IAEA SAFETY STANDARDS SERIES

Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants

SAFETY GUIDE

No. NS-G-2.6

INTERNATIONAL
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IAEA SAFETY STANDARDS

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MAINTENANCE, SURVEILLANCE AND IN-SERVICE INSPECTION IN NUCLEAR POWER PLANTS

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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''.

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FOREWORD

by Mohamed ElBaradei
Director General

One of the statutory functions of the IAEA is to establish or adopt standards of safety for the protection of health, life and property in the development and application of nuclear energy for peaceful purposes, and to provide for the application of these standards to its own operations as well as to assisted operations and, at the request of the parties, to operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of nuclear energy.

The following bodies oversee the development of safety standards: the Commission on Safety Standards (CSS); the Nuclear Safety Standards Committee (NUSSC); the Radiation Safety Standards Committee (RASSC); the Transport Safety Standards Committee (TRANSSC); and the Waste Safety Standards Committee (WASSC). Member States are widely represented on these committees.

In order to ensure the broadest international consensus, safety standards are also submitted to all Member States for comment before approval by the IAEA Board of Governors (for Safety Fundamentals and Safety Requirements) or, on behalf of the Director General, by the Publications Committee (for Safety Guides).

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA for its assistance in connection with the siting, design, construction, commissioning, operation or decommissioning of a nuclear facility or any other activities will be required to follow those parts of the safety standards that pertain to the activities to be covered by the agreement. However, it should be recalled that the final decisions and legal responsibilities in any licensing procedures rest with the States.

Although the safety standards establish an essential basis for safety, the incorporation of more detailed requirements, in accordance with national practice, may also be necessary. Moreover, there will generally be special aspects that need to be assessed on a case by case basis.

The physical protection of fissile and radioactive materials and of nuclear power plants as a whole is mentioned where appropriate but is not treated in detail; obligations of States in this respect should be addressed on the basis of the relevant instruments and publications developed under the auspices of the IAEA. Non-radiological aspects of industrial safety and environmental protection are also not explicitly considered; it is recognized that States should fulfil their international undertakings and obligations in relation to these.

The requirements and recommendations set forth in the IAEA safety standards might not be fully satisfied by some facilities built to earlier standards. Decisions on the way in which the safety standards are applied to such facilities will be taken by individual States.

The attention of States is drawn to the fact that the safety standards of the IAEA, while not legally binding, are developed with the aim of ensuring that the peaceful uses of nuclear energy and of radioactive materials are undertaken in a manner that enables States to meet their obligations under generally accepted principles of international law and rules such as those relating to environmental protection. According to one such general principle, the territory of a State must not be used in such a way as to cause damage in another State. States thus have an obligation of diligence and standard of care.

Civil nuclear activities conducted within the jurisdiction of States are, as any other activities, subject to obligations to which States may subscribe under international conventions, in addition to generally accepted principles of international law. States are expected to adopt within their national legal systems such legislation (including regulations) and other standards and measures as may be necessary to fulfil all of their international obligations effectively.

EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

The English version of the text is the authoritative version.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Effective maintenance, surveillance and in-service inspection (MS&I) are essential for the safe operation of a nuclear power plant. They ensure not only that the levels of reliability and availability of all plant structures, systems and components (SSCs) that have a bearing on safety remain in accordance with the assumptions and intent of the design, but also that the safety of the plant is not adversely affected after the commencement of operation.

1.2. This Safety Guide supplements Section 6 of the Safety Requirements publication on the Safety of Nuclear Power Plants: Operation [1], which relates to the maintenance, surveillance and in-service inspection of SSCs important to safety. It provides recommendations on the basis of international experience of measures for fulfilling the safety requirements for MS&I. This publication supersedes the following three earlier IAEA Safety Guides: In-service Inspection for Nuclear Power Plants, Safety Series No. 50-SG-O2 (1980), Maintenance of Nuclear Power Plants, Safety Series No. 50-SG-O7 (1990), and Surveillance of Items Important to Safety in Nuclear Power Plants, Safety Series No. 50-SG-O8 (1990).

OBJECTIVE

1.3. The objective of this Safety Guide is to provide recommendations and guidance for MS&I activities to ensure that SSCs important to safety are available to perform their functions in accordance with the assumptions and intent of the design.

SCOPE

1.4. This Safety Guide covers the organizational and procedural aspects of MS&I. However, it does not give detailed technical advice in relation to particular items of plant equipment, nor does it cover inspections made for and/or by the regulatory body.

1.5. This Safety Guide provides recommendations and guidance for preventive and remedial measures, including testing, surveillance and in-service inspection, that are necessary to ensure that all SSCs important to safety are capable of performing as intended.

1.6. This Safety Guide covers measures for fulfilling the organizational and administrative requirements for: establishing and implementing schedules for preventive and predictive maintenance, repairing defective plant items, selecting and training personnel, providing related facilities and equipment, procuring stores and spare parts, and generating, collecting and retaining maintenance records for establishing and implementing an adequate feedback system for information on maintenance.

1.7. MS&I should be subject to quality assurance in relation to all aspects important to safety. Quality assurance has been dealt with in detail in other IAEA safety standards [2] and is covered here only in specific instances, for emphasis.

STRUCTURE

1.8. In Section 2, a concept of MS&I is presented and the interrelationship between maintenance, surveillance and inspection is discussed. Section 3 concerns the functions and responsibilities of different organizations involved in MS&I activities. Section 4 provides recommendations and guidance on such organizational aspects as organizational structure, planning and safety management, administrative control, quality assurance, and training and qualification of personnel. Sections 5 and 6 cover the implementation of an MS&I programme, analysis of results and feedback of experience. Section 7 highlights the areas that need to be given special consideration in relation to the MS&I programme. Finally, Sections 8 to 10 address additional items that are specific to MS&I.

2. MAINTENANCE, SURVEILLANCE AND IN-SERVICE INSPECTION AND THEIR INTERRELATIONSHIP

MAINTENANCE

2.1. The maintenance programme for a nuclear power plant should cover all preventive and remedial measures, both administrative and technical, that are necessary to detect and mitigate degradation of a functioning SSC or to restore to an acceptable level the performance of design functions of a failed SSC. The purpose of maintenance activity is also to enhance the reliability of equipment. The range of maintenance activities includes servicing, overhaul, repair and replacement of parts, and often, as appropriate, testing, calibration and inspection.

Types of maintenance

2.2. While there are various conceptual approaches to maintenance, the relevant activities may be divided into preventive and corrective maintenance. A considerable part of all maintenance activity is performed while the plant is shut down; however, maintenance may be planned and executed under power operation provided that adequate defence in depth is maintained. For definitions of different types of maintenance, see the Glossary.

2.3. Preventive maintenance should include periodic, predictive and planned maintenance activities performed prior to failure of an SSC so as to maintain its service life by controlling degradation or preventing its failure.

(a) Periodic maintenance activities should be accomplished on a routine basis and may include any combination of external inspections, alignments or calibrations, internal inspections, overhauls, and replacements of components or equipment.
(b) Predictive maintenance should involve continuous or periodic monitoring and diagnosis in order to predict equipment failure. Not all equipment conditions and failure modes can be monitored, however; predictive maintenance should therefore be selectively applied where appropriate. Predictive techniques may include condition monitoring, reliability centred maintenance and similar techniques.
(c) Planned maintenance activities should be performed prior to unacceptable degradation or equipment failure and may be initiated on the basis of results of predictive or periodic maintenance, vendor recommendations or experience.

2.4. Corrective maintenance includes actions that, by means of repair, overhaul or replacement, restore the capability of a failed SSC to perform its defined function within the acceptance criteria.

Systems approach to maintenance

2.5. A systems approach to maintenance of safety relevant SSCs should include the following elements:

(a) A systematic evaluation of the functions and objectives of SSCs, to determine the necessary maintenance activities and the related requirements;
(b) A focus on long term maintenance objectives, establishing a proactive as opposed to reactive maintenance programme;
(c) A reliability centred approach to maintenance;

(d) Maintenance planning and scheduling that is derived from overall programme objectives.

Optimization of maintenance

2.6. A systematic approach to evaluation should be taken to establish which maintenance tasks are to be performed, on which SSCs, and at what intervals, in order to optimize the use of resources allocated for maintenance and to ensure the availability of the plant. This approach can be used in establishing a preventive maintenance programme and for optimization of the ongoing maintenance programme. The aim of optimization is to use condition monitoring to determine where unnecessary maintenance work and failures induced by errors in maintenance can be avoided. If a probabilistic safety assessment has been performed, its results may be used for this purpose.

2.7. The operating organization should monitor the performance or condition of SSCs against the goals it has set so as to provide reasonable assurance that the SSCs are capable of performing their intended functions. Such goals should be commensurate with safety and, where practicable, industry-wide operating experience should be taken into account. When the performance or condition of an SSC does not meet the established goals, appropriate corrective action should be taken.

2.8. An adequate condition monitoring programme should be established in support of optimization of the maintenance programme. Such a monitoring programme should be based on the following assumptions as a minimum:

— that the monitored parameters are appropriate indicators for the condition of the SSCs,
— that acceptance criteria are available,
— that all potential failure modes are addressed,
— that the behaviour of the potential failure is traceable and predictable.

2.9. The scope of the condition monitoring programme should include, but is not limited to:

— SSCs which ensure safe operations or whose failure could challenge a safety function;
— SSCs which are relied on to remain functional following a design basis accident to ensure the continued performance of safety functions, or whose failure could prevent safety related SSCs from performing their safety related functions;

— SSCs which are used in plant emergency operating procedures (EOPs) or are relied on to mitigate the consequences of transients or beyond design basis accidents.

For more information on condition monitoring see Safety Guide Q13 in Ref. [2].

2.10. Changes deriving from the optimization of maintenance should be analysed to assess the effects of the changed maintenance approach on system availability and the overall risks to the plant in all operating and shutdown states. A periodic review of the optimization process should incorporate operating experience, including new failure modes and data. In the optimization process, due attention should be paid to maintaining the required reliability of the SSCs and adequate safety margins.

SURVEILLANCE

2.11. The objectives of the surveillance programme are: to maintain and improve equipment availability, to confirm compliance with operational limits and conditions, and to detect and correct any abnormal condition before it can give rise to significant consequences for safety. The abnormal conditions which are of relevance to the surveillance programme include not only deficiencies in SSCs and software performance, procedural errors and human errors, but also trends within the accepted limits, an analysis of which may indicate that the plant is deviating from the design intent.

2.12. The operating organization should establish a surveillance programme to verify that the SSCs important to safety are ready to operate at all times and are able to perform their safety functions as intended in the design. Such a surveillance programme will also help to detect trends in ageing so that a plan for mitigating the effects of ageing can be prepared and implemented.

IN-SERVICE INSPECTION

2.13. Over the plant's operating lifetime, the operating organization should examine SSCs for possible deterioration so as to determine whether they are acceptable for continued safe operation or whether remedial measures should be taken. Emphasis should be placed on examination of the pressure boundaries of the primary and secondary coolant systems, because of their importance to safety and the potentially severe consequences of their failure.

2.14. Baseline data should be collected for future reference. These data are normally collected in the pre-service inspection carried out before the start of plant operation; they give information on initial conditions which supplements manufacturing and construction data in providing a basis for comparison with the data from subsequent examinations. In the pre-service inspection the same methods, techniques and types of equipment should be used as those which are planned to be used for in-service inspections. Whenever an SSC has been repaired or replaced, a pre-service inspection should be performed before putting it into operation.

2.15. When new inspection methods are introduced, a comparison with the previous methods should be made. Such a comparison will provide a revised baseline for future inspections.

INTERRELATIONSHIP BETWEEN MAINTENANCE, SURVEILLANCE AND IN-SERVICE INSPECTION

2.16. Maintenance, surveillance and in-service inspection have a common objective, which is to ensure that the plant is operated in accordance with the design assumptions and intent, and within the operational limits and conditions. Maintenance, for example, should always be followed by a series of tests. Results of surveillance or in-service inspection should be compared with the acceptance criteria. If the results fall outside the acceptance criteria, corrective actions should be initiated. Such actions should include corrective maintenance measures such as adjustment, repair or replacement of defective items to prevent recurrence. These activities should be planned and co-ordinated effectively. A common database should be established in order to share relevant data and evaluations of results among the organizations that are involved in the planning and implementation of MS&I activities.

2.17. Testing consists of post-maintenance testing, surveillance testing and in-service inspection testing. The purpose of the tests is to confirm that the SSCs continue to meet the design intent. In this Safety Guide, testing is dealt with separately for maintenance, surveillance and in-service inspection, as appropriate. Further guidance on testing can be found in Safety Guide Q4 in Ref. [2].

3. FUNCTIONS, RESPONSIBILITIES AND INTERFACES

THE OPERATING ORGANIZATION

3.1. The operating organization is required to prepare and implement a programme of MS&I for those SSCs which are important to safety. This programme is required to be in place prior to fuel loading, and full details of it are required to be made available to the regulatory body. The operational limits and conditions as well as any other applicable regulatory requirements are required to be taken into account in the programme and are required to be re-evaluated as necessary in the light of experience [1]. Recent scientific and technological advances should also be taken into consideration.

3.2. The operating organization should ensure that MS&I for SSCs important to safety are of such a standard and frequency as to ensure that the level of reliability and functionality of the SSCs remains in accordance with the design assumptions and intent throughout the plant's operating lifetime.

3.3. The operating organization should periodically evaluate the performance of SSCs as well as condition monitoring activities and their associated goals, and activities in relation to MS&I. It should thereby take into account and, where practicable, contribute to industry-wide operating experience. Adjustments should be made where necessary to ensure that the objective of preventing failures of SSCs by means of maintenance or detecting them through testing, surveillance and in-service inspection is appropriately balanced against the objective of minimizing the unavailability of those SSCs due to monitoring or MS&I. In performing these activities, an assessment of all the plant equipment that is out of service should be made and the overall effect of this unavailability on the performance of safety functions should be determined and taken into account.

THE REGULATORY BODY

3.4. The extent of the regulatory body's involvement in MS&I activities at nuclear power plants will depend on the practices in the State concerned. In general, the regulatory body's main concern will be to ensure that all such activities are properly conducted, particularly for SSCs important to safety. In most cases, the regulatory body may be involved in the following activities as a minimum:

— establishing rules and conditions to ensure the appropriateness of the MS&I for SSCs important to safety (for example, in terms of rules and guidelines for the contents of the MS&I programme, requirements for reviewing the maintenance

programme in the light of new approaches or requirements for equipment qualification);
- approving those parts of the MS&I programme that are related to operational limits and conditions, and the changes thereto;
- monitoring compliance with the MS&I programme and the related quality assurance programme (for example, by requiring the operating organization to report on the extent of its compliance with the MS&I programme, or by sample inspections of MS&I records);
- selectively monitoring and assessing the results of the MS&I programme (including functional tests, non-destructive tests, preventive maintenance and surveillance of systems);
- observing selected MS&I activities through its representatives;
- assessing selected MS&I procedures and checklists;
- considering proposals for new approaches to MS&I activities (such as reliability centred maintenance, condition based maintenance or new methods of non-destructive testing);
- monitoring to verify that appropriate actions are taken if unsafe or potentially unsafe conditions are detected.

