety culture;
(m) Human performance;
(n) The interface between safety and nuclear security in relation to maintenance activities;
(o) Ageing management programme.

The level of training in these subjects should be appropriate for the duties assigned to each individual. Personnel should have achieved the necessary level of competence in these subjects before being allowed to work independently. In accordance with para. 7.30 of SSR-3 [1], maintenance personnel are required to 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 installations should be reviewed and incorporated into the training programmes for maintenance personnel, as appropriate.

7.5. Contractor personnel who perform maintenance, periodic testing and inspection at a research reactor should be given training equivalent to that provided to personnel employed by the operating organization. For short term contractor personnel, most of the training identified in para. 7.3 may be replaced by supervision by a member of the maintenance group (see also paras 9.7 and 9.8).

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

7.7. The operating organization should ensure that maintenance personnel are provided with opportunities to further enhance the knowledge necessary to perform their duties.

8. PROCEDURES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION AT RESEARCH REACTORS

8.1. To implement the programmes for maintenance, periodic testing and inspection, the operating organization is required to ensure that appropriate controls are established, as described in para. 7.69 of SSR-3 [1]. These controls usually take the form of administrative procedures and work procedures for performing maintenance, periodic testing and inspection activities at the research reactor. As described in para. 2.10, these procedures should be prepared, reviewed, validated, issued and modified in accordance with the management system for the research reactor. A mechanism should be established to enable users of the procedures to provide feedback and 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. Recommendations on the preparation of procedures, including their format and content and the steps in their preparation, are provided in SSG-83 [4]. Recommendations on administrative controls for maintenance, periodic testing and inspection are provided in para. 8.4 and Section 9.

ADMINISTRATIVE PROCEDURES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION AT RESEARCH REACTORS

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

(a) The use of written procedures for maintenance, periodic testing and inspection;
(b) The use of work permits (see paras 9.2–9.4);

(c) Radiation protection;
(d) Control of the system configuration;
(e) Calibration of tools and equipment;
(f) Non-radiation-related safety and fire safety;
(g) The use of interlocks and keys;
(h) Nomenclature, location and labelling of equipment;
(i) Housekeeping;
(j) Planning of maintenance activities during reactor shutdowns;
(k) Equipment requalification and return of the reactor to an operational state;
(l) Considerations in managing the interface between safety and nuclear security;
(m) Human factors.

WORK PROCEDURES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION AT RESEARCH REACTORS

8.5. Work procedures for maintenance, periodic testing and inspection should include written instructions for performing the following:

(a) Maintenance of SSCs important to safety;
(b) Periodic testing, inspection and calibrations of SSCs 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.

8.6. In the preparation of procedures for maintenance, periodic testing and inspection, attention should be paid to the possible consequences of these procedures on safety systems and on reactor operation. Some procedures may be performed during operation with no impact on the safety of the reactor; other procedures may necessitate shutting down the reactor. Maintenance plans and a system of work permits should therefore be implemented to ensure that the maintenance procedures do not cause any action that will put the operation of the reactor outside the OLCs. 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).

8.7. In the preparation of procedures for maintenance, periodic testing and inspection, the requirement to keep radiation doses as low as reasonably achievable (see para. 2.6 of SSR-3 [1]) should be taken into account. Consideration should also be given during the preparation of procedures to ensuring that safety measures and security measures (including physical security and computer security) do not compromise one another.

8.8. Paragraph 7.69 of SSR-3 [1] states:

> "The procedures [for maintenance, periodic testing and inspection] shall specify the measures to be taken for any changes from the normal reactor configuration and shall include provisions for the restoration of the normal configuration on the completion of the activity."

8.9. Paragraph 7.69 of SSR-3 [1] also states:

> "In accordance with the requirements of the management system, a system of work permits shall be used for maintenance, periodic testing and inspection, including appropriate procedures and checklists before and after the conduct of the work. These procedures shall include acceptance criteria."

The procedures should include a need to obtain a final acceptance (including signature) by an individual qualified to assess the results of the activities performed under the procedures.

