

IAEA Safety Standards

for protecting people and the environment

Maintenance, Periodic Testing and Inspection of Research Reactors

Safety Guide

No. NS-G-4.2



IAEA

International Atomic Energy Agency

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MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

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MAINTENANCE, PERIODIC TESTING AND INSPECTION OF RESEARCH REACTORS

SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

by Mohamed ElBaradei
Director General

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

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

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

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

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

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CONTENTS

1.	INTRODUCTION	1
	Background (1.1–1.2).....	1
	Objective (1.3–1.5).....	1
	Scope (1.6–1.9)	2
	Structure (1.10).....	3
2.	MANAGEMENT SYSTEM FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION	4
	General (2.1–2.4)	4
	Management responsibility (2.5–2.9).....	5
	Resource management (2.10–2.22)	6
	Process implementation (2.23–2.28)	8
	Measurement, assessment and improvement (2.29–2.34)	9
3.	OVERVIEW OF MAINTENANCE, PERIODIC TESTING AND INSPECTION	10
	General (3.1–3.4)	10
	Interrelationship between maintenance, periodic testing and inspection (3.5–3.6)	11
	Maintenance (3.7)	12
	Preventive maintenance (3.8–3.13)	12
	Corrective maintenance (3.14–3.17)	13
	Periodic testing (3.18–3.23).....	14
	Inspection (3.24–3.27)	15
4.	DESIGN CONSIDERATIONS (4.1–4.2)	16
	Design for maintainability (4.3–4.9)	16
	Design for testability (4.10–4.16)	17
	Design for inspectability (4.17–4.18)	18

5.	PROGRAMME FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION	19
	General (5.1–5.5)	19
	Content of the programme (5.6)	20
	General description (5.7)	21
	Management systems (5.8)	21
	Organization and responsibilities (5.9)	21
	Selection, training and qualification of maintenance personnel (5.10)	21
	SSCs included in the programme (5.11)	21
	Technical procedures and administrative controls (5.12–5.14)	21
	Scheduling (5.15–5.16)	22
	Review and verification of the programme (5.17)	23
	Documentation (5.18–5.21)	23
	Review of results (5.22)	24
	Maintenance facilities (5.23)	24
	Procurement and storage of spare parts (5.24)	24
	Additional non-routine maintenance, testing and inspection (5.25–5.30)	24
6.	ORGANIZATION AND RESPONSIBILITIES FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION ..	26
	Organizational structure (6.1–6.7)	26
	Coordination and interfaces (6.8)	28
	Interface control (6.9–6.10)	28
	Responsibilities	28
	Operating organization (6.11)	28
	Regulatory body (6.12)	29
	Safety committee (6.13)	30
	Reactor manager (6.14–6.16)	30
	Maintenance supervisor (6.17)	31
	Outside contractors (6.18–6.20)	32
	Maintenance technicians and craftspersons (6.21)	33
7.	SELECTION, TRAINING AND QUALIFICATION OF PERSONNEL (7.1–7.7)	33

8.	PROCEDURES (8.1–8.4).....	35
	Administrative procedures (8.5)	35
	Procedures for maintenance, periodic testing and inspection (8.6–8.14).....	36
9.	ADMINISTRATIVE CONTROLS (9.1)	38
	Work authorization (work permit) (9.2–9.5)	38
	Work coordination (9.6–9.7).....	41
	Work performed by contractors (9.8–9.9).....	41
10.	MAINTENANCE FACILITIES.....	41
	Workshop facilities (10.1–10.2)	41
	Facilities for maintenance of radioactive items (10.3–10.4)	42
	Decontamination facilities (10.5).....	42
	Lifting and handling facilities (10.6–10.7).....	43
	Special equipment and tools (10.8–10.9).....	43
	Mock-ups and models (10.10).....	44
11.	PROCUREMENT AND STORAGE	44
	Procurement (11.1–11.3)	44
	Receipt (11.4)	45
	Storage (11.5–11.8).....	45
12.	TESTING AND INSPECTION METHODS AND TECHNIQUES (12.1–12.2).....	46
	Visual examination (12.3)	46
	Surface examination (12.4)	46
	Volumetric examination (12.5–12.9)	47
	Other testing techniques (12.10)	47
	APPENDIX: RELATIONSHIPS BETWEEN TERMS USED	49
	REFERENCES	51