3.5. Descriptions of all new approaches to MS&I that may result in significant changes to the approved MS&I strategies should be submitted by the operating organization to the regulatory body, together with the appropriate documentation, for thorough consideration. Examples of such new approaches are the optimization of maintenance, the use of new in-service inspection techniques and methods, or the use of new functional tests and cancellation of the functional tests previously used.

CONTRACTORS

3.6. The operating organization may delegate to other organizations the work of implementing the MS&I programme or any part thereof, but it is required to retain overall responsibility for such delegated work [1].

3.7. The operating organization should ensure that an effective organization is established for MS&I, which should perform all the administrative, technical and supervisory functions necessary in mobilizing and supervising on-site and off-site MS&I resources. The management at the plant is required to remain responsible for all tasks undertaken on its behalf [1].

3.8. Contractors should be subject to the same standards as plant staff, particularly in the areas of professional 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.

3.9. Activities performed by contractors and other personnel who are not permanent employees of the plant should be controlled by means of established management systems. These systems should cover the training and qualification of contractor personnel, radiation protection, familiarity with and adherence to procedures, understanding of plant systems, and applicable administrative procedures for both normal operation and emergency conditions. Contractor personnel should be made aware of their responsibilities in relation to the safety of the plant and the equipment they maintain. However, this shall not diminish the prime responsibility of the operating organization for plant safety and for ensuring that the contractors' work is of the required quality and that they are accountable through appropriate channels [1].

OTHER BODIES, INCLUDING DESIGNERS AND MANUFACTURERS

3.10. A close relationship should exist between the operating organization and the design or manufacturing organizations, so as to ensure that the MS&I programme is based on a clear understanding of the design philosophy and/or the manufacturing technology and technical details of the plant, and that the plant is designed to facilitate and optimize MS&I. Design and manufacturing organizations can also contribute effectively to the training of staff of the operating organization.

3.11. The operating organization should have long term access to organizations that have appropriate competence in design and engineering. Special commercial arrangements may be necessary to ensure continuity of access to these resources over the long term. A close relationship should be maintained between the operating organization and the design or manufacturing organization throughout the plant's operating lifetime. It is essential that, when plant faults occur or modifications are required, effective and timely assistance from the design or manufacturing organization is ensured. For this purpose, the operating organization should arrange for feedback of operating experience and reliability data to the design or manufacturing organization.

INTERFACE CONTROL

3.12. For all MS&I activities, a good interface control system should be in place. There should be a clear understanding of the division of responsibilities between all organizational units participating in MS&I activities (see also paras 5.23–5.26). In particular, the interface between the operating organization and contractors should be

clearly specified, with clear arrangements for the maintenance of configuration control to ensure plant safety during and after the contracted work. For further guidance on interfaces, see Annex II of Safety Guide Q1 and Safety Guide Q13 in Ref. [2].

4. ORGANIZATIONAL ASPECTS

GENERAL PROVISIONS

4.1. Before fuel loading, the operating organization should prepare an MS&I programme with the purpose of preserving the functionality and reliability of SSCs or restoring them as they degrade. Usually such a programme will consist of separate activities in MS&I intended to provide assurance that the plant's safety status remains consistent with the design assumptions and intent and is not adversely affected after the commencement of operation.

4.2. Since the design and the design objectives of a nuclear power plant will have a strong influence on the MS&I programme, development of this programme should be initiated appropriately early in the design phase. The requirements of the MS&I programme should be taken into account in the final design and construction details and in the safety analysis report for the plant. To this end, the operating organization should arrange for experienced personnel to consult regularly with the design organization.

4.3. The MS&I programme should be fully integrated with activities for plant operation and modification. The programme should be routinely reviewed and updated as necessary to take into account on-site and off-site operating experience, modifications to the plant or its operating regime, plant ageing, and methods, both deterministic and probabilistic, for the assessment and evaluation of safety. Documentation, procedures and records deriving from the MS&I programme should be managed in accordance with extant arrangements for quality assurance (see Ref. [2]).

4.4. The goals, objectives and priorities of the MS&I programme should be defined so as to be consistent with the policies and objectives at the plant. Appropriate operational safety performance indicators should be established and used to monitor and enhance the quality of MS&I. Senior management should encourage effective and high quality performance of MS&I. Results and feedback from the performance of MS&I should be used in accountability reviews and in establishing goals and objectives for subsequent planning periods.

4.5. The frequency of MS&I for individual SSCs should be determined on the basis of:

— their relative importance to safety,
— the required reliability,
— the assessed potential for degradation in operation and ageing characteristics,
— operating experience,
— manufacturers' recommendations.

4.6. The organization and the number and qualifications of personnel should be adequate for the purposes of operation of the plant, the outage work to be performed by the plant's staff, and supervision of the work of contractors if these are used.

4.7. Following any abnormal event, the operating organization is required to revalidate the safety functions and the structural and functional integrity of any SSCs that may have been challenged by the event. Necessary corrective actions are required to include maintenance, surveillance and in-service inspection, as appropriate [1].

4.8. In planned shutdowns the opportunity should be taken to undertake MS&I activities. In the event of an unplanned shutdown, it should be considered whether it would be useful to undertake MS&I. Refuelling activities should be taken into account in relevant MS&I schedules. Suitable schedules for MS&I should be readily available for unplanned as well as planned shutdowns.

4.9. Control room operating personnel are directly responsible for safe operation of the plant, including its continued configuration control. They should be informed (by means of a work permit procedure, for example) of all MS&I work before it is commenced, of any changes to the plant that this work entails, and of the return of plant systems to the control of the operator. During the performance of such work, adequate communication should be maintained between the relevant personnel and control room operating personnel.

ORGANIZATIONAL STRUCTURE

4.10. The organization for MS&I will vary greatly between different operating organizations, depending on:

— the operating organization's concepts and practices for operation,
— the type of reactor,
— the refuelling mode,
— the frequency of periodic shutdown.

4.11. The ultimate responsibility for preparing and executing an adequate MS&I programme rests with the operating organization. For every aspect of the MS&I programme, the operating organization should assign the authority and responsibilities, both within its own organizational structure and to other organizations, and should specify lines of communication. It should make available to the plant management sufficient resources in terms of personnel and equipment to implement the appropriate programmes satisfactorily. It should ensure the timely conduct of work activities, their documentation and reporting, and the evaluation of results. Any deviation from the established frequency and extent of the relevant activities should be justified, reviewed and reported to the regulatory body as appropriate.

4.12. The plant management should establish a group on the site to implement the MS&I programme. This group may be divided into mechanical, electrical, and control and instrumentation sections. The detailed organizational structure will depend mainly on which source of personnel, or combination of sources, is employed: the group itself, the operating organization, outside agencies or contractors. The structure of the group and its integration with off-site resources will depend heavily on such factors as the type of plant, the number of reactors on the site, the availability of suitable staff locally, the mode of operation of the reactors, and regulations governing the employment of off-site labour. In all cases, the plant management should ensure that sufficient numbers of adequately qualified personnel are available to implement the programme.

4.13. There are some common factors that will influence the choice of organizational structure of the MS&I group. The organizational structure will depend on whether, and the extent to which, MS&I is implemented by the group, by a central department of the operating organization, by outside agencies or by contractors. These sources of personnel can be successfully used in combination. In each case, however, the plant management is required to retain primary responsibility for implementing the MS&I programme [1].

4.14. In plants designed for on-load refuelling, refuelling activities are routine and continuous and will usually be performed by operating personnel. Subject to the operating organization's policy on the use of off-site resources, the organization for MS&I in plants of this type should be based on the concept of having a sufficient number of staff to deal effectively with a relatively steady flow of MS&I work with a minimum of assistance necessary from off-site sources.

4.15. It is common at many plants to undertake a large amount of MS&I work during refuelling outages or other outages lasting for periods of several weeks or more. Much MS&I work can be accomplished only during this period. This inevitably leads to large

peaks in demand for MS&I resources. To be able to respond effectively to these peak demands, the organization for MS&I should be well structured and adequately staffed, and the on-site organization will require significant supplementary resources to be provided from off-site sources.

4.16. Independent verification that the MS&I programme is being implemented in compliance with the requirements for quality assurance should be carried out by persons from the operating organization who are not directly involved in these activities. For further guidance on provisions for quality assurance, see the relevant Safety Guides in Ref. [2].

PLANNING AND SAFETY MANAGEMENT

4.17. Activities for MS&I should be planned in the context of the overall management of the plant. It is usual practice for the management of the operating organization to establish a planning team to co-ordinate all MS&I activities.

4.18. In planning activities for MS&I, consideration should be given to potential human failures in the performance of such activities. Particular emphasis should be placed on establishing the best work procedure, providing suitable job aids and using sound principles of human engineering design wherever practicable, to ensure that the potential for errors is minimized at all times.

4.19. In planning activities for MS&I that involve the removal from service of SSCs important to safety, it should be ensured that operational limits and conditions and any other applicable regulatory requirements are always met. If tasks for MS&I are discovered to be incompatible with existing operational limits and conditions, then, after invoking the plant modification procedure, either a temporary waiver of or a permanent change to the operational limits and conditions should be effected (see also Ref. [3]).

4.20. As a general rule, MS&I activities should be staggered in cases where there are redundant trains or several trains of similar design. This makes it possible to analyse performance data before proceeding with subsequent tests, and to make adjustments for the subsequent tests if any problems are found.

4.21. Factors important to safety, such as the ageing of safety significant components, as well as maintenance history and operating experience should be taken into account in the long term planning.

4.22. The elimination of plant defects should be tracked to completion, and records should be kept of the work performed. These records should be accessible whenever needed for review.

4.23. Procedures and work related documents should specify preconditions and provide clear instructions for the work to be done, and should be used to ensure that work is performed in accordance with the strategy, policies and programmes of the plant. The procedures and work related documents should be technically accurate, properly validated, verified and authorized, and they should be periodically reviewed. Human factors and the ALARA principle (to keep radiation doses as low as reasonably achievable) should be considered in the preparation of work instructions.

4.24. Implementation of MS&I often calls for a temporary change in the plant configuration required for normal operating conditions. In such cases the risks associated with a particular plant configuration should be assessed and the conditions for safe implementation specified prior to the performance of MS&I. The conditions for safe implementation of MS&I should be part of the operational limits and conditions.

ADMINISTRATIVE PROCEDURES

4.25. In order to implement the MS&I programme and to achieve the objective of safe and reliable operation, the operating organization should ensure that administrative controls are established. These controls will usually take the form of administrative procedures, which will include all administrative controls and requirements for carrying out activities at the plant. Methods should be established in the MS&I programme for identifying the need for any work, for implementing the work identified as necessary and for reporting on that work. Administrative procedures and controls should be established to guide personnel in the entire process.

4.26. The factors to be taken into account in developing administrative controls and procedures applicable to MS&I should include, but are not limited to, the following:

— the generation of adequate written work procedures;
— the use of work order authorizations;
— the use of work permits in connection with equipment isolation;
— radiation protection of personnel;
— control of the plant configuration;
— calibration of tools and equipment;
— industrial safety controls;
— fire hazard controls;

— general risk assessment;
— the use of interlocks and keys;
— training and qualification of personnel;
— control of materials, products and spare parts;
— a control plan and programme for lubrication;
— housekeeping and cleanness;
— nomenclature, location and labelling of equipment;
— a preventive maintenance programme;
— generation and collection of records;
— retention of records;
— planning for work during shutdowns.

4.27. In developing these administrative controls and procedures, account should be taken of the interfaces between each activity and other activities such as maintenance on other systems or components, plant operation and radiation protection. In particular, the following aspects should be explicitly covered:

(a) The delineation of responsibilities between those persons performing MS&I and those directly responsible for plant operation. This should not be taken as diminishing or delegating prime responsibility for safety, which rests with the personnel in charge of operations (for example, the shift supervisor).
(b) Ensuring that the operating personnel have adequate information about the plant status at all times during MS&I activities.
(c) Establishment of a work permit system controlling the issuing and cancellation of appropriate documentation such as work authorizations, equipment isolation work permits, live testing authorizations and limitations to access. This includes the designation of persons in the operating shift who are authorized to issue such permits to those responsible for carrying out MS&I work.
(d) Provision of a direct positive indication of equipment that is not available for the operational state. This includes tagging, where appropriate, and any steps to be taken to prevent unintentional return to service. The tagging should not hide or obscure any indication device.
(e) Ensuring that, after MS&I, the SSCs are inspected for their intended operational state and, where necessary, are tested by authorized persons before being formally declared functional and fully reinstated for normal operation.

In addition, a mechanism should be implemented which enables users to feed back suggestions for the improvement of procedures.

4.28. Temporary changes to procedures should be properly controlled and should be subject to appropriate review and approval. Such temporary changes should be

promptly incorporated into permanent revisions where appropriate, in order to limit the number of temporary procedures and their durations. For further guidance on the management of temporary changes, see Ref. [4].

QUALITY ASSURANCE

4.29. The operating organization should ensure that an adequate quality assurance programme is effected at all stages in the preparation and implementation of MS&I. Quality assurance has a broad scope in the context of this Safety Guide. It should be applied to ensure that safety principles and criteria have been observed. Quality assurance in MS&I should include the proper identification, evaluation and, eventually, approval of changes in approaches and technology, and uses of qualified materials and parts for replacement, including records and traceability. For further guidance on quality assurance in MS&I see Ref. [2], in particular Safety Guide Q2 on Non-conformance Control and Corrective Actions, Safety Guide Q4 on Inspection and Testing, and Safety Guide Q13 on Quality Assurance in Operation.

TRAINING AND QUALIFICATION OF PERSONNEL

4.30. All relevant personnel should be made aware of the importance to safety of the tasks that they perform for MS&I and of the potential consequences for safety of technical, procedural or human errors. Experience of faults and hazards caused by errors in MS&I procedures and practices at the nuclear power plant concerned or at other plants, and in other potentially hazardous industries, should be reviewed and incorporated into personnel training programmes as appropriate.

4.31. Training and qualification of personnel should be integrated into a relevant programme at the plant. Training and qualification should be based on an approved and documented process which is traceable. These recommendations apply both to the permanent staff of the plant and to temporary employees (such as contractor personnel and off-site personnel of the operating organization).

4.32. The operating organization should ensure that the competence of external personnel involved in MS&I activities at the nuclear power plant is adequate for the functions to be performed, by making suitable arrangements with contractors and other participating organizations as appropriate. Emphasis should be placed on the quality and safety of the working conditions of contractor personnel, who should be made aware of the standards required.

