IAEA SAFETY STANDARDS SERIES

Periodic Safety Review of Nuclear Power Plants

SAFETY GUIDE

No. NS-G-2.10

IAEA
International Atomic Energy Agency

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities.

The regulatory related publications by means of which the IAEA establishes safety standards and measures are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (that is, of relevance in two or more of the four areas), and the categories within it are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides.**

Safety Fundamentals (blue lettering) present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

Safety Requirements (red lettering) establish the requirements that must be met to ensure safety. These requirements, which are expressed as 'shall' statements, are governed by the objectives and principles presented in the Safety Fundamentals.

Safety Guides (green lettering) recommend actions, conditions or procedures for meeting safety requirements. Recommendations in Safety Guides are expressed as 'should' statements, with the implication that it is necessary to take the measures recommended or equivalent alternative measures to comply with the requirements.

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.

Information on the IAEA's safety standards programme (including editions in languages other than English) is available at the IAEA Internet site

www.iaea.org/ns/coordinet

or on request to the Safety Co-ordination Section, IAEA, P.O. Box 100, A-1400 Vienna, Austria.

OTHER SAFETY RELATED PUBLICATIONS

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

Reports on safety and protection in nuclear activities are issued in other series, in particular the **IAEA Safety Reports Series**, as informational publications. Safety Reports may describe good practices and give practical examples and detailed methods that can be used to meet safety requirements. They do not establish requirements or make recommendations.

Other IAEA series that include safety related publications are the **Technical Reports Series,** the **Radiological Assessment Reports Series,** the **INSAG Series, the TECDOC Series**, the **Provisional Safety Standards Series**, the **Training Course Series,** the **IAEA Services Series** and the **Computer Manual Series**, and **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**. The IAEA also issues reports on radiological accidents and other special publications.

PERIODIC SAFETY REVIEW
OF NUCLEAR POWER PLANTS

Printed by the IAEA in Austria
August 2003
STI/PUB/1157

SAFETY STANDARDS SERIES No. NS-G-2.10

PERIODIC SAFETY REVIEW OF NUCLEAR POWER PLANTS

SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2003

IAEA Library Cataloguing in Publication Data

Periodic safety review of nuclear power plants : safety guide. — Vienna : International Atomic Energy Agency, 2003.
p. ; 24 cm. — (Safety standards series, ISSN 1020-525X ; no. NS-G-2.10)
STI/PUB/1157
ISBN 92-0-108503-6
Includes bibliographical references.

1. Nuclear power plants — Safety measures. 2. Emergency management. 3. Radiation — Environmental aspects. I. International Atomic Energy Agency. II. Series.
IAEAL 03-00327

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. This Safety Guide supplements the IAEA Safety Fundamentals publication The Safety of Nuclear Installations [1] and the Safety Requirements publication Safety of Nuclear Power Plants: Operation [2]. It supersedes the Safety Guide issued as Safety Series No. 50-SG-O12, Periodic Safety Review of Operational Nuclear Power Plants, in 1994.

1.2. Routine reviews of nuclear power plant operation (including modifications to hardware and procedures, significant events, operating experience, plant management and personnel competence) and special reviews following major events of safety significance are the primary means of safety verification. In addition, some States have initiated systematic safety reassessment, termed periodic safety review (PSR), to assess the cumulative effects of plant ageing and plant modifications, operating experience, technical developments and siting aspects. The reviews include an assessment of plant design and operation against current safety standards and practices, and they have the objective of ensuring a high level of safety throughout the plant's operating lifetime. They are complementary to the routine and special safety reviews and do not replace them.

OBJECTIVE

1.3. The purpose of this Safety Guide is to provide recommendations and guidance on the conduct of a PSR for an existing nuclear power plant. The Safety Guide is directed at plant operating organizations and regulatory bodies.

SCOPE

1.4. This Safety Guide deals with the PSR of an existing nuclear power plant. A PSR is a comprehensive safety review of all important aspects of safety, carried out at regular intervals, typically of ten years.

1.5. The review process described in this Safety Guide is valid for nuclear power plants of any age, but may have a wider applicability, for example, to research reactors and radioactive waste management facilities. A PSR is not intended to deal with the decommissioning phase; however, documentation resulting from a PSR would be an important input for planning decommissioning.

STRUCTURE

1.6. A rationale for and the objective of the PSRs of operational nuclear power plants are given in Section 2. Section 3 presents strategic considerations relating to the conduct of a PSR. Important aspects of the safety of an operational nuclear power plant that are addressed in a PSR are defined as safety factors and these are described in Section 4. The roles and responsibilities of the plant operating organization, the regulatory body and external consultants in the conduct of a PSR are defined in Section 5. Section 6 presents a recommended review procedure. Common aspects relating to the acceptability of continued plant operation are discussed in Section 7. Section 8 deals with post-review activities. Finally, the Appendix extends the description of safety factors given in Section 4 by listing for each safety factor specific topics or activities that should be included in the review.

2. RATIONALE FOR AND OBJECTIVE OF PERIODIC SAFETY REVIEW

RATIONALE FOR A PSR

2.1. Since operation of the first generation of commercial nuclear power plants started in the 1950s there have been substantial developments in safety standards and practices, and in technology, resulting from new scientific and technical knowledge, better analytical methods and lessons learned from operating experience. These developments, however, do not mean that existing operational plants are unsafe; the overall safety record of nuclear power plants has been good [3].

2.2. Operational nuclear power plants in many States are subject to routine and special safety reviews. These safety reviews are generally not comprehensive and do not always take account of improvements in safety standards and operating practices, the cumulative effects of plant ageing, modifications, the feedback of operating experience, and developments in science and technology. Consequently, the concept of PSR has been developed as a method that is complementary to the existing types of reviews.

2.3. PSRs are considered an effective way to obtain an overall view of actual plant safety, to determine reasonable and practical modifications that should be made in order to maintain a high level of safety and to improve the safety of older nuclear power plants to a level approaching that of modern plants. In this connection, it is useful to identify any lifetime limiting features of the plant in order to help evaluate whether a proposed modification is worthwhile.

2.4. On the basis of experience, the first PSR should be undertaken about ten years after the start of plant operation and subsequent PSRs every ten years until the end of operation. Within a period of ten years, the following developments would be expected: a likelihood of significant changes in safety standards, technology and underlying scientific knowledge and analytical techniques; a need for the evaluation of the cumulative effects of plant modifications and ageing; and a possibility of significant changes in the staffing and management structures of both the plant operating organization and the regulatory body.

2.5. If the period between PSRs is extended beyond about ten years, a substantial number of experienced staff in the operating organization and the regulatory body may have left these organizations, thus leading to a loss of the direct knowledge and experience gained during previous reviews and to a loss of continuity. Good documentation of the review process and its results will be of particular value in such circumstances. The documentation should be easily retrievable and clearly understandable.

2.6. A PSR is part of the regulatory system in many States. It is a key regulatory instrument for maintaining the safety of plant operation in the long term and for addressing requests by licensees for authorization to continue plant operation beyond an established licensed term or a period established by safety evaluation. The PSR provides reassurance that there continues to be a valid licensing basis, with plant ageing, modifications made to the plant and current international safety standards taken into consideration.

2.7. It is recognized that some States prefer alternative arrangements to PSRs. A systematic safety assessment programme, dealing with specific safety issues, significant events and changes in safety standards and practices as they arise, is one example. This Safety Guide is not intended to discourage such alternative arrangements. However, each alternative should demonstrate that it can satisfy the objective of a PSR as defined in para. 2.8.

OBJECTIVE OF A PSR

2.8. The objective of a PSR is to determine by means of a comprehensive assessment of an existing nuclear power plant: the extent to which the plant conforms to current international safety standards and practices; the extent to which the licensing basis remains valid; the adequacy of the arrangements that are in place to maintain plant safety until the next PSR or the end of plant lifetime; and the safety improvements to be implemented to resolve the safety issues that have been identified. (An assessment against current safety standards does not imply that all current safety standards have to be met; see para. 7.1.)

3. REVIEW STRATEGY

3.1. The scope of a PSR includes all nuclear safety aspects of a nuclear power plant. For this purpose, a plant consists of all facilities and systems, structures and components (SSCs) on the site covered by the operating licence (including, for example, waste management facilities and on-site simulators) and their operation, together with the staff and its organization. The review also covers radiological protection, emergency planning and radiological impact on the environment — safety factors that are common to all units. Other safety factors (for example, the actual condition of SSCs, ageing and safety performance) are specific to each unit, and this should be taken into account in a PSR for a nuclear power plant with several units of the same design.

3.2. A comprehensive assessment of overall plant safety is a complex task. Experience shows that the task can be divided into a number of elements. These elements are termed safety factors in this Safety Guide. When the concept of safety factors is not used, the comprehensiveness of the review should be ensured by other means.

3.3. Each safety factor is reviewed using current methods and the findings are assessed against current safety standards and practices. Reasonable and practicable corrective actions and/or safety improvements are determined and an implementation plan is agreed, with account taken of the interactions and overlaps between safety factors and hence of the effects of the corrective actions and/or safety improvements on all safety factors. The aim is to complete as many of the corrective actions and/or safety improvements as is reasonable within the time-frame of a PSR; however, it is recognized that it may take longer to implement some corrective actions and/or safety improvements.

3.4. A global assessment of any shortcomings that cannot be reasonably and practicably corrected is made, account being taken of all the corrective actions and/or safety improvements and the strengths of the nuclear power plant. The risks associated with the unresolved shortcomings should be assessed and an appropriate justification for continued operation should be provided.

3.5. The PSR should be conducted typically every ten years and its duration should not exceed three years. The starting point of a PSR is the time of the agreement between the operating organization and the regulatory body on the general scope and requirements for the PSR and its expected outcome. The end point of a PSR is the approval by the regulatory body of an integrated programme of corrective actions and/or safety improvements (containing a list of corrective actions and/or safety improvements and a schedule). (In general, adequate documentation of the design basis and of probabilistic safety assessment (PSA) is needed for a PSR. If such documentation is not readily available and a major effort would be necessary to obtain it, consideration should be given to obtaining it by means of projects separate from the PSR.)

3.6. PSA provides useful insights into the safety of a nuclear power plant and is consequently a useful contributor to a PSR. A PSA should be undertaken for every plant, should be kept up to date and should be utilized in subsequent PSRs.