8.10. Special procedures should be prepared to control maintenance, periodic testing and inspection performed by contractors. These procedures should include prerequisites for the work, specifications for the supervision of contractor personnel and the qualification of these personnel, and arrangements for the coordination of the work.

8.11. The procedures should include corrective actions for resolving any non-conformance with the OLCs (see para. 7.41 of SSR-3 [1]).

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

8.13. Special procedures for inspection for minimization of ageing effects in SSCs important to safety should be developed and implemented (see also para. 5.29).

9. ADMINISTRATIVE CONTROLS FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION AT RESEARCH REACTORS

9.1. Administrative controls should be developed that take into account the interfaces between the maintenance and operation of the research reactor, radiation protection and nuclear security. The following elements should be explicitly addressed in these administrative controls:

(a) The demarcation between personnel performing maintenance and personnel directly responsible for operation of the facility (e.g. the shift supervisor).
(b) Provisions to ensure that the operating personnel have information about the status of the research reactor at all times during maintenance activities.
(c) A work permit system (see paras 9.2–9.4) and the designation of individuals who are authorized to issue and cancel work permits for maintenance, equipment isolation, live testing and access control.
(d) Direct positive indications of equipment that is out of service, including provisions to prevent unintentional return to service.
(e) Assurance that SSCs are inspected and tested after maintenance before being declared functional and returned to service.
(f) Return to operational status.
(g) Provisions to ensure that maintenance activities that affect both safety and nuclear security in the facility including the need for appropriate management of sensitive information, are coordinated in the planning stage to ensure that safety measures and security measures do not compromise one another before, during or after conduct of maintenance, periodic testing or inspection activities. Guidance on nuclear security is provided in the IAEA Nuclear Security Series [16–19].

WORK PERMIT SYSTEM FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION AT RESEARCH REACTORS

9.2. In accordance with para. 7.69 of SSR-3 [1], a system of work permits is required to 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 criteria 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 should consist of a standard form that summarizes the work to be done, the relevant regulatory requirements, and the safety precautions to be taken, and that bears the signatures of the responsible personnel. The work permit should include the following:

(a) Initial work request for maintenance, periodic testing or inspection;
(b) Specific precautions to be taken, including those for safety and nuclear security;
(c) Arrangements for radiation protection;
(d) Work approval;
(e) Notification of personnel in the control room;
(f) Work completion certificate.

An example of a work permit form is provided in Annex III, and the steps are described in more detail in para. 9.4.

9.4. The performance of a maintenance, periodic testing or inspection task should be controlled by implementing the following steps (see the example 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 acceptable, should initiate a work permit identifying the SSC and the task to be performed. (In the sample form in Annex III, this corresponds to the completion of part A.)
(b) The maintenance supervisor should be responsible for determining the necessary requirements relating to the task requested and for assembling all the necessary documents (e.g. procedures, drawings, manuals). The instructions should aim to 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 safety instructions should be provided (e.g. oxygen monitoring in confined spaces, fall protection when working at elevated heights, type of personal protective equipment needed). Any decisions regarding the isolation of equipment or systems should be taken at this stage, and the relevant isolation procedures

should be specified. (In the sample form in Annex III, this corresponds to the completion of part B by the maintenance supervisor.)

(c) The radiation protection officer should consider the task to be performed and should specify the main radiation protection measures to be taken. (In the sample form in Annex III, this corresponds to the completion of part C by the radiation protection supervisor.) These measures generally consist of the following:
   (i) Monitoring and mapping radiation levels in the work area;
   (ii) Monitoring and mapping surface contamination levels in the work area;
   (iii) Monitoring personnel and equipment leaving the work area, and using equipment and procedures for decontaminating personnel and equipment;
   (iv) Establishing control points at the entrances to the work area, including the provision of appropriate personal protective equipment (e.g. clothing, gloves, shoe covers, breathing equipment);
   (v) Giving advice to maintenance personnel on dose levels and dose constraints (see paras 3.28–3.33 of IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [20]) and restrictions on working times, and providing assistance in controlling these;
   (vi) Collecting data on the radiation exposure of maintenance personnel.