4.33. The training of personnel for MS&I should specifically take into account the following aspects:

(a) Surveillance and in-service inspection should be conducted in accordance with prescribed instructions, which should be sufficiently detailed so that the training programme can be standardized. Maintenance of items that are faulty or need some adjustment, however, will be less predictable. Therefore the training for maintenance may be supplemented by special training for specific tasks.
(b) Sometimes it may be necessary to conduct MS&I activities with the plant or plant systems out of service or off-load, and pressure may be exerted on the personnel involved to return the plant or plant systems to normal operational states. Therefore safety culture should be emphasized in the training programmes, for example, by placing the highest importance on reporting, investigating and accordingly correcting any indication of failure or any unexpected findings.
(c) MS&I, and especially maintenance during shutdown, usually consists of various activities with interacting effects and frequently involves various organizations such as contractors, the regulatory body and the operating organization. Therefore the training programme should emphasize the importance of good co-ordination among the personnel involved and among the activities. Training programmes by and for contractor personnel should be well co-ordinated with programmes for personnel of the operating organization.

4.34. All personnel involved in MS&I should be given training in the ALARA principle and in minimization of waste, radiation protection, safety rules, access control and emergency procedures, as appropriate to their duties, and should be adequately qualified in these areas before being allowed to work in controlled areas.

4.35. For special tasks, depending on the nature of the work to be performed, its importance for the safety of the plant, the potential risks involved and the safety precautions that are consequently necessary, maintenance personnel should receive a special briefing in addition to the aforementioned training. Relevant personnel should also be appropriately trained and qualified in the quality assurance requirements applicable to their duties.

4.36. Selected supervisors and craftspersons may be given special training, both at manufacturers' works and on the site, during the construction, fabrication, assembly and testing of particular items important to safety. Arrangements should be made for maintenance personnel to participate in maintenance, inspection and testing activities in the construction and commissioning stages.

4.37. The craftspersons employed should be trained and should initially demonstrate a satisfactory level of skill in their craft. Certain crafts, such as welding, require periodic requalification and authorization to demonstrate that the individual continues to have the necessary skills. Retraining may be necessary for this purpose. The craftspersons should also be trained to understand plant systems and equipment as appropriate to their task. A system should be in place to ensure that craftspersons do use or refresh safety related skills before they start to work, in order to minimize the potential risks to the plant and personnel. This not only will lead to more efficient use of human resources but also may enable variations between the radiation doses to different individuals to be minimized.

4.38. Further information on the training of nuclear power plant personnel can be found in Ref. [5][1].

5. IMPLEMENTATION OF THE MS&I PROGRAMME

PROCEDURES

5.1. The operating organization should develop procedures for all MS&I tasks. These procedures should be prepared, reviewed, validated, issued and modified in accordance with established administrative procedures.

5.2. The operating organization should require the plant management to prepare procedures that provide the detailed instructions and controls necessary for carrying out MS&I activities. The plant management should delegate responsibility for preparing these procedures to the MS&I group. The procedures should normally be prepared in co-operation with the designers, the suppliers of plant and equipment, and the personnel conducting activities for quality assurance, radiation protection and technical support. If persons outside the plant organization prepare procedures for routine activities, these procedures should be submitted to the maintenance manager for approval. The plant management should ensure that the procedures are correctly implemented and that special provisions are included where particular hazards are envisaged.

5.3. Acceptance criteria and actions to be taken if acceptance criteria cannot be met should be clearly specified in the procedures.

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[1] To be superseded by a Safety Guide on Recruitment, Qualification and Training of Personnel for Nuclear Power Plants, in the Safety Standards Series (in preparation).

5.4. Maintenance that could either affect the performance of items important to safety or potentially endanger the health and safety of personnel should be preplanned, and should be performed in accordance with properly approved written procedures or drawings appropriate to the circumstances. However, no maintenance procedure should necessitate the bypass or removal from service of systems or components if this would result in the loss of one or more safety functions (see Ref. [6]).

5.5. Routine activities involving skills that qualified personnel usually possess may not require detailed step by step instructions; they should nevertheless be subject to control by means of general administrative procedures.

5.6. If exceptional circumstances arise in which a particular task has to be commenced or performed without following authorized procedures, this task should be carried out only under the direction of an authorized person. Once the task has been carried out, an appropriate evaluation should be made as soon as possible and in any event before the equipment is restored to normal service.

5.7. In the process of preparing procedures, in particular in determining their technical content, reference documents should be used. These reference documents should include appropriate drawings, codes, standards, instruction books and manuals, as provided by the design organization, construction organization, equipment suppliers and operating organization.

5.8. The information contained in the procedure should be presented step by step in a logical order. All references and interfaces with other relevant procedures should be carefully reviewed and verified. The level of detail should be such that the individual carrying out the work can follow the procedure without further guidance or supervision.

5.9. The content and format of a typical procedure should be in accordance with the provisions established for quality assurance. The content should therefore typically include the following:

(a) Identification of the procedure: numbers, letters or a combination of both that identify each procedure as one in a series. This unique identification should be used to identify the procedure in all subsequent programmes, plans and records that refer to it.
(b) Title: a concise description of the subject of the procedure.
(c) Purpose: a brief statement of the purpose and scope of the activity controlled by the procedure.
(d) Prerequisites: all special conditions for the plant or system, or the status of equipment necessary prior to the commencement of work covered by the

procedure. Any necessary special training or mock-up practice should also be mentioned.

(e) Limiting conditions: any conditions, such as load reduction or the operation of standby equipment or safety systems, that result from carrying out the work and which limit the plant's operations. For example, when a system is undergoing repair, surveillance or testing, it should be considered unavailable for safety purposes unless it can be demonstrated to be able to perform its safety function to an acceptable degree.

(f) Special precautions: any special safety procedures such as special measures for radiation protection, the securing or removal of loose items, and any necessary control of materials (for example, incompatible lubricants or chemicals) and environmental conditions.

(g) Special tools and equipment: a listing of all special tools, rigging and equipment necessary to carry out the work.

(h) References: a list of applicable sections of reference documents that may need to be consulted, such as documents containing baseline data, test and calibration charts, drawings, printouts, instruction books, manuals, applicable codes and standards, photographs and descriptions of mock-ups.

(i) Instruction text: a step by step listing of work details which identifies any changes in radiological or other conditions as work progresses. At selected steps, craftpersons may be required to sign their names or their initials to indicate satisfactory completion of the preceding step or steps, either on the procedure or on an attached checklist.

(j) Inspection witness points: selected points in the work sequence at which an inspection for quality control purposes or another type of inspection by a competent person, as required by the regulatory body, is to be made. Work may not proceed past this point until the inspection has been performed and documented.

(k) Return to service: the actions and checks necessary for returning the equipment or system to an operational condition after the person responsible has certified that the task is completed. Where appropriate, independent checking and acceptance criteria should be specified. These criteria should include correct reinstatement and correct compliance with procedures as well as confirmation of system operability (for example, confirmation of valve line-up).

(l) Operational testing: any operational testing subsequent to a job that is necessary to prove that the equipment is functioning in the intended manner.

Items (k) and (l) are operating functions and may be included either in the MS&I procedure or in a special interfacing operating procedure.

5.10. Procedures should require that instrumentation and alarms associated with the system under test or calibration be checked and left operational as far as possible.

5.11. Procedures should state clearly the operating conditions necessary during the performance of MS&I activities. These conditions should be such that the activities result neither in the violation of operational limits and conditions nor in the loss, even temporarily, of one or more complete safety functions (see also Ref. [3]). If a component of a protective system is taken out of service — for surveillance purposes, for example — the corresponding safety circuit should be left in the configuration most conducive to safety.

5.12. Since certain activities require that systems or components important to safety be removed from service, the MS&I procedures should include both prerequisites for removal and specific directions for the complete and proper return to service of such systems and components, in order to ensure that the limits and conditions for normal operation are not violated. The safety related effects of these activities should be assessed as stated in para. 4.24. The time period for which systems or components important to safety are removed from service should be minimized and, as a minimum, should comply with established limits and conditions. The basis for this should be derived from risk considerations. If the test is interrupted for any reason, these systems or components should expeditiously be restored to normal service.

5.13. Procedures for monitoring plant parameters or system status may stipulate the use of checklists, the filling-in of predesigned tables or the plotting of graphs, all of which should be retained as part of the documentation of work carried out.

WORK CONTROL

5.14. A comprehensive work planning and control system applying the defence in depth principle should be implemented so that work activities can be properly authorized, scheduled and carried out by either plant personnel or contractors, in accordance with appropriate procedures, and can be completed in a timely manner. The work planning system should maintain high availability and reliability of important plant SSCs.

5.15. The comprehensive work control system should include any authorizations, permits and certificates necessary to help ensure safety in the work area and to prevent maintenance activities from affecting other safety relevant areas. The following specific matters should be considered in the work control system:

— work order authorizations;
— equipment isolation, work permits and tagging;
— radiation work permits;

— industrial safety precautions;
— drainage facilities and ventilation;
— fire hazard control;
— electrical and mechanical isolation devices;
— control of plant modifications.

5.16. The authorizations, permits and certificates referred to in para. 5.15 should:

— define the plant item, the type of work to be performed and the boundaries of the work area in which the activities of plant and/or contractor personnel are authorized;
— confirm that the plant item either is in a safe condition to work on or conforms to conditions set out in the prerequisites of the written procedures applying to the authorized work (such conditions should specify any precautions that need to be taken);
— confirm radiological conditions in the work area, note any possible hazards and specify any precautions to be taken in order that the authorized work may be carried out safely;
— define any permission that must be obtained before the work is commenced;
— confirm that all personnel involved have been withdrawn from the work area after completion of the authorized work and that the plant item either can be returned to service or will remain in a known condition.

5.17. The work control system should be used to ensure that plant equipment is released from service for maintenance, testing, surveillance and in-service inspection only upon authorization of designated operating personnel and in compliance with the operational limits and conditions. It should also ensure that, following maintenance, testing, surveillance and in-service inspection, the plant is returned to service only upon completion of a documented check of its configuration and, where appropriate, of a functional test.

5.18. Management of the work should be recognized as a cross-functional process, not exclusive to any one work group but integrating the important activities of all work groups. Consequently, for the work control process to be fully effective, all needs and concerns in relation to operations, maintenance, technical support, radiation protection, procurement and stores, contractors and other matters should be considered and should be accommodated wherever appropriate, consistent with the long term operating strategy for the plant.

5.19. The effectiveness of the work control process should be monitored by appropriate indicators (such as repeated work orders, individual and collective radiation

doses, the backlog of pending work orders, interference with operations) and by assessing whether corrective action is taken whenever required.

OUTAGE MANAGEMENT

5.20. The administrative procedure for outage management should ensure effective implementation and control of all activities performed during planned and forced outages.

5.21. Outage planning should be a continuing process in which account is taken of past, next scheduled and future outages. Milestones should be determined and used to track work prior to the outage. Planning should be completed as far in advance as possible, since circumstances may necessitate the outage to begin earlier than intended.

5.22. The tasks and responsibilities of different organizational units and persons should be clearly established and understood. This is especially important during outage periods, when the organizational structure may be temporarily changed. Nuclear safety during shutdown periods should be given careful consideration.

CO-ORDINATION AND INTERFACES

5.23. Because of the complexity of a nuclear power plant, the activities of different units of the plant's management interface with one another in ways that are significant to safety. In addition, the allocation on and off the site of the resources necessary for effective MS&I is an important activity, owing to the many special components to be maintained. MS&I activities should therefore be planned in the context of overall plant management, and MS&I personnel should work in close consultation with other plant management staff. It is usual practice for the plant management to establish a planning unit to co-ordinate all activities. MS&I personnel should schedule their own work in accordance with the overall plan. It should be ensured that adequate maintenance personnel is available and on call to provide urgent remedial maintenance as necessary.

5.24. Effective co-ordination should be established:

(a) Among different maintenance groups (mechanical, electrical, instrumentation and control, and civil engineering maintenance groups);
(b) Among the operations, radiological protection and MS&I groups;
(c) Among the plant departments and contractors.

5.25. The MS&I group should ensure efficient and effective implementation and control of activities. The organization and staffing of the relevant departments, as well as the responsibilities of different groups of staff, should be defined and communicated in such a way that they are understood by all those involved.

5.26. Interfaces that are relevant to MS&I should be addressed in the quality assurance programme. Appropriate arrangements should be agreed between the operating organization and other organizations performing work at the nuclear power plant or providing specific services for the plant. For further guidance on interfaces see Annex II of Safety Guide Q1 in Ref. [2].

RETURN TO OPERATIONAL STATES

5.27. Returning to an operational state is the final stage of any MS&I activity, or of any other action involving temporary deviations from the normal operational state of a power plant. The return to an operational state should be carried out in accordance with appropriate operational procedures.

5.28. Before returning to an operational state, it is important to ensure that:

- appropriate post-maintenance testing has been carried out (see also para. 8.55);
- the configuration of affected systems is verified;
- all relevant records are reviewed for completeness and accuracy;
- every effort has been made to complete all aspects of MS&I, and any unexpected findings have been reviewed.

5.29. Any necessary precautions and restraints on operation with temporary configurations or conditions should be clearly specified to all relevant personnel, and training should be carried out if necessary.

5.30. Completion of any MS&I activity should include a verification that all temporary connections, procedures and arrangements that were necessary for its implementation have been removed or cancelled and the plant has been returned to fully operational status.

5.31. All safety related SSCs which were changed from their normal states should be returned to normal operational states. Their configuration should be verified by authorized personnel in accordance with prescribed procedures before the system is returned to operation. More information on the management of temporary configurations can be found in Ref. [4].

5.32. A brief but complete review of the repairs carried out should be made and documented. This review should explicitly identify the cause of failure, the remedial action taken, the component that failed and its mode of failure, the total repair time and, if different, the outage time and, finally, the state of the system after repair. Even if a system is found to be within its calibration limits, this fact should be recorded, together with details of any replacement or any adjustment carried out at the discretion of maintenance personnel.

REVIEW AND AUDIT OF THE PROGRAMME

5.33. The operating organization should establish a programme for reviewing MS&I activities. Responsibility for this review programme should be assigned by the operating organization.

5.34. Such a review can assist line managers and supervisors in identifying and correcting programme deficiencies. An evaluation of each programme element should be conducted regularly, and this review should include inputs from all appropriate parts of the organization, including personnel in MS&I, operations and technical support. The evaluation should address the overall effectiveness of the programme elements. Areas needing improvement should be designated for corrective actions and follow-up.

5.35. The possibility of achieving impartiality of the review by bringing in various department heads from plant management should be considered. Additional expertise may be obtained from off-site personnel.