ANNEX I: EXAMPLES OF PREVENTIVE MAINTENANCE
 ACTIVITIES 53

ANNEX II: EXAMPLES OF PERIODIC TESTING ACTIVITIES .. 55

ANNEX III: EXAMPLE OF A WORK PERMIT FORM..... 58

GLOSSARY 59

CONTRIBUTORS TO DRAFTING AND REVIEW 63

BODIES FOR THE ENDORSEMENT OF
 IAEA SAFETY STANDARDS 65

1. INTRODUCTION

BACKGROUND

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

1.2. The safety of research reactors requires provisions in the design to facilitate maintenance and repair and for appropriate functional testing and inspection. During the operational and utilization phase of a research reactor's lifetime, maintenance, periodic testing and inspection¹ are required to ensure the adequacy of the safety status of the reactor and compliance with the operational limits and conditions (OLCs). To help achieve these objectives, Ref. [1] establishes general requirements regarding maintenance, periodic testing and inspection to ensure that the safety level is not reduced during reactor operation and maintenance. However, it does not provide guidance on how to fulfil these requirements or how to conduct maintenance.

OBJECTIVE

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

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

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

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

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

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

SCOPE

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

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

1.8. This Safety Guide deals with maintenance, periodic testing and inspection for all types of heterogeneous, thermal spectrum research reactor having a power rating of up to several tens of megawatts. Research reactors of higher power, specialized reactors (e.g. homogeneous reactors, fast spectrum reactors)

and reactors having specialized facilities (e.g. hot or cold neutron sources, high pressure and high temperature loops) may require additional guidance. The guidance for power reactors, as provided in Ref. [2], may be more suitable for these reactors.

1.9. Low risk research reactors having a power rating of up to several tens of kilowatts and critical assemblies may need a less comprehensive maintenance, periodic testing and inspection programme than that outlined here. While all recommendations in this Safety Guide should be considered, some may not be applicable to these low power reactors. For these reasons, the recommendations in this Safety Guide should be graded² for their applicability to a particular research reactor (see Ref. [1], paras 1.11–1.14). Grading may be of assistance in determining the appropriate frequency for maintenance, periodic testing and inspection. It should be based on the complexity of the activity and the importance to safety of the systems and equipment concerned.

STRUCTURE

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

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

2. MANAGEMENT SYSTEM FOR MAINTENANCE, PERIODIC TESTING AND INSPECTION

GENERAL

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

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

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

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

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

- The regulatory body's requirements;
- Design requirements and assumptions;
- The safety analysis report (SAR);
- The OLCs;
- Administrative requirements of the reactor management³.

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

MANAGEMENT RESPONSIBILITY

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

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

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

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

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

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

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

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

RESOURCE MANAGEMENT

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

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

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

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

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

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

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

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

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

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

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

2.19. The operating organization should have the responsibility for preparing and issuing specifications and procedures for maintenance, periodic testing and inspection. The reactor manager⁴ should be an active participant in executing and evaluating the work in maintenance, periodic testing and inspection. The detailed responsibilities of the reactor manager are presented in para. 6.15 of this Safety Guide.

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

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

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

PROCESS IMPLEMENTATION

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

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

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

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

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

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

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

MEASUREMENT, ASSESSMENT AND IMPROVEMENT

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

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

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

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

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

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

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

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

3. OVERVIEW OF MAINTENANCE, PERIODIC TESTING AND INSPECTION

GENERAL

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

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

All activities for maintenance, periodic testing and inspection should be conducted while maintaining control over the reactor at all times and without reducing or jeopardizing the safety of the reactor. Although maintenance, periodic testing and inspection may be included in one programme and may be performed by the same operating personnel⁵, this Safety Guide draws a clear distinction between these three activities. These distinctions and the applicable terminology relating to maintenance, testing and inspection are defined in the Glossary and are illustrated in the Appendix.

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

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

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

INTERRELATIONSHIP BETWEEN MAINTENANCE, PERIODIC TESTING AND INSPECTION

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

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

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

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

MAINTENANCE

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

Preventive maintenance

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

3.9. Preventive maintenance should be performed on SSCs:

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

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

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

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

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

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

Corrective maintenance

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

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

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