3.7. The operating organization should have prime responsibility for performing the PSR. The requirements for the PSR should either be specified by the regulatory body after consultation with the operating organization or be developed by the operating organization and agreed upon with the regulatory body before the start of the review. These requirements should include clear statements of applicable safety goals, safety standards and the plant design basis. These constitute a reference level for the review and would normally remain unchanged for the duration of the PSR.

3.8. The results of relevant studies, and of routine and special safety reviews, should be utilized in the PSR to minimize any duplication of effort.

Appropriate references should be made and an explanation of the use of these references should be provided.

3.9. A PSR is a major and complex undertaking which necessitates effective project management and the provision of adequate resources. A survey of States indicates that 50–100 person-years are needed for performing a PSR (excluding the efforts made in implementing any corrective actions and/or safety improvements, in conducting a PSA or in recovering information on the design basis).

4. SAFETY FACTORS IN A PERIODIC SAFETY REVIEW

INTRODUCTION

4.1. The 14 PSR safety factors have been selected on the basis of States' experience. These 14 safety factors are divided into five subject areas to facilitate the review. In addition, there is a global assessment to integrate the results of the review of individual safety factors.

Plant

(1) Plant design,
(2) Actual condition of SSCs,
(3) Equipment qualification,
(4) Ageing.

Safety analysis

(5) Deterministic safety analysis,
(6) Probabilistic safety analysis,
(7) Hazard analysis.

Performance and feedback of experience

(8) Safety performance,
(9) Use of experience from other plants and research findings.

Management

(10) Organization and administration,
(11) Procedures,
(12) The human factor,
(13) Emergency planning.

Environment

(14) Radiological impact on the environment.

Global assessment

— Overall assessment of nuclear power plant safety, with account taken of the results of the review of individual safety factors, including agreed corrective actions and/or safety improvements.

4.2. The 14 PSR safety factors selected apply to all the facilities on the plant site, including radioactive waste management facilities (see para. 3.1), and are considered sufficient for a comprehensive review of safety. However, the set of safety factors may vary according to the specific needs of the State and the particular nuclear power plant under consideration, and they should be agreed upon before the PSR is initiated. In this connection, PSR experience from nuclear power plants of the same design should be taken into account in the choice of safety factors.

4.3. All safety factors are important to operational safety, including accident prevention and mitigation of the consequences of accidents. The safety factors are subdivided into groups to facilitate the review; however, the order and numbering of the safety factors do not indicate an order of importance.

4.4. For the purpose of a PSR, the subject area safety analysis is subdivided into three safety factors — deterministic safety analysis, PSA and hazard analysis — to facilitate the review according to current practices. Each of these safety factors requires specific tools and expertise. Quality assurance (QA) and safety culture are not considered to be separate safety factors because they should be an integral part of every activity affecting safety. QA is assessed in its own right as an aspect of organization and administration. As regards safety culture, in reviewing each safety factor, consideration should be given to whether there is evidence of an appropriate safety culture in plant operations. Similarly, radiological protection is not regarded as a separate safety factor since it is related to most of the other safety factors. The arrangements for radiological protection and their effectiveness should generally be reviewed as specific aspects of the safety factors: plant design, actual condition of SSCs, safety performance and procedures of the nuclear power plant. However, it may be desirable in some States to review radiological protection as a separate safety factor.

4.5. A review of the physical protection of nuclear power plants is typically not included in the PSR because of the sensitivity of this subject and the confidentiality aspect. The security arrangements should prevent unauthorized actions that could jeopardize safety and their effectiveness should be periodically reviewed.

4.6. Although the PSR determines the divergences of the plant from current safety standards and practices for individual safety factors, the level of plant safety is determined by a global assessment reflecting the combined effects of all safety factors. Although shortcomings may be individually acceptable, their combined effect should also be reviewed for acceptability, by means of PSA where appropriate. It is also possible that a weakness in one safety factor can be compensated for by a strength in another safety factor. For example, it may be acceptable on a temporary basis to use a strength in human factors (such as operator action supported by adequate procedures) to compensate for a weakness in design or equipment (such as a lack of automatic protection against a postulated slow type of reactor fault of very low probability) until an appropriate modification to the design or equipment can be made. In such a case, the acceptability of the interim arrangements should be confirmed by the safety analysis.

4.7. The review should determine the status of each safety factor at the time of the PSR and whether the established operating regime will in future be capable of identifying and preventing or mitigating potential failures before they could cause a radiological incident. Age related degradation mechanisms that could lead to failures of key SSCs of the nuclear power plant and that could potentially limit the plant operating lifetime should be identified to the extent possible.

4.8. The level of effort necessary in the review of a safety factor is dependent on the availability and retrievability of relevant information.

4.9. The 14 PSR safety factors and the global assessment are defined and explained in the following subsections. The objective of the review of each safety factor is given, as well as a description of the safety factor, its desired status and those aspects of the safety factor that should be reviewed. The Appendix elaborates on the description of safety factors by suggesting further elements that should be included in the review.

PLANT DESIGN

Objective

4.10. The objective of the review of the design of the nuclear power plant is to determine the adequacy of the design and its documentation in an assessment against current international standards and practices. (The term 'nuclear power plant' includes all SSCs on the site, as stated in para. 3.1.)

Description

4.11. Plant SSCs important to safety should have appropriate characteristics and should be combined and laid out in such a way as to meet the requirements for plant safety and performance, including the prevention and mitigation of events that could jeopardize safety. The safety requirements for design are given in Ref. [4]. Adequate design information, including information on the design basis, should be available to provide for the safe operation and maintenance of the plant and to facilitate plant modifications.

4.12. The review of the plant design should establish a comprehensive list of SSCs important to safety (the current version of the safety analysis report may be helpful in performing this activity). It should identify the differences in plant design in an assessment against current safety standards (including relevant design codes) and determine their safety significance (strengths or weaknesses) in relation to the application of defence in depth. The review of the plant design is usually subdivided into review topics by systems, such as reactor core, reactor coolant system, containment system, instrumentation and control systems, electrical power systems and water supply systems.

4.13. For some older nuclear power plants, documentation relating to the safety of the design basis will not have been supplied in full to the operator at the commissioning stage. A PSR should ensure that all significant documentation relating to the original design basis has been obtained, securely stored and updated to reflect all the modifications made to the plant and procedures since its commissioning. This is of particular importance for plants that have undergone many modifications over their lifetime and those for which record keeping has been less than satisfactory. Recommendations on meeting the requirements for document control are presented in Safety Guide Q3 on Document Control and Records [5].

ACTUAL CONDITION OF SYSTEMS, STRUCTURES AND COMPONENTS

Objective

4.14. The objective of the review is to determine the actual condition of SSCs important to safety and whether it is adequate for them to meet their design requirements. In addition, the review should confirm that the condition of SSCs is properly documented.

Description

4.15. Knowledge of the actual condition of the SSCs of the nuclear power plant is of prime importance if an objective PSR is to be carried out. This includes knowledge of any existing or anticipated obsolescence of plant systems and equipment. This knowledge should, as far as possible, be determined at an early stage of the PSR and should then be maintained current. Where data are lacking, they should generally be generated or derived, and special tests or inspections may be necessary to do this. The validity of existing records should be checked to ensure that they accurately represent the actual condition of the SSCs, including any significant findings from ongoing maintenance and inspection. It may not be possible to determine the actual condition of some areas of the plant, owing, for example, to plant layout or operating conditions that preclude a necessary inspection. Such areas should be highlighted and their safety significance considered.

4.16. Having determined the current condition of the SSCs important to safety, each SSC should then be assessed against its design basis to confirm that ageing has not significantly undermined the design basis assumptions. Where consistency with the design basis cannot be fully demonstrated, alternative arrangements should be made to show that the SSC is fit for its purpose, or proposals should be made for corrective action. This may include additional inspections or, in some cases, component replacements. It may be necessary to use the safety analysis to determine any revised duties or loadings on SSCs during normal operation and under accident conditions.

EQUIPMENT QUALIFICATION

Objective

4.17. The objective of the review is to determine whether equipment important to safety is qualified to perform its designated safety function throughout its installed service life.

Description

4.18. Plant equipment important to safety should be properly qualified to ensure its capability to perform its safety functions under postulated service conditions, including those arising from external events and accidents (such as loss of coolant accidents, high energy line breaks and seismic or other vibration conditions) in a manner consistent with the safety classification [4, 6–8]. A qualification procedure should be used to confirm that the equipment is capable of meeting, throughout its service life, the requirements for performing safety functions while subject to the environmental conditions (vibration, temperature, pressure, jet impingement, irradiation, corrosive atmosphere and humidity) prevailing at the time of need, with account taken of the ageing degradation of the equipment that occurs during service.

4.19. Qualification of plant equipment important to safety should be achieved through a process that includes generating, documenting and maintaining evidence that equipment can perform its safety functions during its installed service life. This should be an ongoing process, from the plant design to the end of service life, and plant ageing, modifications, repairs and refurbishment, equipment failures and replacements, and abnormal operating conditions should be taken into account. Although many parties (such as plant designers, equipment manufacturers and consultants) are involved in the equipment qualification process, the operating organization has the ultimate responsibility for the development and implementation of a plant specific equipment qualification programme that includes generating and maintaining the documentation demonstrating qualification.

4.20. The review of equipment qualification should determine (a) whether assurance of the required equipment performance capability was initially provided and (b) whether equipment performance has been preserved by ongoing application of measures such as scheduled maintenance, testing and calibration and has been clearly documented. It should be noted that a review relating to (a) above may not be necessary if a previous review has concluded that adequate initial equipment qualification was established; and a review relating to (b) above should provide assurance that equipment qualification will be satisfactorily preserved in future. A plant walkdown of installed equipment should be performed to identify for qualified equipment any differences from the qualified configuration (abnormal conditions such as missing or loose bolts and covers, exposed wiring or damaged flexible conduits).

AGEING

Objective

4.21. The objective of the review is to determine whether ageing in a nuclear power plant is being effectively managed so that required safety functions are maintained, and whether an effective ageing management programme is in place for future plant operation.

Description

4.22. All SSCs of nuclear power plants are subject to some form of physical changes caused by ageing which could eventually impair their safety function and service lifetime (special attention should be paid to cases of prolonged construction and extended shutdown). The rates of these changes vary considerably. Ageing of all materials (including consumables, such as lubricants) and SSCs that could impair their safety functions should therefore be understood and controlled. Whereas safety factor (2) establishes the actual condition of the SSCs at the time of the PSR, the safety factor of ageing is primarily concerned with the condition of the SSCs in the future.