(d) The reactor manager should review the tasks to be performed and, if necessary, add further instructions. The reactor manager should also schedule the start of the work. (In the sample form in Annex III, this corresponds to the completion of part D by the reactor manager.)

(e) The shift supervisor should review the planned maintenance, periodic testing or inspection task. The shift supervisor should also be responsible for verifying that the equipment or system has been isolated. A method to mark isolated components should be used by the operating personnel that performed the isolation. One way of doing this is by placing isolation tags on the isolated equipment and on remote operation actuators. (In the sample form in Annex III, this corresponds to the completion of part E by the shift supervisor.)

(f) A work completion certification should be issued once the following conditions have been fulfilled (in the sample form in Annex III, this corresponds to the completion of part F):
   (i) The maintenance work has been completed.
   (ii) All necessary adjustments, recalibrations and verifications have been accomplished.

(iii) The system has been restored to its normal status.
(iv) A functional test has been performed.

The maintenance supervisor should confirm the completion of the work after the shift supervisor has certified the restoration of equipment to its normal status. Acceptance by the reactor manager should also be confirmed. This should include a note in the reactor log book that the work has been completed and that the reactor configuration has been verified.

WORK COORDINATION FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION AT RESEARCH REACTORS

9.5. 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 (see paras 6.8–6.11), such as the operations group, the radiation protection group, experimenters and contractors. See also para. 9.1(g) on the need for effective coordination for management of the interface between safety and nuclear security in work planning and implementation.

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

MAINTENANCE, PERIODIC TESTING AND INSPECTION PERFORMED BY CONTRACTORS AT RESEARCH REACTORS

9.7. Administrative controls should be established to supervise maintenance, periodic testing and inspection performed by contractors. A record should be maintained of contractor personnel engaged in performing maintenance, periodic testing and inspection. This record should include information on the type and duration of the work, the identities of the workers and the radiation doses received.

9.8. The maintenance, periodic testing and inspection work performed by contractors at the research reactor should be verified as being done in accordance with written procedures and the management system of the operating organization. This verification may be done by a member of the operating organization designated to supervise the contractor.

10. MAINTENANCE FACILITIES AT RESEARCH REACTORS

WORKSHOP FACILITIES AT RESEARCH REACTORS

10.1. The operating organization should provide suitable workshop facilities with sufficient space and equipment to perform maintenance, testing and inspection activities. The availability and intended use of off-site facilities and the need to deal with radioactive SSCs should be taken into consideration. The maintenance of experimental devices should also 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 OR CONTAMINATED ITEMS AT RESEARCH REACTORS

10.3. For the maintenance of radioactive or contaminated SSCs, the workshop facilities, whether on or off the site, should be designated and marked as either a supervised area or a controlled area, in accordance with Requirement 24 of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [21]. 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, periodic testing or inspection work.

10.4. It might 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 to enable the maintenance work to be done locally. Whichever type of facility is provided, consideration should be given to the following:

(a) Access to control rooms and changing rooms;
(b) Arrangements for ventilation;
(c) The 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 procedures and equipment.

DECONTAMINATION FACILITIES AT RESEARCH REACTORS

10.5. A local facility should be provided for removing radioactive contamination from SSCs, tools or equipment before maintenance or their transfer to another location. In planning this facility, consideration should be given to the following:

(a) Access to control rooms and changing rooms;
(b) Arrangements for ventilation;
(c) The treatment, handling and disposal of liquid and solid radioactive waste;
(d) Radiation protection;
(e) Decontamination procedures and 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 equipment;
(h) Protective equipment for personnel.

MAINTENANCE, PERIODIC TESTING AND INSPECTION OF LIFTING AND HANDLING EQUIPMENT AT RESEARCH REACTORS

10.6. The design of a research reactor is required to include lifting and handling equipment (see Requirement 63 of SSR-3 [1]). The maintenance group should maintain all such lifting and handling equipment, and space should be provided around such equipment for performing maintenance activities and to keep access routes clear. The load capacities of lifting and handling equipment should be clearly indicated on the equipment.