5.36. The review programme should examine the MS&I programme for features such as:

— adequacy of the schedule and its implementation;
— the response of MS&I to requirements;
— adequate control of radiation exposure;
— availability and effective use of resources;
— levels of training, experience and competence;
— compliance with quality assurance requirements;
— adequacy of procedures and instructions;
— effectiveness of the reviewing function within the programme;
— equipment failures and their impact on plant operations;
— repetitive corrective work on the same or similar equipment;

— number and types of deferred and missed actions;
— human resources needed and consumption of spare parts;
— adequacy of tools, equipment and facilities;
— accessibility of plant equipment, or layout problems;
— human errors and their impact on plant operation.

5.37. The findings of the review programme should be reported periodically to the group responsible for MS&I, to plant management and to selected members of the operating organization, and actions should be taken to maintain or enhance the safety and performance of the plant, as appropriate. The results of such an evaluation should be used to make corrections to the programme such as:

— adjustments to the frequency of appropriate actions;
— addition or deletion of actions;
— proposals for design changes;
— adjustments to the levels of stocks of spare parts and materials;
— adjustments to the availability of human resources and/or training;
— modifications to tools, equipment and facilities, or improvements to plant equipment in terms of its capability for MS&I (for recommendations on controlling such modifications, see Ref. [4]).

5.38. The operating organization should establish an audit programme for MS&I activities. These audits should be performed by personnel qualified in auditing and experienced in, but with no direct responsibility for, the area under review. The audits should determine whether the activities are being conducted in compliance with regulatory requirements and in accordance with the operating organization's policies and quality assurance programme. Further guidance on matters relating to audits can be found in Safety Guide Q5 in Ref. [2].

6. ANALYSIS OF RESULTS AND FEEDBACK OF EXPERIENCE

RECORDS AND REPORTS

6.1. Appropriate arrangements should be made for the orderly collection of records and the production of reports on MS&I activities. Records and reports are necessary to provide objective evidence that the MS&I programme is being implemented fully

and in accordance with the quality assurance programme. In addition, records such as equipment history cards and the results of MS&I work are necessary inputs to the continuing review of the effectiveness of these activities, which should be a responsibility of the MS&I group. Another important use of these records is for the generation of data for reliability studies and plant lifetime management.

6.2. The procedures for MS&I should be designed to facilitate the generation of records. In general, records should identify those MS&I personnel and operating personnel who were concerned with the work, and should include certification by supervisors or inspectors as appropriate.

6.3. The MS&I group should be required by an administrative procedure to select records which provide a meaningful history of the plant and to retain them throughout the plant's lifetime. Other records that have only a transitory value (such as records on individual components that have been replaced) should be retained either until they cease to serve the purpose for which they were intended or until they are superseded by subsequent records. An important factor that should be considered in selecting records to be retained is their usefulness in assembling reliability data. More information on the retention of records necessary for quality assurance purposes can be found in Ref. [2], in particular in Safety Guide Q3 on Document Control and Records.

6.4. More information on the specific types of records and documentation relevant to surveillance and in-service inspection is given in paras 9.45–9.46 and 10.45–10.47.

EVALUATION OF RESULTS AND CORRECTIVE ACTIONS

6.5. The operating organization should ensure that the results of MS&I are evaluated in order to verify compliance with the acceptance criteria.

6.6. Acceptance criteria for MS&I can be based on the as-manufactured specific standards. They should be established before the start of the programme and should be submitted to the regulatory body for review when required. When new or revised standards are developed or introduced, they should be agreed with the regulatory body.

6.7. Once an activity for MS&I has been completed, the results should be reviewed by a competent person other than the person who performed the activity. The review should establish whether the activity was appropriate and was properly completed, and should provide assurance that all results satisfy the acceptance criteria. If the results are

found not to meet the acceptance criteria, appropriate corrective action should be initiated. For guidance on control of non-conformances and corrective actions, see Safety Guide Q2 on Non-conformance Control and Corrective Actions in Ref. [2].

6.8. When the results of MS&I for a plant item that is out of service fall outside the acceptance criteria, then that plant item, unless it is repaired, replaced or modified, should remain non-operational until the safety aspects have been reviewed. If a review of the safety aspects for such a safety related plant item shows that its reliability and effectiveness have been affected, and if it is confirmed that a decision was taken not to repair, replace or modify it, then the deviation from the acceptance criteria should be justified in accordance with established procedures as a change to the safety analysis report. Any such plant item should remain non-operational until a justification of the deviation has been completed and approval of the regulatory body, if required, has been obtained. If the results of MS&I or of the review show that other SSCs of the plant may have similar defects, these SSCs should be inspected as soon as possible.

6.9. The MS&I programme should include appropriate actions to be taken in response to postulated deviations from the acceptance criteria, on the basis, primarily, of design information and design analysis. As a general rule, the actions to be taken when a deviation is detected should include, as appropriate:

(a) Actions by plant operating personnel, if required, to compensate for the deviation and to maintain the plant within the limits and conditions for normal operation. For multichannel systems, this may involve placing the failed component or channel in a fail-safe state until repairs and testing have been completed.
(b) Notification of management at the appropriate level of the operating organization.
(c) Remedial maintenance or a modification, to be carried out by plant personnel with the collaboration of specialists if necessary.
(d) Assessment of any safety implications of the deviation with regard to future operation, remedial maintenance and the surveillance programme.
(e) Consultation, if necessary, with design personnel and specialists.
(f) Assessment of the implications of the deviation with regard to the design of the system or component, computer modelling of the system, operator training, plant procedures, emergency measures and regulatory requirements.
(g) Modifications to the appropriate documents, procedures, plans and drawings.
(h) Notification of the regulatory body, if required.

6.10. Additionally, the results should be examined, where appropriate, for trends that may indicate the deterioration of equipment.

FEEDBACK OF EXPERIENCE

6.11. Data on experience with MS&I activities should be collected and analysed in order to enhance the safety of the plant and the reliability of SSCs throughout their service life. Histories of past MS&I should be used for supporting relevant activities, upgrading programmes, and optimizing the performance and improving the reliability of equipment. Adequate historical records should be kept for systems important to the safety and reliability of the plant. Appropriate arrangements should be made for the orderly collection and analysis of records and for the production of reports on MS&I activities. Historical records should be easily retrievable for purposes of reference or analysis. The use of computerized systems for the keeping of historical records would facilitate this process.

6.12. Historical records of MS&I should be periodically reviewed and analysed in order to identify any adverse trends in the performance of equipment or persistent problems, to assess impacts on system reliability and to determine root causes. The information thus obtained should be used to improve MS&I programmes and should be taken into account in the ageing management programme.

6.13. Arrangements for the feedback of MS&I experience should include, but are not limited to, the following:

(a) Collecting, evaluating, classifying and recording details of abnormal events or findings, in order to detect precursors, common mode failure mechanisms and deficiencies of equipment or personnel;
(b) Providing experience gained from actual activities to the design groups, in order to enable them in the future to improve plant features which have a bearing on MS&I, such as ease of access, ease of disassembly and reassembly, and implementation of the ALARA principle;
(c) Utilizing such experience in the training of personnel;
(d) Validating collected reliability data to be used for probabilistic evaluations and for the technical specification of new components;
(e) Ensuring the retrievability of data and the proper transfer of relevant information to the appropriate persons or organizations.

6.14. In addition to the internal feedback of experience, lessons learned from other power plants should be considered important contributions to the further improvement of MS&I programmes. Such information is particularly important for countries with few operating units and in relation to types of reactor that are in use in several countries. The links between national and international systems for the feedback of experience in operational safety broaden the base of information on approaches to

and practices in MS&I, the related lessons learned and corrective measures taken at the plant or national level.

7. AREAS IN WHICH SPECIAL CONSIDERATIONS APPLY

STRUCTURES, SYSTEMS AND COMPONENTS FOR ABNORMAL OPERATING CONDITIONS

7.1. Structures, systems and components important to safety which are installed as redundant items, or are called upon when normal operating conditions are threatened or lost, are normally kept in standby or off-line states. Examples of such SSCs are reactor containment vessels, emergency electric power sources, isolation valves and safety valves. Some of these SSCs cannot be monitored in situ for their operating reliability. Testing and surveillance for the actual conditions under which they are expected to operate, and which are generally difficult or impossible to reproduce, are usually undertaken under simulated conditions. These simulated conditions should be carefully planned, and the results should be interpreted prudently.

RISK ASSESSMENT OF PLANT STATUS UNDER SHUTDOWN CONDITIONS

7.2. Experience has shown that the safety of operations during the shutdown period of a nuclear reactor has increasingly been a cause for concern. Since a considerable amount of MS&I is planned and performed under plant shutdown conditions, the operating organization should perform safety assessments and make the arrangements necessary to minimize the risks during work carried out in this operating mode. The risk assessment should cover reactivity control, removal of residual heat, fuel handling, and the integrity of the primary pressure barrier and containment pressure barrier.

7.3. In view of the number and diversity of activities carried out during the shutdown period, the plant management should pay special attention to the plant configuration. It should take into account the risks involved at each stage of the shutdown and of the return of equipment and systems to operational states if this is required by the operating mode. Typical areas to be controlled and monitored are:

— sources of potential dilution and other means of reactivity control,
— sources of power supply,

— means of removing decay heat,
— means of preventing pressure transients.

7.4. The risk assessment should cover in particular those activities that have a significant influence on the level of risks at the plant, for example, mid-loop operation of a pressurized water reactor. Use should be made of the results of probabilistic safety assessments for the shutdown mode if these are available. Any specific training needs, special procedures for the shutdown mode or additional operating procedures or surveillance necessary should be identified in the risk assessment.

7.5. The sequencing of work should be reviewed in order to ensure that risks arising from concurrent activities are controlled and minimized.

PLANT AGEING

7.6. The operating organization should determine which additional MS&I activities will be necessary as the plant ages. At least two phases of the plant's lifetime should receive special attention in the planning of maintenance: the commencement of operation just after commissioning, and the period when ageing mechanisms could contribute significantly to the deterioration of safety related SSCs. There is no specific moment in time at which safety relevant ageing processes at a plant set in: this time is different for different SSCs. The importance of ageing processes for the safety and availability of a nuclear power plant should be recognized in order to maintain and enhance the plant's long term operating characteristics. Assessments should be made of whether and how the ageing of SSCs would increase the potential for common mode failures and for varying levels of incipient, degraded and catastrophic failures, in order to provide assurance of the availability of aged SSCs important to safety until the end of their service life. Monitoring the reliability and performance of the plant for ageing related degradation should therefore be a feature of the safety management programme, and an appropriate preventive maintenance programme should be in place.

7.7. MS&I programmes will identify and monitor ageing mechanisms of SSCs, which should then be reviewed in the formal periodic safety reviews conducted for the plant (see Ref. [7]). The periodic safety reviews may identify needs for additional or enhanced maintenance or surveillance, and a review or enhancement of the MS&I programme to take such needs into account should be considered.

7.8. In order to manage ageing processes, the MS&I programme should include, but should not be limited to, the following aspects:

— identification of components important to safety that are susceptible to degradation through ageing,
— identification of degradation processes that could adversely affect plant safety,
— adequate and up to date methods for detecting and monitoring ageing processes,
— the keeping of appropriate records to enable the ageing process to be tracked,
— methods of taking corrective actions in order to mitigate and/or prevent the effects of ageing,
— any necessary changes to the MS&I programme ensuing from the analysis of results.

For further guidance on ageing management for nuclear power plants, see Ref. [8].

PLANTS DESIGNED TO EARLIER STANDARDS

7.9. Safety standards and regulations are continuously reviewed in the light of experience and new practices, and are often improved or rationalized accordingly. New standards and regulations are applied as a rule to newly proposed projects. Plants designed, approved and constructed according to earlier safety standards and regulations may be allowed to remain in service in accordance with the original standards, provided that their safety is reviewed and it is found that safety levels continue to be acceptable. An appropriate method of review is the periodic safety assessment of such a plant against the current safety standards and regulations. The operating organization should review the differences between the original and the current standards, and should consider what can be done at the plant to bridge these differences. As part of this review, the operating organization should review the maintenance, testing, surveillance and in-service inspection programmes to confirm that the plant remains within its safety limits and is maintained within them, and, where technically justifiable, should make modifications to the MS&I programme as well as to the plant.

COMPUTER APPLICATIONS IMPORTANT TO SAFETY

7.10. Computer systems are different from conventional components with regard to MS&I. Special tests and procedures are required to prevent, or to detect, defects or deterioration in computer systems. Computer based systems are more vulnerable to electromagnetic disturbances than are conventional systems. Static discharges caused by the accumulation of electrical charges from human body surfaces or from components may cause damage to devices or components which are used to store

programmes or data. Precipitation of fine dust may cause irregularities in the circuitry. For these reasons, the test and maintenance regime for such equipment should be developed in consultation with the designers and manufacturers.

7.11. Computer based systems are used both to perform functions important to safety and to monitor and test systems important to safety. It should be ensured that computer based systems of both types are qualified for use and are maintained in accordance with their importance to safety. Maintenance activities on computer based systems should be carried out and managed in accordance with a maintenance plan that has been agreed between the user and the system developer prior to acceptance of the system.

7.12. A programme for the periodic testing of computer based systems important to safety should include applicable functional tests, instrument checks, verification of proper calibration and response time tests. The periodic functional tests should include, but should not be limited to, the following:

(a) Tests of all basic safety related functions;
(b) Special testing to detect failures that cannot be revealed by provisions for self-checking of the system or by alarms or anomaly indicators;
(c) Tests of the main non-safety-related functions to detect degradation of their performance.

7.13. For modified or new computer based systems, a probationary period of operation should be established during which in-service testing is undertaken more frequently.

7.14. Further guidance on MS&I for computer based systems important to safety is provided in Ref. [9].

8. ADDITIONAL CONSIDERATIONS SPECIFIC TO MAINTENANCE

PRIORITIZATION BY SAFETY SIGNIFICANCE

8.1. Structures, systems and components important to safety should be included in the preventive maintenance programme. The operating organization should review the programme as appropriate in order to ensure that items important to safety have been properly identified and classified, and that the applicable requirements of the

regulatory body have been met. For further guidance on the classification of SSCs in accordance with their importance to safety, see Refs [6, 10].

8.2. Maintenance actions can have significant effects on reliability and risk, but they can also entail a significant expenditure of resources. In order to reconcile potentially conflicting demands, individual maintenance actions should be prioritized according to their importance, and their probable effects on reliability and risk should be quantified. Different approaches can be used for this, all of which are based firstly on the selection of SSCs important to safety and secondly on specifying risk and performance criteria to ensure that the SSCs remain capable of performing their intended functions. The maintenance work that is most important for ensuring the reliability of components and controlling risks should be identified by these means.