4.23. Managing the ageing of SSCs important to safety requires the age related degradation of the SSCs to be controlled within defined limits.. Effective control of ageing degradation is achieved by means of a systematic ageing management process consisting of the following ageing management tasks, based on the understanding of ageing of SSCs:

— Operation within operating guidelines with the aim of minimizing the rate of degradation;
— Inspection and monitoring consistent with the applicable requirements with the aim of the timely detection and characterization of any degradation;

— Assessment of the observed degradation in accordance with appropriate guidelines to assess integrity and functional capability;
— Maintenance (repair or replacement of parts) to prevent or remedy unacceptable degradation.

4.24. There should be an established and effective ageing management programme using this systematic ageing management process at all nuclear power plants. Relevant guidance on the management of plant ageing is given in Refs [9–11].

4.25. The review of the management of ageing should determine whether a systematic and effective ageing management programme is in place, whether adequate arrangements have been made to fulfil required safety functions during future plant operation, and whether there are any features that would limit plant life. Both programmatic aspects (e.g. programme policy, procedures, performance indicators, staffing, resources and record keeping) and technical aspects of ageing management (e.g. ageing management methodology, the extent of understanding of relevant ageing phenomena, SSC specific acceptance criteria, operating guidelines aimed at controlling the rate of ageing degradation, ageing detection and mitigation methods, and actual condition of SSCs) should be evaluated [12].

DETERMINISTIC SAFETY ANALYSIS

Objective

4.26. The objective of the review of the deterministic safety analysis is to determine to what extent the existing deterministic safety analysis remains valid when the following aspects have been taken into account: actual plant design; the actual condition of SSCs and their predicted state at the end of the period covered by the PSR; current deterministic methods; and current safety standards and knowledge. In addition, the review should also identify any weaknesses relating to the application of the defence in depth concept.

Description

4.27. A deterministic safety analysis should be conducted for each nuclear power plant, should confirm the design basis for items important to safety and should describe the plant behaviour for postulated initiating events [6]. Therefore, a documented safety design basis (original and updated) should be available. The current state of this safety analysis should be reviewed for the completeness of the set of postulated initiating events and for its scope, methods and assumptions. (Older design bases did not include events such as anticipated transient without scram, plant blackout or multiple steam generator tube ruptures.) The review should update the current safety analysis as necessary to ensure that it is based on the actual plant design, reflects the current state and predicted state at the end of the review period of SSCs, and considers all postulated initiating events that are appropriate for the plant design and plant location. Current analytical methods should be used, particularly with regard to computer codes for transient analyses. The assumptions used in these calculations (conservative or best estimate) should be justified with respect to the inherent uncertainties in order to gain a better insight into existing safety margins.

4.28. The review of the deterministic safety analysis should determine whether the actual plant design is capable of meeting the prescribed regulatory limits for radiation doses and radioactive releases resulting from postulated accidents. It should also identify or confirm any major weaknesses as well as the strengths of the plant design in relation to the application of defence in depth, and it should evaluate the importance of systems and measures to prevent or control accidents, with a complete set of postulated initiating events taken into account. If the safety concept of the plant design differs from current practice, any advantages or disadvantages inherent in that safety concept should be recognized.

PROBABILISTIC SAFETY ASSESSMENT

Objective

4.29. The objective of the review of the PSA is to determine to what extent the existing PSA remains valid as a representative model of the plant when the following aspects have been taken into account: changes in the design and operation of the plant; new technical information; current methods; and new operational data.

Description

4.30. PSA is a comprehensive and structural approach to identify weaknesses in the design and operation of the plant and to evaluate and compare potential options for remedying any such weaknesses [6, 13–16]. The weaknesses (e.g. the potential for cross-links and the effects of common cause events which were often not adequately considered in older plant designs) are identified by considering the contribution to the risk from groups of postulated initiating events and human errors, and from measures of the importance of safety systems. The results of a PSA should be compared with the probabilistic safety criteria (e.g. for system reliability, core damage and releases of radioactive material) when they have been defined for the plant.

4.31. The PSA should be kept sufficiently up to date during the plant lifetime to make it useful for the decision making process.

4.32. The accident management programme for beyond design basis accidents should be reviewed. It should be determined whether the programme is suitable to prevent severe core damage or to mitigate its consequences [4, 17].

HAZARD ANALYSIS

Objective

4.33. The objective of the review of hazard analysis is to determine the adequacy of protection of the nuclear power plant against internal and external hazards with account taken of the actual plant design, actual site characteristics, the actual condition of SSCs and their predicted state at the end of the period covered by the PSR, and current analytical methods, safety standards and knowledge.

Description

4.34. To ensure the availability of required safety functions and operator actions, SSCs important to safety, including the control room and emergency control centre, should be adequately protected against relevant internal and external hazards. The review should establish a list of relevant internal and external hazards that may affect plant safety, with account taken of the actual plant design, the actual condition of SSCs and site characteristics [6]. Among other things, changes in plant design, climate, flood potential, and transport and industrial activities near the plant site should be considered.

4.35. For the relevant hazards, the review should demonstrate, by using current analytical techniques and data, either that the probability or consequences of the hazard are sufficiently low so that no specific protective measures are necessary, or that the preventive and mitigating measures against the hazard are adequate. Any deficiencies should be identified. The relevant IAEA safety standards to be used for evaluation are Refs [18–23].

SAFETY PERFORMANCE

Objective

4.36. The objective of the review of safety performance is to determine the safety performance of the nuclear power plant and its trends from records of operating experience.

Description

4.37. Safety performance is usually determined from assessments of operating experience, including safety related incidents, and records of safety system unavailability, radiation doses, and the generation of radioactive waste and radioactive effluents. The operating organization should put in place a system for keeping a record of all incidents and evaluating their safety significance. In addition, records of plant operation, maintenance, testing, inspection, replacement and modifications should be regularly evaluated to identify any unsafe situations or trends. The results of these evaluations should be suitably summarized to give an overall assessment of safety performance during each year of plant operation. Safety performance indicators, which have been developed by some States and by the World Association of Nuclear Operators (WANO), could be used for this purpose. Indicators of both failure and success should be utilized. A PSR should include a review of all relevant indicators of safety performance which should be subjected to a trend analysis to highlight potential safety problems. Performance indicators also enable comparisons to be made with other nuclear power plants and provide an opportunity for operators to benefit from each other's experience (see also para. 4.39). References [24, 25] give recommendations and guidance on the use of safety indicators for verifying compliance with the requirements for safe plant operation established in Ref. [2]. A substandard performance in one of the elements of the review should prompt a follow-up review of possible causes (e.g. deficiencies in procedures, training or safety culture).

4.38. The radiation related risk resulting from normal nuclear power plant operation and anticipated operational occurrences is also an important element of plant safety performance. Relevant indicators include data on radiation doses, which provide an indication of the risk posed to plant personnel, and data on radioactive effluents, which provide some indication of the environmental impact. Records of radiation doses and radioactive effluents should be reviewed to determine whether these are within prescribed limits, as low as reasonably achievable and adequately managed. In addition, data on the generation of radioactive waste should be reviewed as such waste contributes to the radiation related risk. The IAEA Safety Requirements publication on Operation [2] establishes the requirements for a radiation protection programme, including requirements for setting prescribed limits and for the management of radioactive waste and effluents arising from the operation of a nuclear power plant, and associated Safety Guides [26, 27] provide relevant recommendations and guidance.

USE OF EXPERIENCE FROM OTHER PLANTS AND RESEARCH FINDINGS

Objective

4.39. The objective of the review of experience from other plants and research findings is to determine whether there is adequate feedback of safety experience from other nuclear power plants and of the findings of research.

Description

4.40. Experience from other nuclear power plants, and sometimes from non-nuclear plants, together with research findings, can reveal unknown safety weaknesses or can help in solving existing problems. In addition, experience from PSRs that have been performed for similar plants (in terms of design and age) can be useful. There are established arrangements for the dissemination of operational experience at nuclear power plants by the IAEA, the OECD Nuclear Energy Agency, WANO, the Institute of Nuclear Power Operations (INPO) and various plant owners' groups. Arrangements for the dissemination of research findings are not as well established, owing partly to commercial considerations and the need to use the research findings in conjunction with operating experience. The operating organization should have arrangements for receiving and assessing information received as feedback as a part of its normal activities. A PSR should include a review of the adequacy of these arrangements and the timely implementation of assessment findings. For an operating organization with many nuclear power plants it may be more advantageous to have generic assessments applicable to several plants rather than specific reviews of this safety factor in PSRs for each plant. PSRs would then be limited for this safety factor to reviewing the implementation of site specific requirements deriving from the generic reviews.

ORGANIZATION AND ADMINISTRATION

Objective

4.41. The objective of the review of organization and administration is to determine whether the organization and administration are adequate for the safe operation of the nuclear power plant.

Description

4.42. The impact of organization and administration on nuclear safety should be analysed in every PSR. Together with human factors, they play a significant role in defining safety culture. (Reference [28] gives advice on safety culture, including indicators that should be examined in a PSR in the review of organization, administration and human factors.) The review should examine the organization and administration to ensure that these comply with accepted good practices and do not present an unacceptable contribution to risk [29]. The aspects of the review should include: management (including arrangements for self-assessment and continuous improvement, and for the control of any changes to the organizational structure or the resources of the plant operating organization that may affect safety), succession planning, configuration control, the management of technical and contractual support, training, quality assurance, records, and compliance with regulatory requirements and other statutory requirements. The review should determine whether there is an adequate number of suitably qualified staff to carry out the safety related work. Because some of these aspects deal with the manner in which the operating organization conducts its affairs, it may be difficult for that organization to carry out an objective review and therefore external specialists may be needed.

PROCEDURES

Objective

4.43. The objective of the review of the procedures of a nuclear power plant is to determine whether the procedures are of an adequate standard.