10.7. Lifting and handling equipment should be subject to preventive maintenance and periodic testing (e.g. inspections, tests and servicing), which should be incorporated into the programmes for maintenance, periodic testing and inspection in accordance with existing national regulations. Cautionary notices and mechanical and electrical measures should be provided to limit the movement of loads over specified areas.

10.8. All operations involving lifting and rigging should be performed by trained personnel.

SPECIAL EQUIPMENT AND TOOLS FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

10.9. Paragraph 7.73 of SSR-3 [1] states that "Equipment and items used for maintenance, periodic testing and inspection shall be identified and controlled to ensure their proper use."

10.10. Measurement devices used for the periodic testing needed for fuel surveillance should be calibrated against appropriate calibration standards prior to first use and thereafter as specified in the equipment calibration programme for the research reactor.

10.11. Special equipment and tools that are intended to ensure that occupational exposures are as low as reasonably achievable and to optimize protection and safety should be provided by the operating organization. Examples are as follows:

(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, endoscopes, remotely operated cameras and underwater telescopes;
(e) Special lighting equipment, including for underwater lighting;
(f) Special communication systems (e.g. for use with respiratory protective equipment);
(g) Containers for contaminated items;
(h) Shielded containers and transport equipment for irradiated items;
(i) Portable shielding;
(j) Personal protective clothing and other equipment for radiation protection;
(k) Materials and equipment for controlling the spread of radioactive contamination (e.g. plastic sheets and tents, paper floor covering, strippable coating material, vacuum cleaners equipped with filters).

MOCK-UPS AND MODELS FOR RESEARCH REACTORS

10.12. Simulations, mock-ups and models of particular sections of the research reactor should be used for the following purposes:

(a) Rehearsing work to be performed in areas with high radiation levels or high levels of contamination;

(b) Preparing and validating maintenance, periodic testing and inspection procedures;
(c) Developing and improving tools for use in maintenance, periodic testing and inspection;
(d) Gaining experience with tools and protective equipment;
(e) Training and qualifying personnel;
(f) Confirming estimates of work duration and numbers of workers for the purpose of making dose estimates.

11. PROCUREMENT, RECEIPT AND STORAGE OF SPARE PARTS, COMPONENTS AND MATERIALS AT RESEARCH REACTORS

11.1. The procurement of spare parts, components and materials is required to be undertaken in accordance with the management system for the research reactor (see para. 4.19 of SSR-3 [1]). The certification of suppliers of materials used in the reactor should also conform to the management system (see Section 2).

11.2. The operating organization should arrange the purchasing of appropriate quantities of spare parts, components and materials for the research reactor. The maintenance group may have direct responsibility for procurement, receipt and storage. If this responsibility rests with another group, the maintenance group should ensure that it receives adequate supplies of spare parts, components and materials that meet the same technical and quality specifications and standards as those already installed or used at the research reactor. The maintenance group should ensure that spare parts, components and materials are stored appropriately prior to use.

11.3. The minimum shelf quantities (and quantities on order) of spare parts, components and materials, including consumables, should be determined on the basis of maintenance experience, the time between procurement and receipt, and the shelf life.

11.4. Upon receipt, purchased spare parts, components and materials should be inspected against the purchase specifications, in accordance with the management system for the research reactor.

11.5. Spare parts, components and materials should be stored in appropriate environmental conditions to prevent deterioration prior to their use. The stored spare parts, components and materials should be regularly examined for signs of deterioration.

11.6. Access to stored spare parts, components and materials that will form part of SSCs important to safety should be controlled.

11.7. A method of identifying and cataloguing spare parts, components and materials should be established as part of the management system for the research reactor.

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

12. TESTING AND INSPECTION METHODS AND TECHNIQUES FOR RESEARCH REACTORS

12.1. Many methods and techniques may be used in the programmes for maintenance, periodic testing and inspection at a research reactor. They include dimensional measurements, electrical measurements and chemical analysis, as well as methods such as non-destructive examination of the surfaces and volume of structures. Regardless of the methods or techniques employed, it should be demonstrated that they are appropriate for the purposes of the test or inspection. The work should be done by personnel who are qualified to use the methods and techniques employed (see Section 7) in accordance with appropriate procedures (see Section 8). The results should be evaluated by qualified personnel and compared with baseline data to detect any changes.