8.3. The use of risk informed maintenance strategies should be considered, to provide a reasonable balance in the mixture of corrective, preventive and predictive maintenance (see paras 2.2–2.4) and to facilitate proactive maintenance rather than exclusively reactive maintenance.

8.4. Preventive maintenance should be of such a frequency and extent as to ensure that the levels of reliability and functionality of the plant's SSCs important to safety remain in accordance with the design assumptions and intent. It should also ensure that the safety status of the plant has not been adversely affected since the commencement of operation. In establishing the frequency and extent of preventive maintenance, the following aspects should be considered:

— the importance of SSCs to safety,
— designers' and vendors' recommendations,
— relevant experience available,
— results of condition monitoring,
— the probability of failure to function properly,
— on-line maintenance,
— the necessity of maintaining radiation doses as low as reasonably achievable (the ALARA principle).

8.5. The frequency with which SSCs not normally in use are maintained should be optimized to prevent possible wear-out due to subsequent overtesting, but also to provide confidence that they will perform their functions satisfactorily when called upon and to reduce the probability of errors in their reinstatement.

Workshop facilities

8.6. The operating organization should provide suitable workshop facilities with sufficient space and equipment to carry out maintenance effectively. The availability and intended use of off-site facilities and the need to deal with radioactive plant items should be taken into account. On-site workshops should be provided for mechanical, electrical, control and instrumentation equipment.

8.7. Each of the workshops should be equipped with the following:

(a) An office area (if not provided elsewhere), including facilities for the processing and storage of records and procedures;
(b) A fitting and overhaul area with suitable work benches for the disassembly, repair and reassembly of those plant items that are intended to be dealt with in the workshop;
(c) Secure storage facilities for special tools and testing equipment needed for maintenance.

8.8. On-site or off-site facilities should include at least:

(a) Mechanical workshops:

  (i) Space and equipment for welding, sheet metal and plate fabrication, pipe fitting, and handling of heavy equipment and materials;
  (ii) Machine tools such as lathes, milling machines, shapers, pedestal drills, grinders and presses;
  (iii) A clean room with equipment for lapping, polishing and surface checking.

(b) Electrical workshops:

  (i) Test benches with appropriate power supplies connected;
  (ii) A motor overhaul and test facility;
  (iii) A high voltage test area with controlled access;
  (iv) Instrument and relay testing and calibration facilities;
  (v) A small coil rewind facility.

(c) Control and instrumentation workshops:

(i) Test benches with the necessary electrical, electronic, pneumatic and hydraulic supplies and test equipment;
(ii) Calibration and testing facilities for instruments, controls and portable calibration equipment;
(iii) A facility for safe fault-finding on energized equipment.

(d) Other items:

(i) Facilities for acceptance testing of overhauled and/or replacement equipment, as necessary;
(ii) Preventive maintenance tools such as vibration analysers, bearing monitoring tools and non-destructive testing facilities.

Facilities for maintenance on radioactive items

8.9. It may be impracticable or impossible to decontaminate some plant items sufficiently to allow them to be maintained in the workshops for clean items. Special facilities should be provided for the maintenance of contaminated items, in order to keep radiation doses to individuals as low as reasonably achievable and to prevent the spread of contamination. This may be accomplished by providing specific maintenance facilities for particular plant items and by providing workshops, located within the controlled area, for work on radioactive parts brought to them. Dedicated tool stores may also be appropriate; their use should be controlled.

8.10. The management at the plant may occasionally find it necessary to supplement the above permanent arrangements by a temporary facility erected around a plant item or a machine tool.

8.11. Whichever type of facility is provided, the following should be considered:

— access control and changing rooms;
— ventilation with discharge filters;
— handling and temporary storage of solid and liquid radioactive waste;
— equipment for radiation monitoring and radiation protection;
— equipment for shielding and remote handling;
— provisions for storing radioactive items in conformity with established standards, with non-conforming items segregated from conforming items;
— decontamination requirements;
— access structures and platforms, if necessary.

Decontamination facilities

8.12. The operating organization should provide facilities for removing radioactive contamination from plant items, tools and equipment prior to their maintenance or any other disposition. Such facilities should include the following features:

— access control and changing rooms;
— ventilation with discharge filters;
— handling, storage and disposal of liquid radioactive waste;
— handling, storage and disposal of solid radioactive waste;
— equipment for radiation monitoring and radiation protection;
— decontamination tanks and special equipment capable of decontaminating the largest plant items likely to require decontamination;
— an adequate electric power supply and adequate supplies of steam, hot water, compressed air and appropriate chemical decontaminating agents;
— other decontamination systems, such as those for glass blasting or ultrasonic techniques.

8.13. Changing rooms and decontamination facilities should be provided that can accommodate the maximum use made during periods of intensive maintenance work.

8.14. In some cases, it may be desirable to undertake some local decontamination of individual components before removing them and bringing them to the decontamination facility. Suitable equipment should be provided together with instructions for its use, which should be validated in order to prevent damage to equipment, undue exposure of personnel or spreading of contamination.

Other facilities, tools and equipment

Mock-ups

8.15. In some cases, there may be advantages for maintenance in designing and constructing simulations, mock-ups or models of particular sections of the plant, either full size or smaller, in areas remote from the section of the plant concerned. Such facilities should be considered in particular for:

— rehearsing work to be carried out in high radiation areas or on highly contaminated plant items, particularly for personnel not familiar with the plant or for an unusual or specialized task;
— preparation and validation of procedures, to avoid errors and reduce exposure;
— the gathering of experience with tools and protective equipment;

— development and improvement of tools and equipment;
— training and qualification of personnel for specific work, and confirmation of estimates for work durations.

Special equipment and tools

8.16. In addition to the special equipment essential to maintenance, the plant management should provide special equipment where this could significantly reduce exposure or enhance safety, and should provide adequate training in its use. Examples of special equipment that should be considered are:

— remote handling manipulators and remotely operated special purpose tools;
— automatic welding and cutting equipment;
— remotely operated non-destructive testing equipment;
— automatic in situ valve seat lapping machines;
— remote viewing equipment such as mirrors, binoculars, telescopes, periscopes, boroscopes, fibrescopes, closed circuit television and remotely operated cameras;
— communication systems such as direct line telephones and radio, and communications equipment for use when protective respiratory equipment is being worn;
— special containers for contaminated items;
— shielded containers and portable shielding;
— protective clothing and equipment, possibly incorporating advanced dosimetry techniques, for increasing awareness of occupational exposure and improving its management;
— material and equipment for controlling and containing radioactive contamination (for example, plastic sheeting and tents, paper floor covering, suction cleaners and floor cleaning equipment);
— fixed or rapidly assembled equipment for access in order to reduce personnel exposure (for example, permanent ladders or telescopic cradles).

Photographic and video records and computer simulations

8.17. During plant construction, the operating organization should ensure that comprehensive photographic and, where appropriate, video records and computer simulations are compiled, particularly of plant areas that will eventually be inaccessible or will be subject to intense irradiation. These visual construction records of as-built conditions should show identification marks and should be comprehensively catalogued with descriptive captions. This will ensure that similar photographs taken or tapes made during subsequent inspections or maintenance work can be easily

compared, and will help in any work planning and familiarization of personnel that are undertaken before the start of maintenance work.

Lifting and handling facilities

8.18. The operating organization should ensure that adequate facilities and space as well as clear access ways are provided in the design of the plant for all plant items that are likely to be removed and transported.

8.19. Plant management should provide suitable mobile lifting and transport facilities, with clear indications of their lifting capacity. In the selection and use of these facilities, due account should be taken of the possible radiological consequences of their failure. Examples of precautions taken include regular examination and maintenance of lifting equipment, periodic testing, special inspections before major operations involving lifting and rigging, and cautionary notices limiting movements of loads over specified areas. All operations involving lifting and rigging should be performed by trained personnel.

8.20. Special consideration should be given to the use of mobile lifting and transport facilities as a possible means of substantially reducing occupational exposure (for example, filter removing equipment).

SPARE PARTS AND STORES

Organization

8.21. The operating organization should establish a suitable organizational unit to procure, receive, store and issue materials, spare plant items and components for use with systems important to safety. The section receiving, storing and issuing such items on the site should report to the plant management. The procurement section should also report to the plant management, but it may be located elsewhere, for example to serve a number of plants. In the latter case, the operating organization should ensure that written procedures are in place to control the interface between the off-site procurement section and plant management. These procedures should clearly define who has the authority to specify technical requirements and quality assurance requirements and to select suppliers. When that authority is vested in an off-site organization, the procedures should require consultation with and approval by the plant management. Whatever the organizational structure, the operating organization should establish written procedures to cover these activities and should provide appropriate training in quality assurance for the personnel involved.

8.22. The organizational unit that receives, stores and issues items important to safety should have its responsibilities defined in writing by the plant management. A satisfactory arrangement would be for personnel in charge of the stores to be answerable to the head of an on-site procurement unit. If the plant management considers allocating this responsibility to an administrative group, suitable procedures will be necessary to ensure that this group responds to the requirements of the maintenance group.

8.23. The maintenance group should be responsible for ensuring that adequate spare parts and components, tools and resources for achieving its objectives are available. It should also be responsible for establishing stock levels and authorizing the issue and use of spare items and components.

Procurement

8.24. The operating organization should arrange to purchase appropriate quantities of spare items and components for systems important to safety at the same time as purchasing those to be installed at the plant. These spares should, as a minimum, meet the same technical standards and quality assurance requirements as the equivalent installed plant items, but with additional provisions for ensuring adequate protection during long term storage.

8.25. The initial quantities of spare items and components to be purchased should be approved by the plant management after consulting with the vendor and taking account of relevant maintenance experience available to the operating organization. Factors to be considered include:

— the number and importance of major plant items that could be subject to serious failure;
— any special nature of a manufacturing process that would preclude subsequent manufacture of a plant item;
— any uncertainties in the future supply of parts and components that are currently available;
— anticipated delivery times;
— the estimated duration of repairs to a plant item, in comparison with the time of unavailability of the item permitted by the operational limits and conditions;
— the shelf-life of the component.

8.26. Spare items and components, materials and parts should be procured in accordance with the provisions of Safety Guide Q6 on Quality Assurance in the Procurement of Items and Services for Nuclear Power Plants [2]. Deviations from the

original specification, however minor, should not be permitted before the change has been referred to the plant management for consideration under the procedure established for plant modifications. Modern production processes can make it very difficult to discover that a manufacturer has made a change to an item. This is particularly true for electronic equipment or small sealed items of control equipment. Close liaison with manufacturers should therefore be maintained.

8.27. It should be the responsibility of the procurement unit to ensure that materials and items are obtained only from suppliers who have been approved by the operating organization. Safety Guide Q6 in Ref. [2] provides guidance in this connection.

8.28. Routine reordering of materials and plant items already held in store should be initiated automatically in accordance with written procedures whenever a predetermined low stock limit is reached. This limit should be based on the expected or known rate of use and the anticipated delivery time or shelf-life. The procurement unit should ensure, by means of documented reviews at the time of reordering, that the technical requirements and quality assurance requirements have been updated as appropriate and incorporated into routinely generated procurement documents.

8.29. Procurement of maintenance items not held in store should be initiated by the maintenance group. This group should be responsible for ensuring, in accordance with an established procedure, that the technical requirements and quality assurance requirements have been correctly established and specified to the procurement unit. It should then be the responsibility of the procurement unit to ensure that these technical requirements and quality assurance requirements are incorporated into the procurement documents without any change.

Receipt

8.30. The operating organization should provide adequate facilities for receiving on the site all materials, spare parts and components for items important to safety. The receiving area should include equipment for safe, convenient handling, and sufficient space with appropriate environmental conditions for proper inspection of items upon receipt. A separate and secure quarantine area should be provided for the temporary retention of stocks not cleared for final storage or issue.

8.31. The plant management should allocate in writing the responsibility for receiving on the site any materials, spare parts and components, and should issue a special procedure to control the receiving and acceptance process. This procedure should include visual external inspection for transit damage or deterioration, and verification

of correct packaging and identification. Identification details should be recorded for subsequent controls of materials and stocks. Items that are found to be incomplete or incorrect or that carry inadequate documentation should not be accepted for final storage. The procedure should also include a requirement to label or tag such items until the non-conformance is resolved. Detailed guidance on inspections upon receipt is provided in Safety Guide Q6, Ref. [2].

Storage

8.32. The operating organization should ensure that storage facilities offer adequate space and provide for the secure retention of stocks in suitable environmental conditions, in order to prevent deterioration. Access and the installed handling equipment should be adequate for the types and sizes of items to be stored.

8.33. Plant management should make administrative arrangements to ensure that the storage facility is operated in a manner that preserves the proper environmental conditions, guards against fire hazards and prevents unauthorized access to stored items. The stored items should be arranged so that regular examination of all stocks may be conveniently accomplished, where necessary with the use of suitable handling equipment.

8.34. The administrative arrangements should include written procedures assigning the responsibility for regularly examining stored items and auditing the administration of stores in order to detect any deterioration or any unauthorized or unrecorded use of stored items. Particular attention should be paid to retention of the original identification of items during storage.

8.35. Plant management should include, in the procedure relating to modifications, steps to initiate, control and record the modification of spare parts following modification of the equivalent items installed at the plant.

8.36. If the packaging of an item incorporates protection against deterioration in storage and it is found necessary to invalidate that protection, for example to modify or inspect the item, then the protective function should be restored or deterioration should be prevented by some other equivalent means.

8.37. Items that have a limited shelf-life should, if not used, be replaced at the appropriate time in order to ensure suitability for the expected function when they are needed. Information on storage matters can be found in Safety Guide Q13 on Quality Assurance in Operation, in Ref. [2].

Issuing of stored items

8.38. Storage facilities should provide for convenient and orderly issuing of stored items. This is normally done with the aid of a counter or barrier through which the issue of stocks can take place without contravening arrangements for security and proper environmental conditions.

8.39. Stored items should only be issued by authorized persons in response to written requests presented by persons having authority to receive these items. Appropriate records should be generated to document the ultimate destination of issued items, in order to facilitate tracing. The issuing procedures should require that excess or unused items be returned to the store in accordance with normal receiving procedures.

8.40. Unless organizational arrangements such as full shift staffing allow continuous access to the store, the procedures should permit emergency issue of urgently required items on the authority and under the control of the shift supervisor, in a manner compatible with the normal issuing process.

REPAIR AND REPLACEMENT

General provisions

8.41. In general, components should be repaired or replaced if they have been assessed to be unacceptable for further service. They should also be replaced in the event of obsolescence.

8.42. Repairs to or replacement of defective items should be carefully controlled, particularly when current standards require approaches and techniques that differ from those used in the original manufacturing process. In such situations, the standards to be applied to the repair or replacement should be considered by the operating organization by way of the formal plant modification arrangements. Current standards should be applied whenever possible. Proposals for repairs or replacements to be made according to non-original standards should take into account the following:

(a) The requirements relating to the design, fabrication and inspection of the item should be reviewed, and it should be confirmed that the original safety requirements have not been compromised.
(b) Mechanical interfaces, fits and tolerances affecting performance should not be changed by the later editions of existing codes or standards, or by new codes or standards.