Description

4.44. Procedures should be comprehensive, validated, formally approved and subject to rigorous change control. In addition, they should be unambiguous and relevant to the actual plant (with modifications taken into account), and should reflect current practice and due consideration of human factor aspects (for example, it should be considered whether the procedures are user friendly). The review should focus on those procedures that are of high safety significance; it should not entail a technical review of all procedures. (The safety significance can be determined from a deterministic safety analysis and a PSA.) The system for the development and control of procedures should be reviewed. (As far as possible, staff should participate in the development of the procedures that they use.) The review of this safety factor should include:

(a) Operating procedures for normal and abnormal conditions (including design basis accident conditions and post-accident conditions);
(b) Procedures for the management of beyond design basis accidents;
(c) Maintenance, test and inspection procedures;
(d) Work permit procedures;
(e) Control procedures for the modification of the plant design, procedures and hardware, including the updating of documentation;
(f) Procedures for radiation protection, including those for on-site transfers of radioactive material.

The IAEA Safety Requirements publication on Operation [2] establishes the requirements for operating procedures and associated Safety Guides [22–24, 26, 30] provide relevant recommendations and guidance.

HUMAN FACTORS

Objective

4.45. The objective of the review of human factors is to determine the status of the various human factors that may affect the safe operation of the nuclear power plant.

Description

4.46. Human factors influence all aspects of the safety of a nuclear power plant. The review should examine the status of the human factors to determine whether these comply with accepted good practices and do not present an unacceptable contribution to risk. In particular, it should determine whether the operator actions that are claimed to be in support of safety are feasible and properly supported. In addition, human factors in maintenance should be assessed. The review should be wide ranging and should include staffing, selection and training, personnel related issues, the style of procedures and the human–machine interface. It should be carried out with the assistance of appropriately qualified specialists. Because of the difficulties associated with carrying out an objective review of what is essentially its own human performance, the operating organization may decide that specific elements of the review can only be carried out by external consultants. This is the case in particular when nuclear power plants are operated by relatively small organizations. The assessment of human factors is a complex topic that is linked, in particular, to the safety factors of safety performance, procedures and safety analysis. Further recommendations and guidance can be found in Refs [28, 31, 32].

EMERGENCY PLANNING

Objective

4.47. The objective of the review of emergency planning is to determine (a) whether the operating organization has adequate plans, staff, facilities and equipment for dealing with emergencies and (b) whether the operating organization's arrangements have been adequately co-ordinated with local and national systems and are regularly exercised.

Description

4.48. The design and operation of a nuclear power plant should prevent releases of radioactive substances that could affect the health of workers or the public. Emergency planning for the possibility of such a release is a prudent and necessary action not only by the operating organization but also by local and national authorities. A PSR should include an overall review to check that the emergency planning at the plant continues to be satisfactory. Emergency plans should be maintained in accordance with current safety analyses, accident mitigation studies and good practices. Emergency exercises should demonstrate and identify possible shortcomings in the competence of on-site and off-site staff, the required functional capability of equipment (including communications equipment) and the adequacy of planning. PSRs should check that account has been taken of significant changes at the nuclear power plant site and in its use, of organizational changes at the plant and changes in the maintenance and storage of emergency equipment, and of industrial, commercial and residential developments around the site. The IAEA Safety Requirements [33] establish the requirements for emergency preparedness and response for a nuclear or radiological emergency and other publications [34–38] provide relevant recommendations and guidance.

RADIOLOGICAL IMPACT ON THE ENVIRONMENT

Objective

4.49. The objective of the review of the radiological impact of the nuclear power plant on the environment is to determine whether the operating organization has an adequate programme for surveillance of the radiological impact of the plant on the environment.

Description

4.50. The operating organization should have an established and effective surveillance programme that provides radiological data on the surroundings of the plant site. In some States such a programme is also carried out by public organizations, which can facilitate independent validation of the data provided by the operating organization. Examples of such data are the concentrations of radionuclides in air, water (including river water, sea water and groundwater), soil, agricultural and marine products and animals. These data should be compared with the values measured before the nuclear power plant was put into operation. In the event of significant deviations, an explanation should be given with relevant factors external to the nuclear power plant taken into account. A PSR should examine whether this programme is appropriate and sufficiently comprehensive to check all relevant environmental aspects. The radiological impact of the plant on the environment should not be significant compared with that due to naturally occurring sources of radiation.

GLOBAL ASSESSMENT

4.51. The objective of the global assessment is to present an assessment of plant safety that takes into account all unresolved shortcomings, all corrective actions and/or safety improvements and the plant strengths identified in the review of all PSR safety factors.

4.52. A global assessment report should be prepared that presents significant PSR results (including plant strengths), the integrated implementation plan for corrective actions and/or safety improvements, and a ‘global risk’ judgement on the acceptability of continued plant operation with any shortcomings remaining after all corrective actions and/or safety improvements have been implemented. Interactions between safety factors, individual shortcomings and corrective actions and/or safety improvements, including compensatory measures, should be considered in assessing the overall plant safety. The global assessment should show to what extent the safety requirements of the defence in depth concept are fulfilled, in particular for the basic safety functions of reactivity control, fuel cooling and the confinement of radioactive material.

5. ROLES AND RESPONSIBILITIES

5.1. The primary responsibility for conducting a PSR and reporting its findings lies with the operating organization of the plant. The operating organization should report all significant findings of the review to the regulatory body as soon as they are available.

5.2. The regulatory body has the responsibility of specifying or approving the requirements for a PSR, reviewing the conduct and conclusions of the review and the consequential corrective actions and/or safety improvements, and taking appropriate licensing actions. It is also responsible for reporting the outcome of the PSR to the national government and the general public.

5.3. Under certain circumstances, for example if there are insufficient capabilities of the operating organization or of the regulatory body, assistance in performing or reviewing the PSR may be required from external consultants or technical support organizations. However, the operating organization should have sufficient technical expertise to manage work effectively that has been contracted to outside parties.

5.4. Certain parts of a PSR should be carried out by external consultants so as to ensure objectivity. An example of this is the review of the safety factors of organization and administration and human factors. While the primary responsibility for carrying out the review rests with the operating organization, an independent review should be conducted to provide the necessary objectivity.

6. REVIEW PROCEDURE

INTRODUCTION

6.1. The basic procedure for implementing the strategy described in Section 3, which is applicable to all the safety factors, is shown in Fig. 1. It consists of parallel activities by the operating organization and the regulatory body which are illustrated in Figs 2–5. The activities of the operating organization can be divided into three steps. The first is the preparation for the PSR project, the second is the conduct of the PSR reviews and the third is the preparation of a programme of corrective actions and/or safety improvements. The regulatory body's activities are carried out throughout the PSR project. These activities are described in the following paragraphs. The procedure is intended to be sufficiently flexible to allow a State to consider each safety factor and to modify it in detail to comply with national requirements and to facilitate the use of findings of relevant studies and routine or special safety reviews.

6.2. Before a PSR is started, a number of prerequisites should be satisfied. The main prerequisite is an agreement between the operating organization and the regulatory body as to the scope and objectives of the PSR, and its schedule and

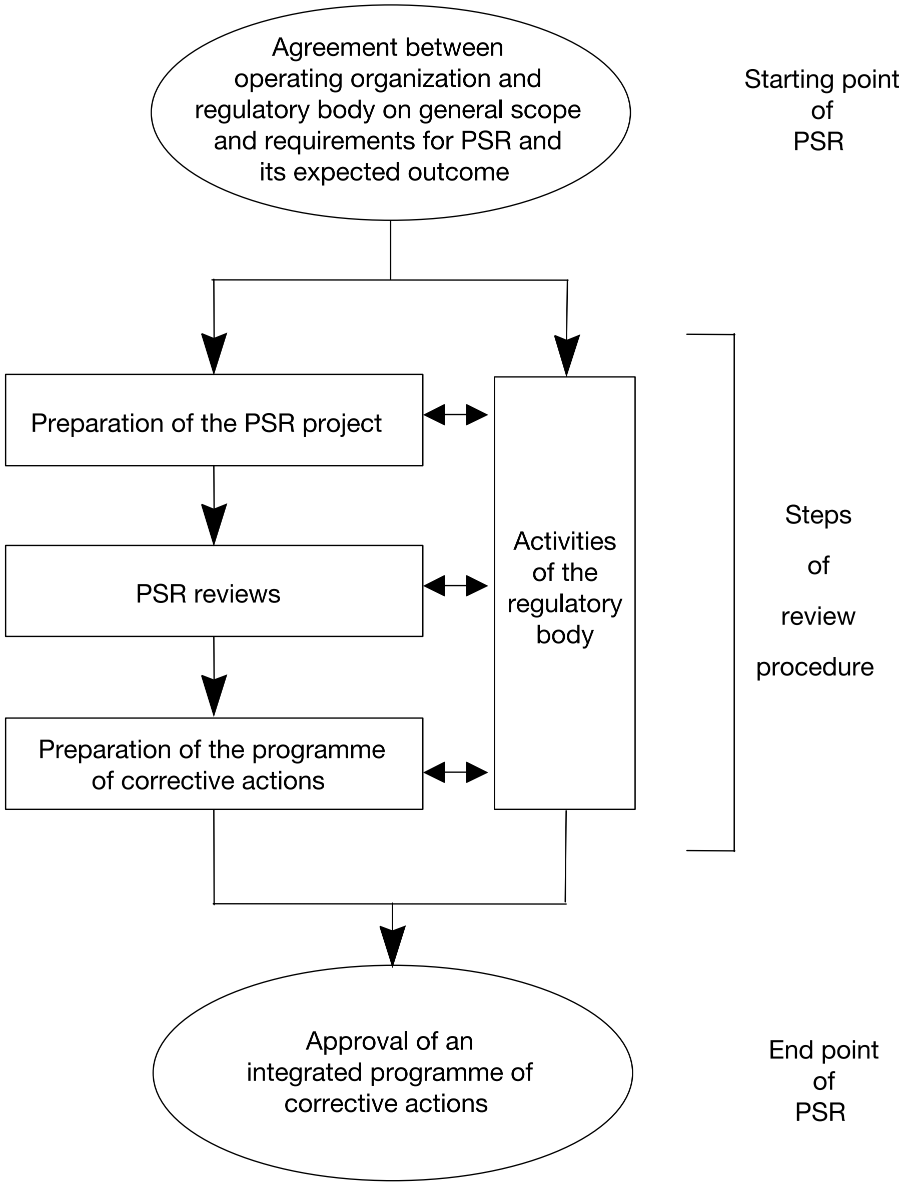


FIG. 1. Procedure for a PSR of a nuclear power plant: flow chart of an overall process.