12.2. Many of the activities in the testing and inspection programmes involve non-destructive testing and non-destructive examination. A brief description of some of these techniques is given in paras 12.3–12.9. Further recommendations on testing and inspection techniques and their application are provided in section 10 of SSG-74 [12].

VISUAL EXAMINATION

12.3. Visual examination should be used to provide information on the general condition of SSCs, including conditions such as scratches, wear, cracks, corrosion or erosion of the surface, and evidence of leakage. Optical aids such as cameras, endoscopes, underwater telescopes, binoculars and mirrors may be useful for this activity. Criteria to distinguish between reportable and non-reportable findings should be defined.

SURFACE EXAMINATION

12.4. A surface examination should be used to indicate 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 should be used to indicate the presence, depth or size of a surface breaking or subsurface flaw or discontinuity; such examinations usually involve radiographic, ultrasonic or eddy current techniques. Radiographic techniques, employing penetrating radiation such as X rays, gamma rays or thermal neutrons, may be used with appropriate image recording devices to detect the presence of flaws and establish their dimensions and location within an item.

12.6. Eddy current examination and ultrasonic testing are normally applied to tubing and tubular configurations to establish the existence and depth of flaws.

12.7. Inspections and testing using the techniques described in paras 12.4–12.6 and 12.8 should be performed by specialists who are specially qualified to use the techniques and to interpret the results.

OTHER TESTING TECHNIQUES

12.8. Other testing techniques, such as thermography, hydrostatic testing of pressure equipment and helium leak testing, may be used as appropriate.

12.9. Computer based systems should also be subjected to appropriate testing after maintenance.

Appendix

RELATIONSHIPS BETWEEN TERMS USED TO DESCRIBE MAINTENANCE, PERIODIC TESTING AND INSPECTION

A.1. The relationships between terms used in this Safety Guide for maintenance, periodic testing and inspection are shown in Fig. 1.