(c) The materials used should be compatible with and suitable for the installation and operating requirements of the system.

8.43. Components that have been repaired or replaced for any reason should be re-inspected in accordance with the recommendations of this Safety Guide, and pressure retaining components should be tested in accordance with the appropriate procedure before being returned to service. Such a re-inspection should include the method by which the deterioration was detected, and should form the basis for comparison with the results of subsequent in-service inspections.

8.44. When systems or components require modifications, alterations or additions, the provisions in this Safety Guide for repair and replacement should be followed.

Remedial maintenance

8.45. The maintenance group, with the assistance of outside organizations if necessary, should be capable of restoring the plant to its normal operational capability by remedial maintenance such as the replacement or repair of defective plant items.

8.46. The need for remedial maintenance may arise when deficiencies or failures are detected during plant operation. The plant's management, in anticipation of such cases, should prepare appropriate procedures detailing how such failures are to be reported to the maintenance group and how plant items are to be withdrawn from service for remedial maintenance (for example, procedures for work order authorizations and equipment isolation work permits). These procedures should require the operating personnel to assign priority to remedial work on the basis of its importance to safety, with account taken of the operational limits and conditions as well as the necessity of preventing the loss of any safety function.

8.47. After any remedial maintenance has been completed, a brief report on the repairs or replacements carried out should be prepared. The component that failed, its mode of failure, the remedial action taken, the total repair time, the total outage time and the state of the system after completion of the remedial maintenance work should be identified. For major failures of components important to safety, a root cause analysis should be carried out in order to prevent recurrence.

8.48. The maintenance group should periodically review the maintenance records for evidence of incipient or recurring failures. When a need for remedial maintenance is identified, either in this review or during preventive maintenance of the plant, the maintenance group should initiate remedial maintenance in accordance with the

administrative procedures mentioned above. If appropriate, the preventive maintenance programme should be revised accordingly.

Replacement of defective items

8.49. When remedial maintenance can most conveniently be accomplished by substituting a proven identical spare for the defective plant item, this should be done in accordance with established procedures such as those for issuing work order authorizations. A defective plant item not suitable for subsequent repair should be disposed of by a suitable process that prevents its reuse. The accumulation of defective components in work areas should not be allowed.

8.50. When a defective item has been replaced, suitable functional or performance tests should be carried out in conjunction with the operating personnel. The tests should be documented and the results recorded. The plant item should be returned to service or to standby duty in accordance with established procedures (see also paras 5.27–5.32).

Repair of defective items

8.51. Defective items, whether or not they have been removed from the plant, should be repaired in accordance with established procedures such as those for issuing equipment isolation work permits and work order authorizations, as appropriate.

8.52. When plant repairs consist of more than merely replacing parts and components with identical spares, a review should be made to assess whether the repair will involve sufficient changes to require application of the procedure for the control of plant modifications.

8.53. If repairs are made in situ, post-maintenance testing should be performed and procedures for returning to service should be followed, as mentioned in paras 8.50 and 8.55.

8.54. Plant items that have been repaired in the workshop should be inspected and tested to ensure, as far as possible, their full return to serviceability. If testing cannot be completed in the workshop, cautionary labels or tags should be applied to the respective item to warn that testing has still to be completed before reuse. When these post-repair processes are complete, items not intended for immediate installation should be returned to the stores through normal receiving processes.

POST-MAINTENANCE TESTING

8.55. Before any system or component is returned to service after maintenance, tests should be performed to ensure that the objective of the maintenance has been achieved, that the limits and conditions for normal operation associated with that system or component are satisfied, and that the plant can be operated safely. This procedure should include testing of connected systems and other systems in the work area that may have been affected by the maintenance action.

9. ADDITIONAL CONSIDERATIONS SPECIFIC TO SURVEILLANCE

SURVEILLANCE PROGRAMME

9.1. A surveillance programme should be established by the operating organization to verify that provisions for safe operation that were made in the design and checked during construction and commissioning continue in effect during the operating lifetime of the plant and continue to supply data to be used for assessing the residual service life of SSCs. At the same time, the programme should verify that the safety margins are adequate and provide a high tolerance for anticipated operational occurrences, errors and malfunctions. Particular attention should be paid to the following aspects:

— integrity of the barriers between radioactive materials and the environment (such as fuel cladding, primary pressure boundary and containment);
— availability of safety systems such as the protection system, the safety system actuation systems and the safety system support features (see Ref. [11]);
— availability of items whose failure could adversely affect safety.

9.2. The surveillance programme should fulfil the following functions:

— delineating in sufficient scope and depth the aims of surveillance in accordance with operating limits and conditions and other requirements that are applicable to SSCs important to safety;
— specifying the frequency of surveillance and providing for the scheduling of surveillance activities;
— specifying standards to be applied and providing for appropriate procedures to be followed in the conduct and assessment of each surveillance activity;

— verifying that SSCs important to safety remain within the operational limits and conditions;
— specifying the authorities and responsibilities assigned both to individuals and to on-site and off-site organizations involved in deciding on and carrying out surveillance activities;
— specifying the qualifications of personnel performing surveillance activities;
— indicating the points at which tests are required and deficiencies, if any, are rectified;
— specifying the requirements for records to be kept and for the retention and retrievability of such records;
— providing cross-references to other documents relevant to the surveillance programme;
— ensuring that regular or periodic reviews of surveillance programmes are carried out (see paras 5.33–5.38).

9.3. In compliance with the fourth item of para. 9.2, an appropriate surveillance requirement should be established for each operational limit and condition (for further information regarding operational limits and conditions, see Ref. [3]).

9.4. Some data from plant operation, such as the number of trips or the numbers and values of variations in temperature and power, may be obtained not by the usual methods of surveillance such as monitoring, measuring and testing, but directly from the records of the plant operating history. This Safety Guide does not deal with such items; however, it is recognized that the collection and evaluation of these data are of fundamental importance for the assessment of plant performance and residual lifetime.

9.5. Not all SSCs require the same frequency and extent of surveillance. The use of quality assurance principles enables the surveillance requirements to be derived in a graded manner such that the extent of the requirements is consistent with the safety functions performed by the SSCs. Account should be taken of the probability of failure to perform properly (PSA results can be used if applicable) and of the requirement to maintain radiation exposures as low as reasonably achievable. The frequency with which SSCs not normally in use are tested should be optimized, so that they can perform their functions satisfactorily when required and possible wear-out due to overtesting is avoided. In deciding on the extent of the surveillance requirements, systems may be classified in accordance with their importance to safety.

9.6. In developing the programme components mentioned in para. 9.2, the following should be considered:

— the requirements established in the safety analysis report, the operational limits and conditions, and other applicable requirements of the regulatory body;
— results of the commissioning programme, with particular attention being paid to baseline data, the as-built state of the plant and the acceptance criteria;
— the availability of items important to safety, and the detection of deficiencies and incipient failures that might occur during operation or prior to returning items to service after maintenance, repair or modification.

9.7. The surveillance programme should be developed by the operating organization sufficiently early to permit it to be properly implemented as and when plant items become operational in the commissioning phase or, where appropriate, upon installation. Implementation should be scheduled such that the safety of the plant does not depend on untested or unmonitored SSCs.

9.8. To meet the provisions of para. 9.7, the surveillance programme should be established early enough to permit:

(a) Supporting procedures to be developed, reviewed and approved in a timely manner;
(b) The surveillance procedures to be tested, to the extent practicable, in the commissioning phase;
(c) Certain parameters to be recorded (during and after construction but prior to the commencement of operation) for use as reference points in monitoring. (Certain benchmarks and alignment references, for example, may need to be permanently marked, measured and recorded to provide as-built references for subsequent comparison.)

9.9. In preparing and reviewing the surveillance programme, special attention should be paid to ensuring that, whenever surveillance tests are carried out, control of the plant configuration is maintained and sufficient redundant equipment remains operable, even when the plant is shut down, to ensure that no operational limits and conditions are violated.

SURVEILLANCE OF THE INTEGRITY OF BARRIERS

9.10. Surveillance measures that should be taken to verify the integrity of fuel cladding include, but are not necessarily limited to:

— inspection of new fuel, core components and associated items such as flow restricting devices and locating devices, in accordance with an agreed schedule

prior to loading into the core; this inspection (see Ref. [12]) may include visual, metrological and more sophisticated methods (such as helium tests);
— monitoring of thermal and hydraulic conditions such as flow, temperature, pressure and gross and local power, in order to ensure compliance with operational limits and conditions;
— monitoring of the reactor coolant's activity and chemical composition (for example, by sample analysis);
— appropriate inspection of irradiated fuel before reuse, storage or transport (for example, by visual inspection or leak tests);
— monitoring of the activity and chemistry of water or gas in the irradiated fuel storage facilities;
— monitoring for discharges of radioactive material to the environment.

9.11. Surveillance measures that should be taken to verify the integrity and assess the residual service life of the pressure boundary for the primary reactor coolant include, but are not necessarily limited to:

— leak rate measurements, for example, by measuring the flow of make-up water to the primary coolant system or the flow to the leakage collection sump (a steady state condition is generally necessary for such measurements in order to eliminate transient effects);
— inspection of and hydrostatic pressure tests on the primary pressure boundary;
— recording of system transients and their comparison with the assumptions made in the safety analysis report, where appropriate;
— testing of the operability and tightness of closure devices that are part of the pressure boundaries;
— monitoring of leak detection systems (such as instruments for process and area monitoring, temperature detectors, acoustic detection equipment);
— monitoring to ensure that transition temperature requirements (for example, reference nil-ductility) are satisfied;
— monitoring of the chemical quality of the primary and secondary reactor coolants as appropriate;
— monitoring of samples of reactor pressure vessel components that are subject to irradiation.

9.12. Surveillance measures necessary to verify the containment integrity include, but are not necessarily limited to:

— leak rate tests performed on the containment;
— tests of penetration seals and closure devices such as air locks and valves that are part of the boundaries, to demonstrate their leaktightness and, where appropriate, their operability;

— inspections for structural integrity (such as those performed on liner and prestressing tendons);
— monitoring of conditions within the containment such as temperature, pressure and atmospheric composition.

9.13. The surveillance programme should include periodic tightness checks, pressure tests and/or leak tests of all systems of which parts are located outside the containment and which could contain highly radioactive liquids or gases in the event of an accident. Examples of such systems are:

— residual heat removal systems,
— safety injection systems,
— containment spray systems,
— chemical and volume control systems,
— treatment systems for radioactive fluid waste,
— core spray systems (for boiling water reactors).

9.14. The surveillance programme should include tightness checks, leak tests of all other systems and components designed to contain radioactive materials, or continuous testing as appropriate.

SURVEILLANCE OF SAFETY SYSTEMS

9.15. The surveillance of safety systems should cover systems and components provided to shut down the reactor and keep it shut down, and to ensure that safety limits are not exceeded either owing to anticipated operational occurrences or during the initial operation of systems that are required in order to mitigate the consequences of accident conditions. Such mitigation could be done through:

(a) Protection of the primary systems against unacceptable pressure surges (e.g. by steam dumping or safety and relief valve actuation); or
(b) Actuation of protection systems as intended.

The surveillance shall demonstrate the availability of the protection system, including all redundant parts, and shall verify the set points at which actuation occurs and the acceptability of all response times.

9.16. All SSCs with functions that mitigate the consequences of accident conditions should be subject to periodic surveillance, to demonstrate their availability

and effectiveness as far as practicable and to detect any degradation of their performance. Their functions include, but are not necessarily limited to:

— emergency core cooling and heat transport to the ultimate heat sink,
— containment isolation,
— cooling down of the containment and pressure limitation,
— control of discharges of radioactive effluents arising as a result of accident conditions,
— control of combustible gases within the containment,
— functioning of the standby shutdown system.

9.17. The availability of safety system support features should be confirmed. The functions associated with SSCs important to safety that should be considered include, but are not necessarily limited to, the supply of:

— emergency power,
— cooling water,
— air,
— cooling and lubrication,
— control and instrumentation.

SURVEILLANCE OF OTHER ITEMS

9.18. Other items that should be subject to surveillance are those that, if they were to fail, would be likely to give rise to or contribute to unsafe conditions or accident conditions. Such items include:

— systems that are relied on for shutting down and cooling the reactor under normal plant conditions, including control systems such as those provided to control and monitor reactivity, primary water chemistry, feedwater supply, reactor pressure and temperature;
— instrumentation for both operational states and accident conditions;
— the control room, with respect to habitability and access;
— high energy piping and associated piping restraints;
— structural supports (stack stay wires, pipe supports);
— fire prevention, detection and fighting systems;
— emergency facilities and equipment;
— protection systems for internal and external events;
— communication systems;
— storage facilities for irradiated fuel, including cleanup systems;

— fuel handling equipment and facilities;
— treatment and storage facilities for radioactive waste;
— turbine and generator speed control systems and their protection systems, where appropriate;
— measures for physical protection.

FREQUENCY AND EXTENT OF SURVEILLANCE

Determination of the frequency and extent of surveillance

9.19. The frequency and extent of the surveillance of individual SSCs should be determined primarily on the basis of their relative importance to safety. Access limitations and the requirement to keep radiation doses to personnel as low as reasonably achievable should also be taken into account.

9.20. The frequency and extent of surveillance should be adequate to fulfil the following functions:

— ensuring that the plant parameters, including the availability of specified items, continue to remain in accordance with the prescribed operational limits and conditions;
— detecting incipient failures or the need for more frequent maintenance in order to ensure satisfactory functioning and availability;
— ensuring that a defect does not develop and/or grow between two successive surveillance actions to such an extent as to become unacceptable or to lead to accident conditions;
— yielding information that allows an assessment of possible effects of excessive fatigue and/or premature ageing;
— meeting the relevant requirements of the regulatory body and of the applicable regulations, industrial codes and standards.

9.21. Surveillance frequencies should be determined on the basis of:

— the importance to safety and the need to meet reliability objectives;
— manufacturers' recommendations and information such as the results of type tests, endurance tests and cycle tests;
— expected mechanisms of failure, results of reliability analyses, age of the item or system, type of component and conditions of service;
— experience of failure rates gained from maintenance or from experience in the plant or in similar plants;
— the extent of automation of the surveillance.