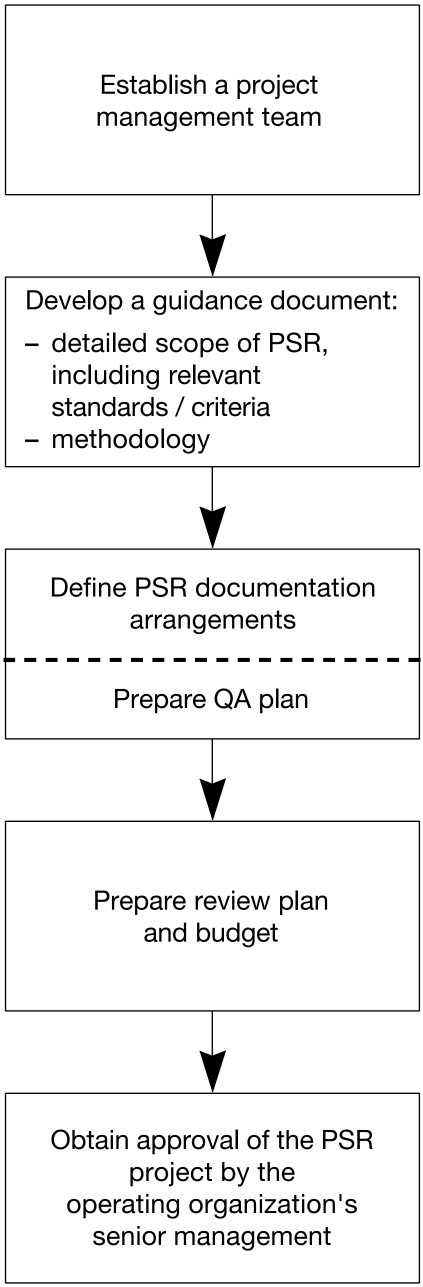


FIG. 2. Flow chart for the preparation of the PSR project.

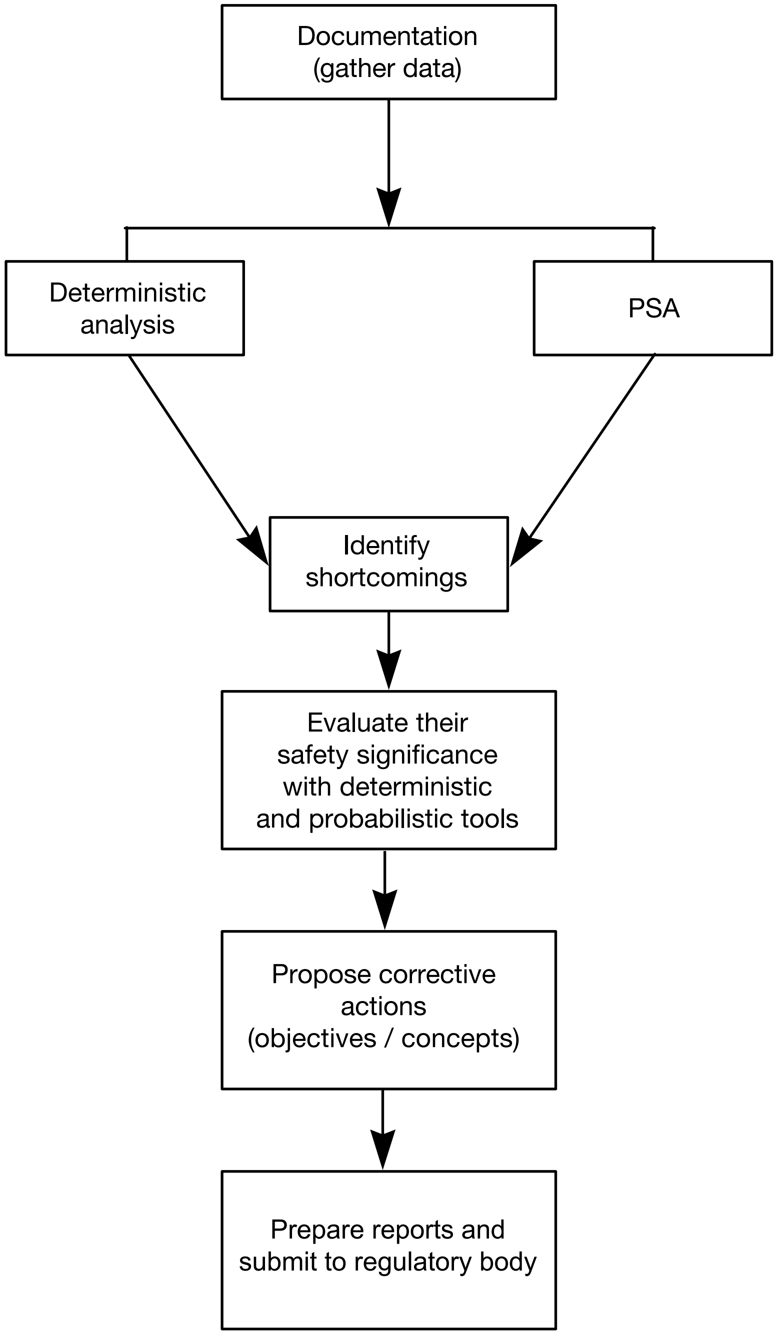


FIG. 3. Flow chart for PSR reviews.

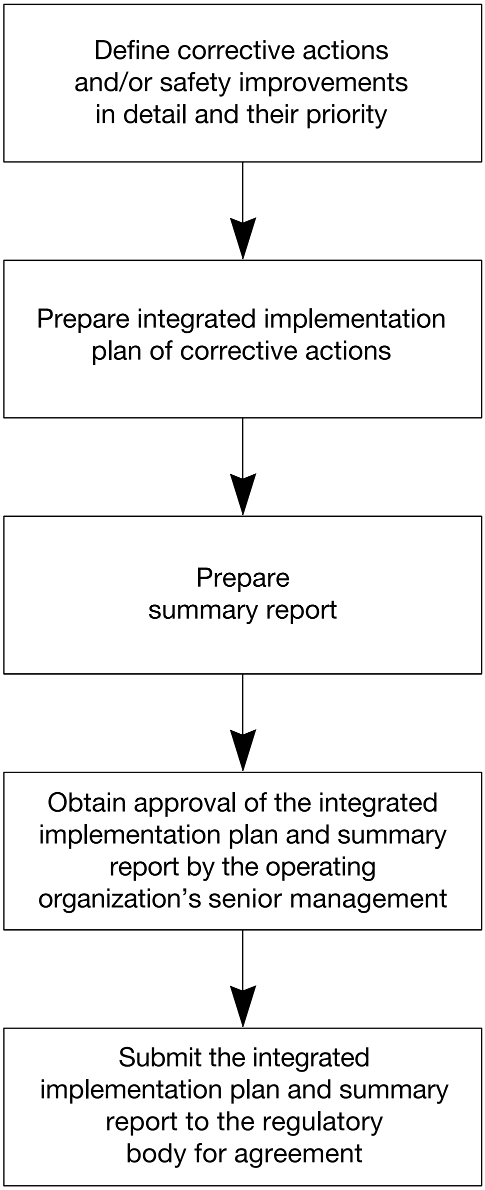


FIG. 4. Preparation of the programme of corrective actions and/or safety improvements.

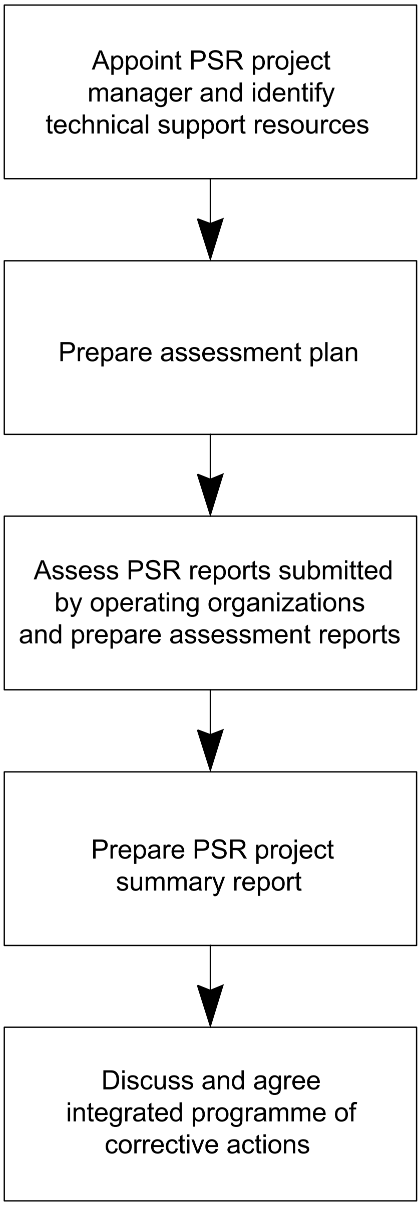


FIG. 5. Activities of the regulatory body.

expected outcome (the documentation structure for the PSR). In addition, a documented design basis is necessary for the assessment of the plant safety against the original as well as the current safety standards. The scope should include, as a minimum, the safety factors given in Section 4. A State may wish to extend the list of safety factors, for example, by considering quality assurance or radiological protection as separate safety factors. If any of the safety factors given in Section 4 are not to be included, this fact should be documented when developing the scope and a rationale should be given for their exclusion from the PSR.

ACTIVITIES OF THE PLANT OPERATING ORGANIZATION

Step 1: Preparation of the PSR project

6.3. Since the PSR is a major task, an appropriate project management team should be established at the outset. This is necessary in order to achieve the expected outcome within the agreed time-scale and budget.

6.4. The PSR is typically performed by a number of review teams in parallel. A document should therefore be prepared to provide guidance on how to review the different safety factors so as to ensure a comprehensive, consistent and systematic approach. This guidance document should elaborate on the agreed general scope of the PSR. It should also identify applicable safety standards, methods and practices which, in most cases, will be based on current national standards and practices and will reflect current knowledge. If there are no adequate national standards, reference should be made to international codes and standards (such as those of the IAEA, the International Organization for Standardization and the International Electrotechnical Commission) or, where appropriate, of a recognized organization of a particular State (e.g. the American Society of Mechanical Engineers or the Institute of Electrical and Electronics Engineers). The standards and practices of the design and operating organizations, such as the good practices of INPO, could also be relevant and should be taken into account. A more recent version of a relevant reactor design could also be used as a reference level for comparison.