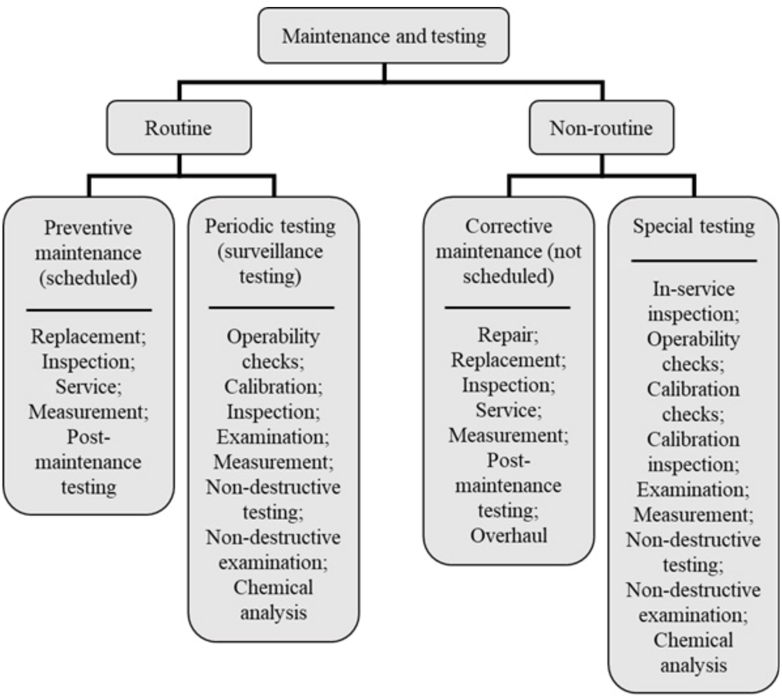

FIG. 1. Relationships between terms used in this Safety Guide for maintenance, periodic testing and inspection.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Research Reactors, IAEA Safety Standards Series No. SSR-3, IAEA, Vienna (2016).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Commissioning of Research Reactors, IAEA Safety Standards Series No. SSG-80, IAEA, Vienna (2023).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Core Management and Fuel Handling for Research Reactors, IAEA Safety Standards Series No. SSG-82, IAEA, Vienna (2023).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Limits and Conditions and Operating Procedures for Research Reactors, IAEA Safety Standards Series No. SSG-83, IAEA, Vienna (2023).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors, IAEA Safety Standards Series No. SSG-84, IAEA, Vienna (2023).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors, IAEA Safety Standards Series No. SSG-85, IAEA, Vienna (2023).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management for Research Reactors, IAEA Safety Standards Series No. SSG-10 (Rev. 1), IAEA, Vienna (2023).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Instrumentation and Control Systems and Software Important to Safety for Research Reactors, IAEA Safety Standards Series No. SSG-37 (Rev. 1), IAEA, Vienna (2023).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Research Reactors and Preparation of the Safety Analysis Report, IAEA Safety Standards Series No. SSG-20 (Rev. 1), IAEA, Vienna (2022).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety in the Utilization and Modification of Research Reactors, IAEA Safety Standards Series No. SSG-24 (Rev. 1), IAEA, Vienna (2022).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Nuclear Safety and Security Glossary: Terminology Used in Nuclear Safety, Nuclear Security, Radiation Protection and Emergency Preparedness and Response, 2022 (Interim) Edition, IAEA, Vienna (2022).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Maintenance, Testing, Surveillance and Inspection in Nuclear Power Plants, IAEA Safety Standards Series No. SSG-74, IAEA, Vienna (2022).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors, IAEA Safety Standards Series No. SSG-22 (Rev. 1), IAEA, Vienna (2023).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, IAEA Safety Standards Series No. GSR Part 2, IAEA, Vienna (2016).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, IAEA, Vienna (2009).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2011).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Physical Protection of Nuclear Material and Nuclear Facilities (Implementation of INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 27-G, IAEA, Vienna (2018).

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Security During the Lifetime of a Nuclear Facility, IAEA Nuclear Security Series No. 35-G, IAEA, Vienna (2019).

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Security of Nuclear Information, IAEA Nuclear Security Series No. 23-G, IAEA, Vienna (2015).

[20] INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7, IAEA, Vienna (2018).

[21] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

Annex I

EXAMPLES OF PREVENTIVE MAINTENANCE ACTIVITIES AT RESEARCH REACTORS

PREVENTIVE MAINTENANCE ACTIVITIES

I–1. The following are examples of preventive maintenance activities applicable to all research reactors, critical assemblies and subcritical assemblies:

(a) Walkdown inspections (e.g. looking for leaks, oil spills, vibration, hot spots and unusual noise);
(b) Measurement of operational parameters (e.g. current, temperature);
(c) Monitoring of conditions (e.g. ageing, overuse);
(d) Lubrication;
(e) Filter replacement;
(f) Chemistry control;
(g) Cleaning and preserving;
(h) Internal inspections;
(i) Calibrations, alignments and alignment checks;
(j) Oil checks and oil 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.

APPLICATION OF PREVENTIVE MAINTENANCE ACTIVITIES TO SPECIFIC EQUIPMENT

I–2. The following are examples of the application of preventive maintenance activities to specific types of equipment. Some of this equipment might not be present in some types of research reactor, critical assembly or subcritical assembly, depending on the design:

(a) Valves:
    (i) Visual inspection;
    (ii) Lubrication;
    (iii) Cleaning and preserving;

(iv) Replacement of parts.

(b) Rotating equipment (e.g. pumps, compressors):
  (i) Visual inspection;
  (ii) Balancing of rotating assemblies;
  (iii) Greasing of couplings;
  (iv) Measurements of electrical current;
  (v) Checks of protection circuits (for overload, vibration, overheating);
  (vi) Replacement of equipment internals.

(c) Heat exchangers:
  (i) Internal inspections;
  (ii) Tube cleaning;
  (iii) Backflushing;
  (iv) Tube sealing and plugging.