9.22. Optimization of the surveillance frequencies may involve consideration of the following:

— the extent of redundancy of the respective system, in relation to the need to remove SSCs from service for surveillance;
— operational constraints that have a bearing on the implementation of surveillance activities;
— the scheduling of surveillance in conjunction with other activities such as planned maintenance and shutdowns or other operating cycles;
— facilitating the performance of a number of surveillance activities during a shutdown;
— flexibility to allow reasonable safety margins without impairing the effectiveness of surveillance;
— flexibility to allow surveillance to be carried out during unplanned shutdowns;
— flexibility to allow the performance of tests at a time when plant conditions are most suitable with regard to both the validity of the surveillance and the safety of the plant;
— the need to conduct surveillance without placing an undue burden on the plant organization and while still ensuring plant safety;
— the need to perform surveillance in operational conditions that are as close as possible to the normal operating conditions of the systems and components involved;
— the need to avoid spurious reactor trips or adverse effects on operation;
— the need to avoid any unnecessary shortening of the service life of a component or the introduction of errors by an excessive series of tests and operations;
— the requirement to maintain personnel radiation exposures as low as reasonably achievable;
— special considerations (see paras 9.23–9.29, for example).

Special considerations

9.23. In using calculated reliability figures to determine the surveillance frequency, the following limitations should be recognized:

(a) The difficulty of obtaining statistically meaningful data on fault events of low frequency.
(b) The difficulty of conducting sufficient testing to provide conclusive reliability figures; in such cases, the frequency of surveillance may be based on the best estimates of the operating organization for future failure rates and other criteria as recommended in this Safety Guide.
(c) The difficulty of assessing the significance of common cause failures.

9.24. Where only limited experience on the reliability of SSCs is available, the surveillance frequency initially adopted should be based on conservative assumptions. As experience is gained, changes may be made in accordance with para. 9.30.

9.25. The reliability of SSCs may be adversely affected by an excessive number of thermal, mechanical or other cycles. To reduce cycling caused by testing, the testing of components that provide a given safety function may be suspended during periods in which that particular function is not required to be available, provided that the surveillance requirements are met before any change in the operational state is made that requires the respective safety function to be available.

9.26. The reliability of SSCs may be adversely affected if technological limits defined by the designer are exceeded. These limits should be considered in the surveillance procedures, which should include acceptance criteria if appropriate.

9.27. The reliability of SSCs may be degraded by human induced faults (for example, calibration of redundant instruments on the same day by the same individual may introduce similar errors into both components and thus increase the potential for common cause failure). The frequency of such faults may be reduced, for example, by establishing detailed procedures.

9.28. Where certain redundant systems and components are kept on standby, operation of these systems and components should be rotated in order to subject all components to similar operating times and thus to similar surveillance procedures and frequencies. Maintenance intervals should be adjusted to ensure that not all systems and components wear out at the same time.

9.29. To increase confidence that the surveillance programme will detect unrevealed faults, diverse methods should be used where practicable during the testing of items subjected to surveillance.

Periodic re-evaluation of the frequency and extent of surveillance

9.30. The established frequency and extent of surveillance should be periodically re-evaluated to verify that they are effective in maintaining the SSCs in an operational state. Where appropriate, PSA based methods can be used to optimize surveillance. Procedures should be established for ensuring that these re-evaluations are carried out and that any necessary changes are approved by the appropriate authorities. In these re-evaluations, the following points should be considered:

(a) The performance of the SSCs, particularly their failure rate;

(b) The corrective action required after a failure;
(c) The performance of similar SSCs in similar plants and environments;
(d) Design changes associated with SSCs important to safety;
(e) Information on failure modes that cause abnormal occurrences or accidents;
(f) The effects of component ageing.

SURVEILLANCE METHODS

Monitoring

9.31. Monitoring gives operating personnel an immediate indication of the plant status. The parameters to be monitored are those that are most significant for safe plant operation and for the status of those SSCs that are not normally in operation but which may be required to operate under abnormal conditions.

9.32. Monitoring is normally conducted by the operating personnel either from the main control room or on periodic tours of the plant. It takes the form of noting down the parameter values shown by instruments, data loggers or computer printouts and observing plant conditions.

9.33. Monitoring may also involve sampling. Sampling may be done automatically or manually, and may be for chemical analysis, radiochemical analysis, material analysis or isotopic purity analysis. Since the techniques involved in such sampling and analyses are specialized, these activities should generally be conducted by specially trained personnel.

Instrument checks

9.34. The availability of instrument channels that give readings should be verified by means of one or both of the following:

(a) Comparing readings on channels that monitor the same variable, with an allowance for differences in the process variable between sensor locations;
(b) Comparing readings between channels that monitor different variables and bear a known relationship to one another.

Verification of calibration and response times

9.35. A calibration verification test is intended to check whether a known input to the instrument or channel gives the required output (analog, digital or bistable). In analog channels, linearity and hysteresis may also be checked.

9.36. Response time testing of safety systems or subsystems should be required to verify that the response times are within the specified limits. The response time test should include as much of each safety system — from sensor input to actuated equipment — as is practicable in a single test. Where the entire system from sensor to actuated equipment cannot be tested as a whole, the system response time should be verified by measuring the response times of discrete portions of the system and showing that the resultant of all response times is within the limits of the overall system requirements.

9.37. Calibration and response times should be verified by means of tests that do not necessitate the removal of detectors from their installed locations, unless such tests are not capable of determining whether changes in response time are beyond the acceptable limits. In such cases, sensors should be removed for a special bench test if this is practicable. If it is not practicable, then the manufacturer's test results may be used, provided that:

(a) Satisfactory assurance is obtained that ageing does not degrade performance beyond acceptable limits;
(b) The manufacturer's test results are not invalidated by the design of the system in which the sensor is installed;
(c) The tests have been performed and the test results documented in accordance with the quality assurance requirements of the operating organization's quality assurance programme.

FUNCTIONAL TESTS

9.38. A functional test shall ensure that the tested system or component is capable of performing its design function. To the extent practicable, SSCs should be tested under the conditions in which they will operate when performing their intended functions. A functional test of equipment should consist, as appropriate, of one or more of the following:

(a) Manual startup of equipment. The test duration should be sufficient to achieve stable operating conditions. Where starting a specified component is not practicable, operation of the starting device in the 'test' position may be acceptable if the component is subsequently tested at the first opportunity provided by plant operations.
(b) Manually controlled electric operation of valves, with timing of the stroke, if appropriate. In cases where a full stroke of the valve is not permissible because of the operating conditions, a partial stroke test or a test of the valve control system may be acceptable; however, full stroke testing should be done routinely

during plant shutdown, at conditions representative of operation where this is possible.

(c) Activation of a test signal of an appropriate magnitude to give a suitable actuation of the output or a readout, as required.

(d) Initiation of the actuating device and observation of the resultant operation.

(e) Testing of automatically calculated set points to verify the responses to each variable entering the computation.

(f) Checking of the manual initiation of safety functions.

(g) Testing of the status and operability of interlocks, bypasses, bypass and test indications, and bypass and test annunciation circuits.

(h) Monitoring of the appropriate parameters during the test.

Special tests

9.39. When special tests or experiments which are not included in the surveillance programme or which are not performed frequently are considered necessary, these tests or experiments should be justified. A special procedure for each test should be prepared and subjected to an independent review and assessment by qualified persons other than the originator of the proposal, in order to ensure that neither the operational limits and conditions nor the design basis will be violated and that no unsafe conditions will arise.

9.40. These special procedures should specify responsibilities for the conduct of the tests, but plant management should have the ultimate responsibility for deciding whether or not a test should proceed. The operating personnel should comply with standing orders to bring the plant back into safe conditions if an unplanned violation of the operational limits and conditions is observed or foreseen, and an appropriate briefing on this subject should be held before such a test or experiment is performed. The procedure should be submitted to the regulatory body for prior approval, as required.

Test equipment

9.41. The operating organization should ensure that all necessary test equipment, whether called for in the design or otherwise required for the surveillance programme, is available, operable and calibrated. So far as is practicable, test equipment should be permanently installed.

9.42. A programme should be established and maintained for the calibration and control of test equipment and reference standards used in surveillance. This programme

should provide for the prompt detection of inaccuracies and for timely and effective corrective actions. It should include the following general requirements:

(a) Equipment identification: test equipment used as a calibration reference standard should be identified, to enable verification of its calibration status.
(b) Equipment verification: before test equipment is used in a surveillance test, its calibration status and operability should be verified.
(c) Calibration procedures: detailed procedures should be provided for the calibration of test equipment; the accuracy of calibration should be commensurate with the functional requirements, and, where appropriate, reference standards should be used.
(d) Calibration records: records should be maintained for each piece of equipment in order to be able to demonstrate that established schedules and procedures for calibrating test equipment and reference standards have been followed.

9.43. The calibration records referred to in para. 9.42(4) should provide a calibration history showing calibration intervals, the date of the last calibration, the date when the next calibration is due, conformance or non-conformance with required tolerances before and after adjustments, and any limitations on use. It is often desirable to affix a sticker directly to the test equipment, giving the date of the last calibration and the planned date of the next calibration.

9.44. When test equipment is found to be out of calibration, the validity of the tests performed since the last calibration should be evaluated. For this purpose a history of usage should be maintained for each piece of test equipment. Test equipment found to be out of calibration should be identified by a tag or other suitable means.

DOCUMENTATION AND RECORDS OF SURVEILLANCE

9.45. All documents and results of surveillance activities should be retained in accordance with quality assurance requirements. The following is a listing of typical documents relating to surveillance activities:

— logs and logbooks containing the readouts of safety system parameters;
— recorder charts and computer printouts;
— reports of tests, calibrations and inspections, including evaluation of results and corrective actions taken;
— surveillance procedures;
— records of completed surveillance activities;
— reports of relevant reviews and audits;
— checklists for the status of systems and components.

9.46. These documents should be used as a basis for reviews carried out:

(a) To demonstrate compliance with operational limits and conditions;
(b) To detect trends indicating deterioration of systems or components.

10. ADDITIONAL CONSIDERATIONS SPECIFIC TO IN-SERVICE INSPECTION

IN-SERVICE INSPECTION PROGRAMME

10.1. Over the operating lifetime of a nuclear power plant, components may be exposed to influences whose single and combined effects cannot be predicted for the entire operating lifetime of the plant with the accuracy desirable for nuclear safety. The most important influences are stress, high temperature, irradiation, hydrogen absorption, corrosive attack, vibration and fretting, all of their effects depending on time and operating history. These influences may result in changes of material properties due to irradiation or thermal embrittlement, corrosion fatigue and the initiation and growth of flaws.

10.2. The systems and components of the plant should be examined for possible deterioration so as to assess whether they are acceptable for continued safe operation of the plant or whether remedial measures should be taken. Emphasis should be placed on examination of the pressure boundaries of the primary and secondary coolant systems, because of their importance to safety and the possible severity of the consequences of failure.

10.3. The in-service inspection programme includes those examinations and tests that are to be performed over the operating lifetime of the nuclear power plant. It is emphasized that, for successful implementation of this programme, a pre-service inspection should be performed before the commencement of operation in order to provide the baseline data with which examination and test results of the in-service inspection programme may be compared, and against which the possible development of flaws and the acceptability of components may be assessed.

EXTENT OF IN-SERVICE INSPECTION

10.4. In establishing the extent of the in-service inspection programme, consideration should be given to the following systems and components in accordance with their importance to safety:

(a) Pressure retaining parts of components in the reactor coolant system;
(b) Components of or connected to the primary reactor coolant system that are essential for ensuring the shutdown of the reactor and cooling of the nuclear fuel in relevant operational states and in postulated accident conditions;
(c) Other components, such as main steam lines or feedwater lines, whose dislodgement or failure might put in jeopardy the systems mentioned in items (1) and (2) above.

10.5. Components subjected to in-service inspection in accordance with para. 10.4 should generally be examined by visual, surface and volumetric methods. In addition, the pressure retaining components should be checked for possible leakage by means of a leak test.

10.6. Depending on their importance to safety, some components may be exempted from the surface and volumetric examinations because of either their size, the size of their connections, or the number of barriers between them and the fuel or the outside atmosphere. In such cases, however, these components should still be examined for integrity as part of the system hydraulic tests.

10.7. The number, frequency and extent of in-service inspections of similar systems and components may be reduced by a sampling programme that will vary according to the design, the number of similar components or systems involved, operational requirements and the existence of identical units in a multiple unit plant. The sampling rate should be consistent with the importance to safety of the respective component and the rate of degradation. Sample selection should be planned to ensure wide coverage of the sample population over an appropriate period.

INSPECTION SCHEDULES

10.8. In-service inspections of nuclear power plants should be carried out at intervals whose length should be chosen on the basis of conservative assumptions, to ensure that any deterioration of the most exposed component is detected before it can lead to failure. The inspection schedule should provide for repetition of the inspections over the operating lifetime of the nuclear power plant. The inspection programme may involve regular inspection intervals or, alternatively, the inspection intervals may be varied over the operating lifetime of the plant to improve the correlation between inspection intervals and the probabilities and characteristics of component failures. The intervals for evenly distributed inspections may be chosen to be from a few years to about ten years; for the variably distributed inspections, these

intervals may be shorter in the early years of the plant's operating lifetime and then lengthened as experience permits. Whichever programme is adopted, however, the results of inspections may necessitate a shortening of the intervals towards the end of the plant's operating lifetime.

10.9. The inspection intervals should be subdivided into inspection periods, in the course of which a required number of examinations should be completed, depending upon the component, the type of examination and the accessibility allowed by normal plant operations or scheduled outages. Such examinations may be considered a part of the total inspection required for the whole interval.

10.10. Examinations that necessitate the disassembly of components (such as the disassembly of pumps or valves to volumetrically examine large bolting, or the removal of fuel or of core support structures in reactor vessels in order to examine welds or nozzle radius sections) may be deferred until the end of each inspection interval except in cases where, on the basis of results of examinations conducted on analogous components, an earlier inspection is necessary. This should in no way diminish the requirements on the frequency of examinations formulated in the relevant design codes (for example, those of the American Society of Mechanical Engineers or the German Nuclear Safety Standards Commission).

PRESSURE AND LEAKAGE TESTING

10.11. Pressure retaining systems and components should be subject to:

(a) A system leakage and hydrostatic pressure test as part of the pre-service inspection;
(b) A system leakage test before resuming operation after a reactor outage in the course of which the leaktightness of the reactor coolant pressure boundary may have been affected;
(c) A system hydrostatic pressure test at or near the end of each major inspection interval, if required.

10.12. To the extent practicable, the pressure retaining components should be visually examined while the system is operating under the test pressure and temperature conditions. The test pressure and temperature should be maintained for a sufficient period before the examination to ensure that all possible leakages can be identified. The accessibility of components to be visually examined should be considered (for example, with regard to the possible need for removal of insulation). Acoustic emission methods may be used as part of such inspections.

10.13. If leakages (other than normal controlled leakages) are detected in the aforementioned tests, their source should be located and the area examined to the extent necessary to establish whether any corrective action is required.