6.5. The results of the reviews should be recorded in a systematic and auditable manner. PSR documentation arrangements that identify the documents to be produced and their formats should therefore be clearly defined. To ensure the appropriate quality for these documents, a QA plan should be prepared which, among other things, defines the requirements for the preparation and verification of PSR documentation. The QA plan should also ensure that all reviewers use the same input data to provide for consistency across all areas of the review.

6.6. In order that the PSR is completed within the agreed schedule, a detailed action plan should be prepared that identifies all the activities to be performed for the PSR, the timelines and the responsibilities. On the basis of this plan, an overall budget for the PSR should then be prepared. Because the development of a PSA is a resource intensive activity, its scope and depth and their implications for the overall time-scale for the PSR should be considered in the planning stage.

6.7. Before the start of the reviews, the senior management of the plant operating organization should approve the action plan and budget.

6.8. As the PSR process is a complex undertaking involving non-routine work by many of the staff of the operating organization, appropriate training of the reviewers would facilitate effective and efficient completion of the PSR.

Step 2: PSR reviews

6.9. A single database of information to be used should be established to ensure consistency across all areas of the review. This should include not only the historical data but also predictions of future operating regimes and service lifetime.

6.10. Where appropriate, the review of each of the safety factors should be carried out for all service conditions (including accident conditions), using current deterministic and probabilistic methods and an assessment made against current safety standards and practices. A list of shortcomings should be prepared, showing areas where current standards and practices are not achieved. In addition, areas where current safety standards and practices are exceeded should be identified as plant strengths.

6.11. The safety significance of the shortcomings should be evaluated using deterministic and probabilistic methods as appropriate [39]. If any serious shortcoming is found, appropriate corrective actions and/or safety improvements should be implemented immediately.

6.12. The impact on safety associated with the shortcomings for all the safety factors should be evaluated in their totality by a global assessment. This is important because it is possible that each shortcoming considered in isolation may appear acceptable but when taken together with others may prove to be unacceptable. This is particularly relevant in considering human and organizational factors. However, in some cases, corrective actions and/or safety improvements may not be necessary for shortcomings that are balanced by relevant plant strengths.

6.13. The reports on the review of each of the safety factors that are submitted to the regulatory body should include proposals of objectives and/or concepts of corrective actions and/or safety improvements.

Step 3: Preparation of the programme of corrective actions and/or safety improvements

6.14. Detailed proposals for the implementation of corrective actions and/or safety improvements should be prepared after receiving the feedback from the regulatory body on the submitted reports. This should include the outcome of discussions with the regulatory body regarding the scope and adequacy of the outline proposals of corrective actions and/or safety improvements. In addition, the corrective actions and/or safety improvements should be prioritized. Different approaches exist for the prioritization of corrective actions and/or safety improvements on the basis of deterministic analyses, PSA and engineering judgement.

6.15. An integrated implementation plan for the corrective actions and/or safety improvements should be prepared that takes into account possible interactions between individual corrective actions and/or safety improvements, including appropriate configuration control. The integrated implementation plan should specify the schedules and resources needed. If the operator identifies a corrective action or safety improvement that provides significant safety benefit and is judged to be reasonably practicable, implementation should not await the completion of the PSR. The aim is to complete as many of the corrective actions and/or safety improvements as is practicable within the time frame of a PSR; however, it is recognized that implementation of some corrective actions and/or safety improvements may require a longer time.

6.16. A summary report should be prepared that presents the significant PSR results and the integrated implementation plan for the corrective actions and/or safety improvements.

6.17. The integrated implementation plan of corrective actions and/or safety improvements and the summary report should be subject to approval by the senior management of the plant operating organization, who should commit the necessary human and financial resources to implement the planned corrective actions and/or safety improvements according to a reasonable schedule. These approved documents should then be submitted to the regulatory body for review and final decision in accordance with national requirements and nuclear law.

ACTIVITIES OF THE REGULATORY BODY

6.18. The regulatory overview of the PSR is a major responsibility that involves ongoing communication with the operating organization. To ensure that this is carried out efficiently and effectively, the regulatory body should designate a PSR project manager to co-ordinate all the regulatory body's PSR activities and to be a focal point for communication with the operating organization.

6.19. The task of the regulatory body is to ensure that the operating organization carries out a comprehensive PSR and implements appropriate corrective actions and/or safety improvements within the agreed time. The main part of this task is the assessment of the PSR reports submitted by the operating organization. An assessment plan should therefore be prepared that covers all areas of the review and focuses resources on those areas that are likely to have the highest safety significance (on the basis of previous regulatory experience and advice from technical experts). The plan should also identify the source and availability of the technical experts to carry out the assessments and the assessment criteria to be used.

6.20. During the assessment process, the regulatory body and/or its technical support staff should communicate with the operating organization to clarify issues, including any additional issues identified by the assessor, and to acquire any necessary additional information. The results of these interactions should be documented for future reference.

6.21. On completion of the assessment, the technical experts should prepare assessment reports that clearly identify all significant issues which, in their opinion, need to be resolved. The assessment reports should also give an initial indication of the acceptability of the objectives/concepts of corrective actions and/or safety improvements proposed by the plant operating organization.

6.22. Using the individual assessment reports, the regulatory body's PSR project manager should prepare a project report. The purpose of this project report is to present, in a concise way, the regulatory body's view of the adequacy of the operating organization's PSR as documented in the submitted reports, including the corrective actions and/or safety improvements identified. The project report should identify each issue for which the regulatory body considers that corrective actions and/or safety improvements are required, including the time-scale on which these should be carried out. This should take into account the corrective actions and/or safety improvements already identified by the operating organization.

6.23. The regulatory body's project report should be formally discussed with the operating organization. This may involve several meetings which should lead to a commitment by the operating organization to the agreed integrated implementation plan of corrective actions and/or safety improvements.

6.24. In the unlikely event that the PSR identifies a safety shortcoming which poses an immediate significant risk to health and safety for workers or the public, the regulatory body should ensure that the operating organization takes prompt corrective action and does not wait until the end of the PSR process. This may involve proposing or imposing operating restrictions or temporarily shutting down a reactor pending the resolution of the issue.

7. BASIS FOR ACCEPTABILITY OF CONTINUED PLANT OPERATION

7.1. The procedure described in Section 6 should be followed to identify any differences between the safety status of a nuclear power plant and current safety standards and practices (a reference level used for comparison). Some differences may actually be strengths because the safety status of a plant on particular issues may be better than for current standards and practices. The procedure does not require that a nuclear power plant meet all current standards; however, practicable improvements should be made as steps towards meeting them. It is recognized that some safety features, such as current seismic features, cannot easily be backfitted, and some design aspects, such as plant layout, are difficult to modify. For these cases, the procedure requires that the risk associated with the shortcomings be assessed and that a justification for continued plant operation be provided.

7.2. The differences that are classified as shortcomings should be assessed and a 'risk' judgement should be made on the acceptability of continued operation with the shortcomings remaining after all corrective actions and/or safety improvements have been implemented. The aspects involved in this judgement may include:

(1) *The remaining period of operation proposed by the operating organization.* If the remaining period of operation is sufficiently short, the risk associated with continued operation may be judged acceptable during this period if adequate remedial measures can be put into effect.
(2) *Time required to implement corrective actions and/or safety improvements.* Any decision by the regulatory body to require corrective actions and/or safety improvements should take account of the actual benefit to safety that the action will achieve and the duration of the benefit (the remaining period of plant lifetime). If the modification is necessary on grounds of unacceptable risk, then continued operation should not be permitted until it has been made or adequate interim measures have been taken.
(3) *Use of PSA*. The results of an adequate PSA that is acceptable to the regulatory body may be used as a measure of the risk posed by any of the unresolved shortcomings. Information from a PSA is clearly helpful, but the uncertainties in data and techniques do not allow decisions on continued operation or plant shutdown to be made on the basis of PSA results alone. However, PSA results may provide an acceptable basis for determining, in the framework of a cost–benefit analysis, whether a corrective action is a mandatory prerequisite for continued operation.
(4) *Use of expert judgement*. Deterministic consideration should be given to the total effect on the safe operation of the plant of all unresolved shortcomings and all corrective actions and/or safety improvements and strengths identified in the PSR, to ensure that the overall level of plant safety is adequate.

7.3. The plant operating organization should commit itself effectively to the integrated plan of implementation of corrective actions and/or safety improvements.

8. POST-REVIEW ACTIVITIES

8.1. *Implementation of the programme of corrective actions and/or safety improvements.* Safety is enhanced by implementing the corrective actions and/or safety improvements. Therefore, it is essential that both the operating organization and the regulatory body maintain adequate arrangements for project management to ensure the timely completion of a committed plan of corrective actions and/or safety improvements.

8.2. *Documentation from the PSR* should be stored in a suitable system with sufficient detail to allow easy retrieval and interrogation, by both the operating organization and the regulatory body. The documentation should contain the last accepted version of the PSR documentation and information on lessons learned from the PSR.

8.3. *Updating of plant documentation*. The PSR and associated corrective actions and/or safety improvements will invariably necessitate changes to plant documentation. Therefore, the plant operating organization should update all plant documentation including, for example, the safety analysis report, operating and maintenance procedures and training materials to reflect the outcomes of the PSR.

8.4. *Reporting PSR results.* The operating organization and/or the regulatory body should report the outcomes to the government and the public in accordance with national legal requirements, custom and practice. The reporting arrangements required under international conventions will also apply.

Appendix

ELEMENTS OF THE REVIEW

A.1. This appendix lists a number of generic review elements for each safety factor. These elements describe specific topics or activities within the safety factor that should be reviewed. The meaning of an element should be interpreted in the light of the review objective for the respective safety factor as is stated in the main text. The elements listed may not cover all topics or activities associated with the safety factor and therefore addressing all of them does not necessarily mean that the particular safety factor is fully covered.

A.2. Before a PSR, the elements of the review should be agreed upon between the regulatory body and the operating organization responsible for conducting the PSR. These elements should be updated in accordance with current knowledge, standards and practices, and should be checked for consistency with the relevant national and international codes and standards.