(d) Electrical distribution:
  (i) Visual inspections;
  (ii) Cleaning of switchgear and distribution panels;
  (iii) Replacement of filters (for motor air intakes, ventilation, instrument cabinets);
  (iv) Impedance measurements.

(e) Instrumentation and control systems:
  (i) Calibrations;
  (ii) Operational checks, verification tests for output signals;
  (iii) Replacement of relays, fuses and contacts.

(f) Confinement:
  (i) Leak tests;
  (ii) Replacement of seals;
  (iii) Cleaning of filters.

Annex II

EXAMPLES OF PERIODIC TESTING ACTIVITIES FOR RESEARCH REACTORS

II–1. Criteria for periodic testing (surveillance requirements) are generally established in terms of parameters for structures, systems and components 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: operability checks, calibrations and inspections. The term ‘inspection’ as used here refers to an inspection activity or action as part of a periodic test; it is not part of the major in-service inspection programme. Table II–1 indicates research reactor structures, systems, components and parameters that are usually subject to periodic testing, as well as the type of test applied. The examples in Table II–1 do not fully apply to most designs of subcritical assemblies. Nevertheless, these examples could be used as general guidance for the periodic testing of such assemblies.

TABLE II–1. EXAMPLES OF PERIODIC TESTING ACTIVITIES FOR RESEARCH REACTORS

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculations
Reactivity limits			
Core excess reactivity			+
Reactivity worth of control rods			+
Shutdown margin			+
Protection and shutdown systems			
Overpower shutdown	+	+	

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

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculations
Startup channel	+	+	
Log count rate channel	+	+	
Period safety channel	+	+	
Flux level safety channels	+	+	
Power–flow mismatch scram[b]	+		
Safety channel–heat balance comparison		+	
Reduced flow shutdown	+	+	
Primary pump failure shutdown	+		
Reduced core pressure difference shutdown	+	+	
Loss of electrical power shutdown	+		
Radiation monitors (operation, alarm, shutdown)	+	+	
Control rods release time			+
Control rods drop time			+
Manual shutdown switch	+		
Magnet power key switch	+		
Coolant temperature rundown[c]	+	+	

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

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculations
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 or containment isolation logic	+		

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

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculations
Changeover to emergency mode operation			
— Ventilation system turned off	+		
— Ventilation dumpers closed	+		
— Emergency system turned on	+		
Measurement of closing speed of confinement valves			+
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	+		
Emergency communication equipment	+		

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

	Operability check	Calibration	Inspection[a]: measuring, monitoring, sampling, calculations
Emergency monitoring instruments	+	+	+
Emergency personal protective equipment			+
Reflector elements condition			+
Core visual inspection			+
Fuel storage pool system			
— Level	+		
Auxiliary systems			
— Compressed air	+		
— Cover gas	+		
— Shield cooling system	+		
Lifting and handling equipment	+		

Note: + indicates the type of surveillance test that should be included in periodic testing activities.

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

[b] In forced flow operation mode only.

[c] ‘Rundown’ means automatic insertion of control elements.

Annex III

EXAMPLE OF A WORK PERMIT FORM FOR A RESEARCH REACTOR

WORK PERMIT PRIOR APPROVAL 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 involved:	
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)		
Confirmation that the equipment has been isolated (if necessary):		
	Date:	Signature:
F. WORK COMPLETION CERTIFICATION		
Maintenance supervisor	Date:	Signature:
Reactor manager	Date:	Signature:
Shift supervisor	Date:	Signature:

CONTRIBUTORS TO DRAFTING AND REVIEW

D'Arcy, A.	Consultant, South Africa
Du Bruyn, J.F.	Necsa, South Africa
Hargitai, T.	Consultant, Hungary
Hirshfeld, H.	Israel Atomic Energy Commission, Israel
Kennedy, W.	International Atomic Energy Agency
Rao, D.V.H	International Atomic Energy Agency
Sears, D.F.	International Atomic Energy Agency
Shaw, P.	International Atomic Energy Agency
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