10.14. The final system leakage test cannot always be performed at or above the specified system operating pressure unless the plant is at full temperature. Under such conditions, a graded approach to leakage testing should be followed, ending with the full operating condition.

10.15. The duration of tests performed at a pressure higher than the system's design pressure should be limited so as to prevent excessive stressing and creep of the components.

METHODS AND TECHNIQUES

General

10.16. The methods and techniques used for the examinations should be in accordance with standards recognized by the regulatory body. The examinations are categorized as visual, surface and volumetric examinations. Each term describes a general method, permitting a selection of different techniques or procedures to be applied with that method so as to accommodate varying degrees of accessibility and radiation levels and the automation of equipment for performing the examinations.

Visual examination

10.17. A visual examination should be made to yield information on the general condition of the part, component or surface to be examined, including such conditions as the presence of scratches, wear, cracks, corrosion or erosion on the surface, or evidence of leaking. Optical aids such as television cameras, binoculars and mirrors may be used. Surface replication as a method of visual examination may be considered acceptable, provided that the resolution at the surface is at least equivalent to that obtainable by visual observation. Any visual examination that requires a clean surface or decontamination for the proper interpretation of results should be preceded by appropriate cleaning processes.

Surface examination

10.18. A surface examination should be made to confirm the presence of or to delineate surface or near-surface flaws. It may be conducted by a magnetic particle method, liquid penetrant method, eddy current method or electrical contact method.

Volumetric examination

10.19. A volumetric examination, which will usually involve radiographic or ultrasonic techniques, should be made for the purpose of indicating the presence and depth or size of a subsurface flaw or discontinuity. Radiographic techniques employing penetrating radiation such as X rays, gamma rays or thermal neutrons may be utilized with appropriate image recording devices, to detect the presence of flaws and also to establish their size. An ultrasonic testing method is most commonly used to establish both the length and the depth of flaws.

Alternative methods of examination

10.20. Alternative methods of examination, a combination of methods, or newly developed techniques may also be used, provided that the results have a demonstrated equivalence or superiority to those of the methods mentioned above and are comparable with them.

EQUIPMENT

10.21. All equipment used for examinations and tests should be of a quality, range and accuracy that are acceptable according to standards recognized by the regulatory body.

10.22. Similar standards should be applied to calibration blocks where these are needed. If standards for calibration blocks are not established, these blocks should be of a material and surface finish that is identical with the component being examined and should be subjected to the same fabrication or construction conditions (such as heat treatment). Where possible, the calibration blocks that were used in manufacture and for pre-service inspections should also be used for subsequent in-service inspections.

10.23. All items of equipment together with their accessories should be calibrated before they are used. All equipment should be properly identified in the calibration records, and the validity of the calibration should be regularly verified by the operating organization in accordance with the quality assurance programme. All items should be calibrated against standards recognized by the regulatory body.

QUALIFICATION OF IN-SERVICE INSPECTION SYSTEMS

10.24. Qualification here means a systematic assessment by all necessary methods in order to provide reliable confirmation that the non-destructive testing system (i.e.

the equipment, procedures and personnel) is capable of the required performance under real inspection conditions.

10.25. The details and scope of any qualification process, in terms of required inspection area(s), method(s) of non-destructive testing, defects being sought and required effectiveness of inspection, should be agreed upon in writing between the operating organization and the regulatory body. Account should be taken of the safety significance of each particular case and of relevant national and international experience. This statement of the scope of or technical specification for the inspection to be qualified should be agreed upon before any qualification process is started and should form part of the documentation of the qualification process.

10.26. The qualification body — that is, the organization managing, conducting, evaluating and certifying an in-service inspection system's qualification process — should be independent of any commercial or operational considerations. Qualification bodies may also be an independent part of the licensee's organization.

10.27. The qualification body should operate according to a quality assurance programme giving consideration also to the independence, impartiality and confidentiality of that body.

10.28. Any qualification process should be carried out according to written qualification protocols which clearly define the administrative interfaces and the types (unrestricted, restricted, confidential), paths and timing of the information to be exchanged between all parties involved (the regulatory body, qualification body, licensee, inspection organization) pursuant to the qualification process.

10.29. Written qualification procedures should be developed by the operating organization, reviewed by the qualification body and agreed upon by the interested parties. They should specify:

— the number, type, geometry, materials and surface conditions of test specimens to be used in practical trials;
— the types and ranges of the geometrical parameters of the flaws to be detected and/or sized in practical trials;
— the conditions of the practical trials (open, blind);
— the minimum and maximum numbers of flawed and unflawed grading units;
— the grading criteria for the detection and sizing of flaws;
— the acceptance criteria for detection and sizing;
— special requirements, where applicable (such as requirements on time limitations, access restrictions, environmental conditions).

10.30. Upon successful qualification of a non-destructive testing procedure and the associated equipment, the qualification body should issue a certificate to the licensee and/or inspection organization which clearly identifies the aspects of the procedure and the equipment that have been qualified.

10.31. The certification of a non-destructive testing procedure and its associated equipment should be valid indefinitely unless changes affecting essential variables and/or parameters are made to the equipment and/or the procedure, or to any mandatory document whose requirements must be met.

10.32. The responsibility for ultimate approval of an inspection system using non-destructive testing, on the basis of evidence derived from the qualification process and provided by the qualification body, remains with the operating organization.

10.33. For each successful candidate, the qualification body should issue, separately from the inspection organization, a personnel certificate that is complementary to the national certificate. The validity of a personnel certificate should be limited in time. Personnel certificates should be revoked when a certified individual ceases to work for the inspection organization which presented him or her for qualification, or when the inspection organization cannot produce documentary evidence of the certified individual's continuous satisfactory involvement in the qualified inspection process.

10.34. Personnel certificates should clearly specify their scope, including applicability and scope of competence (with regard to procedure, detection or sizing, for example).

EVALUATION OF RESULTS OF IN-SERVICE INSPECTIONS

10.35. Any examination indicating a flaw that exceeds acceptance criteria may be supplemented by other non-destructive methods and techniques of examination, to establish the character of the flaw (size, shape and orientation) and thus to determine the suitability of the component for further operation. Care should be taken, in choosing these supplementary techniques and methods, to ensure that the conditions affecting the component are thoroughly investigated.

10.36. If analysis based on fracture mechanics is employed, the stresses in the area of the flaw should be analysed for all conditions of operation, including postulated accident conditions and actual as well as predicted normal operating conditions. The worst stress case should then be selected. Care should be taken to consider all aspects of the problem so that the worst case is always assumed in the analysis. The methods of calculation should be in accordance with accepted standards.

10.37. When an evaluation leads to the conclusion that continued operation would be unacceptable, the component in question should be repaired or replaced.

10.38. When a flaw that exceeds the acceptance standards is found in a sample, additional examinations should be performed to investigate the specific problem area in the analysis of additional analogous components (or areas), whose number should be approximately equal to the number of components (or areas) examined in the sample.

10.39. In the event that the additional examinations indicate further flaws exceeding the acceptance standards, all the remaining analogous components (or areas) should be examined to the extent specified for the component or item in the initial sample, except in cases where paras 10.40 and 10.41 apply.

10.40. Where the required piping examination in the sampling programme is limited to one loop or branch run of an essentially symmetrical piping configuration, and examinations indicate the presence of flaws that exceed the acceptance standards, the additional examinations recommended in para. 10.38 should include an examination of a second loop or branch run.

10.41. In the event that an examination of the second loop or branch run indicates further flaws that exceed the acceptance standards, the remaining loops or branch runs that perform similar functions should be examined.

10.42. The sequence in which the examinations of components are carried out during an inspection interval should, to the extent practicable, be maintained constant during successive inspection intervals.

10.43. Whenever examination of a component results in the evaluation of flaw indications but qualifies the component as acceptable for continued operation, that portion of the component containing the flaws should be re-examined in each of the next three inspection intervals, as an extra recommendation over and above the schedule of the original programme.

10.44. In the event that the re-examinations recommended in para. 10.43 indicate that the flaws remain essentially unchanged over three successive inspection intervals, the schedule for examinations of that component may revert to the original schedule for the subsequent inspections.

DOCUMENTATION AND RECORDS OF IN-SERVICE INSPECTIONS

10.45. The documentation necessary for proper implementation of the in-service inspection programme should be readily available to the operating organization and

the regulatory body, as required. This documentation should include, but is not limited to, the following items:

— specifications and as-built drawings,
— samples of materials used,
— records of personnel qualification,
— pre-service inspection data and reports,
— the in-service inspection programme and detailed examination and test procedures (including relevant codes and standards),
— reports and charts from examinations and tests,
— calibration records,
— acceptance standards,
— evaluations.

10.46. The first item on the list of para. 10.45 should include component drawings, material specifications, heat treatment records, records of the manufacturing process, specifications and drawings for fabrication and installation, and records of any acceptance of deviations from the specifications.

10.47. The records of each activity should include the following:

(a) Information on the identification of components, the location and size of the inspection area, work technique, type of equipment, type of sensor, calibration equipment and sensitivity standards, such that the MS&I activity could be repeated and similar results obtained;
(b) All relevant indications that are in excess of the minimum recording level, and all pertinent information concerning these indications (such as location, magnitude, length);
(c) All recordings (if no indication is obtained, a note to this effect should be made in the records);
(d) Comparisons with previous results and evaluations;
(e) Evaluations and reports;
(f) Radiation doses received, as appropriate.

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GLOSSARY

commissioning. The process during which nuclear power plant components and systems, having been constructed, are made operational and verified to be in accordance with the design and to have met the required performance criteria. Commissioning may include both non-nuclear and nuclear testing.

condition monitoring. Continuous or periodic tests, inspections, measurement or trending of the performance or physical characteristics of SSCs to indicate current or future performance and the potential for failure. Condition monitoring is usually conducted on a non-intrusive basis.

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

in-service inspection. Inspection of structures, systems and components undertaken by or on behalf of the operating organization.

licence. A legal document issued by the regulatory body granting authorization to perform specified activities related to the siting, design, construction, commissioning, operation and decommissioning of a nuclear power plant.

licensee. The holder of a current licence.

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

corrective maintenance. Actions that restore, by repair, overhaul or replacement, the capability of a failed structure, system or component to function within acceptance criteria.

periodic maintenance. Form of preventive maintenance consisting of servicing, parts replacement, surveillance or testing at predetermined intervals of calendar time, operating time or number of cycles.

planned maintenance. Form of preventive maintenance consisting of refurbishment or replacement that is scheduled and performed prior to unacceptable degradation of a structure, system or component.

predictive maintenance. Form of preventive maintenance performed continuously or at intervals governed by observed condition to monitor, diagnose or trend a structure, system or component's condition indicators; results indicate current and future functional ability or the nature of and schedule for planned maintenance.

preventive maintenance. Actions that detect, preclude or mitigate degradation of a functional structure, system or component to sustain or extend its useful life by controlling degradation and failures to an acceptable level.

reliability centred maintenance (RCM). A process for specifying applicable preventive maintenance requirements for the safety related systems and equipment in order to prevent potential failures or to control the failure modes optimally. The RCM utilizes a decision logic tree to identify the maintenance requirements according to the safety consequences and operational consequences of each failure and the degradation mechanism responsible for the failures.

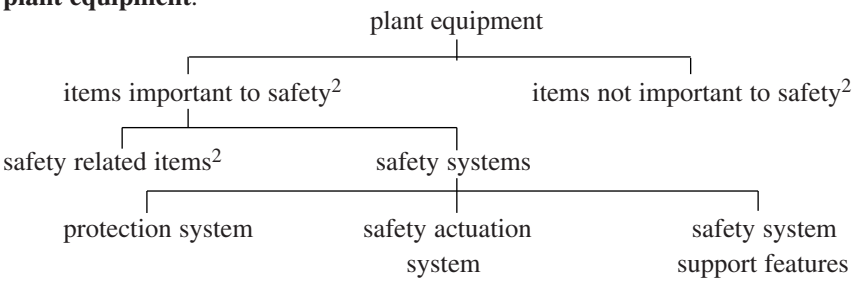
operating life/lifetime. The period during which an authorized facility is used for its intended purpose, until decommissioning or closure.

operating organization. The organization applying for authorization or authorized by the regulatory body to operate a nuclear power plant and responsible for its safety.

operation. All activities performed to achieve the purpose for which a facility was constructed. For a nuclear power plant, this includes maintenance, refuelling, in-service inspection and other associated activities.

operational limits and conditions. A set of rules setting forth parameter limits, the functional capability and the performance levels of equipment and personnel approved by the regulatory body for safe operation of a nuclear power plant.

plant equipment.



[2] In this context, an 'item' is a structure, system or component.

item important to safety. An item that is part of a safety group and/or whose malfunction or failure could lead to radiation exposure of the site personnel or members of the public.

protection system. System which monitors the operation of a reactor and which, on sensing an abnormal condition, automatically initiates actions to prevent an unsafe or potentially unsafe condition.

safety actuation system. The collection of equipment required to accomplish the necessary safety actions when initiated by the protection system.

safety related item. An item important to safety which is not part of a safety system.

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

safety system support features. The collection of equipment that provides services such as cooling, lubrication and energy supply required by the protection system and the safety actuation systems.

plant states.

operational states			**accident conditions**		
				beyond design basis accidents	
normal operation	anticipated operational occurrences	a	design basis accidents	b	severe accidents
				Accident management	

a: Accident conditions which are not explicitly considered design basis accidents but are encompassed by them.
b: Beyond design basis accidents without significant core degradation.

accident conditions. Deviations from normal operation more severe than anticipated operational occurrences, including design basis accidents and severe accidents.

accident management. The taking of a set of actions during the evolution of a beyond design basis accident:

— to prevent the escalation of the event into a severe accident;
— to mitigate the consequences of a severe accident; and
— to achieve a long term safe stable state.

anticipated operational occurrence. An operational process deviating from normal operation which is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions.

design basis accident. Accident conditions against which a nuclear power plant is designed according to established design criteria, and for which the damage to the fuel and the release of radioactive material are kept within authorized limits.

normal operation. Operation within specified operational limits and conditions.

operational states. States defined under normal operation and anticipated operational occurrences.

severe accident. Accident conditions more severe than a design basis accident and involving significant core degradation.

regulatory body. An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating nuclear, radiation, radioactive waste and transport safety. The national competent authority for the regulation of radioactive material transport safety is included in this description, as is the Regulatory Authority for radiation protection and safety.

service life. The period from initial operation to final withdrawal from service of a structure, system or component.

structures, systems and components (SSCs). A general term encompassing all of the elements (items) of a nuclear power plant which contribute to protection and safety, except human factors. Structures are the passive elements: buildings, vessels, shielding, etc. A system comprises several components, assembled in such a way as to perform a specific (active) function.

surveillance testing. Periodic testing to verify that structures, systems and components continue to function or are in a state of readiness to perform their functions.

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