THE PLANT

Plant design

(a) A detailed description of the plant design, supported by drawings of the layout, system and equipment.
(b) A list of SSCs important to safety and their classification.
(c) The documented design basis (original and updated).
(d) Significant differences (strengths and shortcomings) between the present plant design and the current standards (used for comparison).
(e) The safety significance of the identified shortcomings relating to the application of defence in depth.

Actual condition of systems, structures and components

(a) A list of SSCs important to safety and their classification.
(b) Information about the integrity and functional capability of SSCs important to safety, including material case histories.
(c) Information on the existing or anticipated obsolescence of any SSCs important to safety.
(d) Findings of tests that demonstrate the functional capability.
(e) Results of inspections.
(f) Maintenance records.

(g) Description of the present condition of SSCs important to safety.
(h) Description of the support facilities available to the plant both on and off the site, including maintenance and repair shops.

Equipment qualification

(a) List of equipment covered by the equipment qualification programme and a list control procedure.
(b) Qualification report and other supporting documents (e.g. equipment qualification specifications and qualification plan).
(c) Verification that the installed equipment matches the qualified equipment.
(d) Procedures to maintain qualification throughout the installed service life of the equipment.
(e) Mechanisms for ensuring compliance with these procedures.
(f) A surveillance programme and a feedback procedure to ensure that ageing degradation of qualified equipment remains insignificant.
(g) Monitoring of actual environmental conditions and identification of 'hot spots' of high activity.
(h) Analysis of the effects of equipment failures on equipment qualification and appropriate corrective actions and/or safety improvements to maintain equipment qualification.
(i) Protection of qualified equipment from adverse environmental conditions.
(j) Physical condition and functionality of qualified equipment (to be confirmed by walkdowns).
(k) Records of all qualification measures taken during the installed service life of the equipment.

Ageing

(a) Programme policy, organization and resources.
(b) A documented method and criteria for identifying SSCs covered by the ageing management programme.
(c) A list of SSCs covered by the ageing management programme and records that provide information in support of the management of ageing.
(d) Evaluation and documentation of potential ageing degradation that may affect the safety functions of SSCs.
(e) The extent of understanding of dominant ageing mechanisms of SSCs.
(f) The availability of data for assessing ageing degradation, including baseline, operating and maintenance history.

(g) The effectiveness of operational and maintenance programmes in managing ageing of replaceable components.
(h) The programme for timely detection and mitigation of ageing mechanisms and/or ageing effects.
(i) Acceptance criteria and required safety margins for SSCs.
(j) Awareness of physical condition of SSCs, including actual safety margins, and any features that would limit service life.

SAFETY ANALYSIS

Deterministic safety analysis

(a) A compilation of the existing deterministic safety analyses and their assumptions.
(b) Limits and permitted operational states.
(c) Anticipated operational occurrences.
(d) Postulated initiating events (for the existing safety analyses and a comparable list for a modern nuclear power plant) [6].
(e) Analytical methods and computer codes used in the existing deterministic safety analyses and comparable methods for a modern nuclear power plant, including validation.
(f) Radiation doses and limits on radioactive releases for accident conditions.
(g) Guidelines for deterministic safety analyses, including guidelines for single failure criterion, redundancy, diversity and separation.

Probabilistic safety assessment

(a) Existing PSA and its assumptions.
(b) Updating of PSA to reflect the current plant status.
(c) Postulated initiating events (for the existing PSA and a comparable list for a modern nuclear power plant).
(d) Analytical methods and computer codes used in the existing PSA and comparable methods for a modern nuclear power plant, including validation.
(e) Guidelines for PSA of operator action, common cause events, cross-link effects, redundancy and diversity.
(f) Consistency of the accident management programme for beyond design basis accidents with PSA results.

Hazard analysis

(a) Internal hazards:
- fire (prevention, detection and suppression);
- flooding;
- pipe whip;
- missiles;
- steam release;
- spray;
- toxic gas;
- explosion.

(b) External hazards:
- changes in site characteristics;
- flooding, including tsunami;
- high winds;
- temperature extremes;
- seismic hazards;
- aircraft crash;
- toxic gas;
- explosion.

PERFORMANCE AND FEEDBACK OF EXPERIENCE

Safety performance

(a) A system for identifying and classifying safety related incidents.
(b) Arrangements for root cause analysis of incidents and feedback of results.
(c) Methods for selecting and recording safety related operational data, including those for maintenance, testing and inspection.
(d) Trend analyses of safety related operational data.
(e) Feedback of safety related operational data to the operating regime.
(f) Analyses of safety performance indicators such as:
- the frequency of unplanned trips while a reactor is critical;
- the frequency of selected safety system actuations and/or demands;
- the frequency of safety system failures;
- safety system unavailability;
- the collective dose of radiation per year;
- trends in causes of failure (operator errors, plant problems, administration and control problems);
- the backlog of outstanding maintenance;

— the extent of repeat maintenance;
— the extent of corrective (breakdown) maintenance;
— the frequency of unplanned operator actions in the interests of safety and their success rate;
— the rate of arisings of radioactive waste;
— the quantities of stored radioactive waste.

(g) Records of the integrity of physical barriers for the containment of radioactive material.
(h) Records of radiation doses to persons on the site.
(i) Records of data from off-site radiation monitoring.
(j) Records of the quantities of radioactive effluents.

Use of experience from other plants and of research findings

(a) Arrangements for the feedback of experience relevant to safety from other nuclear power plants and relevant non-nuclear plants.
(b) Assessments of and actions on the above experience.
(c) Arrangements for the receipt of information on the findings of relevant research programmes.
(d) Assessments of and actions on the research information.
(e) Plant modifications resulting from the above.

MANAGEMENT

Organization and administration

(a) Safety policy stating that safety takes precedence over production and implementation of the policy.
(b) Mechanism for setting operating targets and safety targets.
(c) Documented roles and responsibilities of individuals and groups.
(d) Procedures for the feedback of experience to the staff, including experience relating to organizational and management failures.
(e) Mechanisms for maintaining configuration of the nuclear power plant and its documentation.
(f) Formal arrangements for employing external technical, maintenance or other specialist staff.
(g) Staff training facilities and programmes.
(h) QA programme and regular QA audits involving independent assessors [5].
(i) Compliance with regulatory requirements.

(j) Comprehensive, readily retrievable and auditable records of baseline information and operational and maintenance history [5].
(k) Programme for continuous improvement and/or self-assessment.
(l) Arrangements for control of any changes to the organizational structure or resources of the operating organization that may affect plant safety.

Procedures

(a) Formal approval and documentation of all safety related procedures.
(b) Formal system for modification of a procedure.
(c) Understanding and acceptance of these procedures by management and on-site staff.
(d) Evidence that these procedures are followed.
(e) Adequacy of these procedures in comparison with good practice.
(f) Arrangements for regular review and maintenance of these procedures.
(g) Clarity of procedures with human factor principles taken into account.
(h) Compliance of these procedures with the assumptions and findings of the safety analysis, plant design and operating experience.
(i) Symptom based emergency operating procedures for restoring critical safety functions.

Human factors

(a) Staffing levels for the operation of the nuclear power plant with due recognition of absences, shift working and overtime restrictions.
(b) Availability of qualified staff on duty at all times.
(c) Policy to maintain the know-how of the plant staff.
(d) Systematic and validated staff selection methods (e.g. testing for aptitude, knowledge and skills).
(e) Programmes for initial training, refresher training and upgrading training, including the use of simulators.
(f) Training in safety culture, particularly for management staff.
(g) Programmes for the feedback of operating experience for failures and/or errors in human performance that have contributed to safety significant events and of their causes and corrective actions and/or safety improvements.
(h) Fitness for duty guidelines relating to hours of work, good health and substance abuse.
(i) Competence requirements for operating, maintenance, technical and managerial staff.

(j) Human–machine interface: design of the control room and other work stations; analysis of human information requirements and task workload; linkage to PSA and deterministic analyses.
(k) Style and clarity of procedures.

Emergency planning

(a) Studies of the mitigation of accident consequences.
(b) Strategy and organization for emergencies.
(c) Plans and procedures for emergencies.
(d) On-site equipment and facilities for emergencies.
(e) On-site emergency centres.
(f) Communications.
(g) Emergency training, exercises and records of experience.
(h) Interactions of relevant organizations such as the regulatory body, police, fire departments, hospitals, ambulance services, local authorities, public welfare authorities and the information media.
(i) Arrangements for regular reviews of emergency plans and procedures.
(j) Security arrangements for emergencies.

ENVIRONMENT

Radiological impact on the environment

(a) Potential sources of radiological impact.
(b) Release limits for effluents.
(c) Records of effluent releases.
(d) Off-site monitoring for contamination levels and radiation levels.
(e) Alarm systems to respond to unplanned releases of effluents from on-site facilities.
(f) Publication of environmental data.
(g) Changes in the use of areas around the site.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safety of Nuclear Installations, Safety Series No. 110, IAEA, Vienna (1993).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Operation, Safety Standards Series No. NS-R-2, IAEA, Vienna (2000).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, A Common Basis For Judging the Safety of Nuclear Power Plants Built to Earlier Standards, INSAG Series No. 8, IAEA, Vienna (1995).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, Safety Standards Series No. NS-R-1, IAEA, Vienna (2000).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for Safety in Nuclear Power Plants and Other Nuclear Installations: Code and Safety Guides Q1-Q14, Safety Series No. 50-C/SG-Q, IAEA, Vienna (1996).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment and Verification for Nuclear Power Plants, Safety Standards Series No. NS-G-1.2, IAEA, Vienna (2002).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Seismic Design and Qualification for Nuclear Power Plants, Safety Standards Series No. NS-G-1.6, IAEA, Vienna (2003).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Equipment Qualification in Operational Nuclear Power Plants: Upgrading, Preserving and Reviewing, Safety Reports Series No. 3, IAEA, Vienna (1998).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety, Technical Reports Series No. 338, IAEA, Vienna (1992).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing, Safety Series No. 50-P-3, IAEA, Vienna (1992).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Implementation and Review of a Nuclear Power Plant Ageing Management Programme, Safety Reports Series No. 15, IAEA, Vienna (1999).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, AMAT Guidelines: Reference Document for the IAEA Ageing Management Assessment Teams (AMATs), IAEA Services Series No. 4, IAEA, Vienna (1999).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 1), Safety Series No. 50-P-4, IAEA, Vienna (1992).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 2), Safety Series No. 50-P-8, IAEA, Vienna (1995).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 3), Safety Series No. 50-P-12, IAEA, Vienna (1996).

[16] OECD NUCLEAR ENERGY AGENCY, Level 2 PSA Methodology and Severe Accident Management, Rep. OECD/GD(97)198, OECD, Paris (1997).
[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Implementation of Accident Management Programmes in Nuclear Power Plants, Safety Reports Series No. 32, IAEA, Vienna (2003).
[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Evaluation of Seismic Hazards for Nuclear Power Plants, Safety Standards Series No. NS-G-3.3, IAEA, Vienna (2003).
[19] INTERNATIONAL ATOMIC ENERGY AGENCY, External Human Induced Events in Site Evaluation for Nuclear Power Plants, Safety Standards Series No. NS-G-3.1, IAEA, Vienna (2002).
[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Flood Hazards for Nuclear Power Plants on Coastal and River Sites, Safety Standards Series No. NS-G-3.5, IAEA, Vienna (2003).
[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Meteorological Events in Site Evaluation for Nuclear Power Plants, Safety Standards Series No. NS-G-3.4, IAEA, Vienna (2003).
[22] INTERNATIONAL ATOMIC ENERGY AGENCY, Protection against Internal Fires and Explosions in Nuclear Power Plants, Safety Standards Series, IAEA, Vienna (in preparation).
[23] INTERNATIONAL ATOMIC ENERGY AGENCY, Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants, Safety Standards Series, IAEA, Vienna (in preparation).
[24] INTERNATIONAL ATOMIC ENERGY AGENCY, Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants, Safety Standards Series No. NS-G-2.6, IAEA, Vienna (2002).
[25] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Safety Performance Indicators for Nuclear Power Plants, IAEA-TECDOC-1141, IAEA, Vienna (2000).
[26] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants, Safety Standards Series No. NS-G-2.2, IAEA, Vienna (2000).
[27] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants, Safety Standards Series No. NS-G-2.7, IAEA, Vienna (2002).
[28] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Safety Culture, Safety Series No. 75-INSAG-4, IAEA, Vienna (1991).
[29] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Management of Operational Safety in Nuclear Power Plants, INSAG Series No. 13, IAEA, Vienna (1999).
[30] INTERNATIONAL ATOMIC ENERGY AGENCY, The Operating Organization for Nuclear Power Plants, Safety Standards Series No. NS-G-2.4, IAEA, Vienna (2001).

[31] INTERNATIONAL ATOMIC ENERGY AGENCY, Human Reliability Analysis in Probabilistic Safety Assessment for Nuclear Power Plants, Safety Series No. 50-P-10, IAEA, Vienna (1996).
[32] INTERNATIONAL ATOMIC ENERGY AGENCY, Recruitment, Qualification and Training of Personnel for Nuclear Power Plants, Safety Standards Series No. NS-G-2.8, IAEA, Vienna (2002).
[33] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE CO-ORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, Safety Standards Series No. GS-R-2, IAEA, Vienna (2002).
[34] INTERNATIONAL ATOMIC ENERGY AGENCY, Preparation, Conduct and Evaluation of Exercises to Test Preparedness for a Nuclear or Radiological Emergency, IAEA-EPR, IAEA, Vienna (in preparation).
[35] INTERNATIONAL ATOMIC ENERGY AGENCY, Developments in the Preparation of Operating Procedures for Emergency Conditions of Nuclear Power Plants, IAEA-TECDOC-341, Vienna (1985).
[36] INTERNATIONAL ATOMIC ENERGY AGENCY, Experience with Simulator Training for Emergency Conditions, IAEA-TECDOC-443, Vienna (1987).
[37] INTERNATIONAL ATOMIC ENERGY AGENCY, Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Accidents, IAEA-TECDOC-953, Vienna (1997).
[38] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Assessment Procedures for Determining Protective Actions during a Reactor Accident, IAEA-TECDOC-955, Vienna (1997).
[39] INTERNATIONAL ATOMIC ENERGY AGENCY, Evaluation of the Safety of Operating Nuclear Power Plants Built to Earlier Standards, Safety Reports Series No. 12, IAEA, Vienna (1998).

GLOSSARY

ageing. General process in which characteristics of a structure, system or component gradually change with time or use.

ageing management. Engineering, operations and maintenance actions to control within acceptable limits ageing degradation and wearing out of structures, systems or components.

— Examples of engineering actions include design, qualification, and failure analysis. Examples of operations actions include surveillance, carrying out operational procedures within specified limits, and performing environmental measurements.

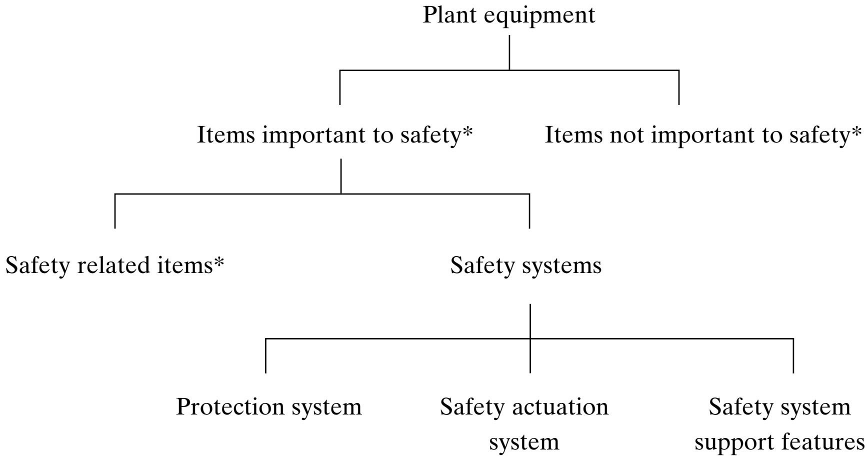
— **life management** (or **life cycle management**) is the integration of ageing management with economic planning to: (1) optimize the operation, maintenance and service life of structures, systems and components; (2) maintain an acceptable level of performance and safety; and (3) maximize return on investment over the service life of the facility.

design basis. The range of conditions and events taken explicitly into account in the design of a facility, according to established criteria, such that the facility can withstand them without exceeding authorized limits by the planned operation of safety systems.

licensing basis. A set of regulatory requirements applicable to a nuclear installation.

periodic safety review. A systematic reassessment of the safety of a nuclear power plant carried out at regular intervals to deal with the cumulative effects of ageing, modifications, operating experience, technical developments and siting aspects, and is aimed at ensuring a high level of safety throughout the operating lifetime of the plant.

plant equipment.



items 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.

Items important to safety include:

— those structures, systems and components whose malfunction or failure could lead to undue radiation exposure of site personnel or members of the public;

— those structures, systems and components which prevent anticipated operational occurrences from leading to accident conditions; and

— those features which are provided to mitigate the consequences of malfunction or failure of structures, systems or components.

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. The 'system' in this case encompasses all electrical and mechanical devices and circuitry, from sensors to actuation device input terminals.

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

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

---

* In this context, an item is a structure, system or component.

safety systems. A system important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents. Safety systems consist of the protection system, the safety actuation systems and the safety system support features. Components of safety systems may be provided solely to perform safety functions or may perform safety functions in some plant operational states and non-safety functions in other operational states.

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.

CONTRIBUTORS TO DRAFTING AND REVIEW

Banks, P.	Nuclear Electric Ltd, United Kingdom
Barbaud, J.Y.	Electricité de France, EDF/SEPTEN, France
Berg, H.P.	Bundesamt für Strahlenschutz, Germany
Briegleb, P.	AIB-Vincotte Nucléaire, Belgium
Cordoba, I.	Nuclear Safety Council, Spain
Cserhati, A.	Paks Nuclear Power Plant, Hungary
Kotyza, V.	International Atomic Energy Agency
Pachner, J.	International Atomic Energy Agency
Svensson, J.	Bärseback Kraft AB, Sweden
Tanaka, N.	Nuclear Power Engineering Corporation, Japan
West, B.	Health and Safety Executive, United Kingdom

BODIES FOR THE ENDORSEMENT OF SAFETY STANDARDS

An asterisk (*) denotes a corresponding member. Corresponding members receive drafts for comment and other documentation but they do not generally participate in meetings.

Commission on Safety Standards

Argentina: Oliveira, A.; *Brazil*: Caubit da Silva, A.; *Canada*: Pereira, J.K.; *China*: Zhao, C.; *France*: Gauvain, J.; Lacoste, A.-C.; *Germany*: Renneberg, W.; *India*: Sukhatme, S.P.; *Japan*: Suda, N.; *Korea, Republic of*: Eun, S.; *Russian Federation*: Vishnevskiy, Yu.G.; *Spain*: Azuara, J.A.; Santoma, L.; *Sweden*: Holm, L.-E.; *Switzerland*: Schmocker, U.; *Ukraine*: Gryschenko, V.; *United Kingdom*: Pape, R.; Williams, L.G. (Chairperson); *United States of America*: Travers, W.D.; *IAEA*: Karbassioun, A. (Co-ordinator); *International Commission on Radiological Protection*: Clarke, R.H.; *OECD Nuclear Energy Agency*: Shimomura, K.

Nuclear Safety Standards Committee

Argentina: Sajaroff, P.; *Australia*: MacNab, D.; *Belarus*: Sudakou, I.; *Belgium*: Govaerts, P.; *Brazil*: Salati de Almeida, I.P.; *Bulgaria*: Gantchev, T.; *Canada*: Hawley, P.; *China*: Wang, J.; *Czech Republic*: Böhm, K.; *Egypt*: Hassib, G.; *Finland*: Reiman, L. (Chairperson); *France*: Saint Raymond, P.; *Germany*: Feige, G.; *Hungary*: Vöröss, L.; *India*: Sharma, S.K.; *Ireland*: Hone, C.; *Israel*: Hirshfeld, H.; *Italy*: del Nero, G.; *Japan*: Yamamoto, T.; *Korea, Republic of*: Lee, J.-I.; *Lithuania*: Demcenko, M.; *Mexico*: Delgado Guardado, J.L.; *Netherlands*: de Munk, P.; *Pakistan*: Hashimi, J.A.; *Peru*: Ramírez Quijada, R.; *Russian Federation*: Baklushin, R.P.; *South Africa*: Bester, P.J.; *Spain*: Mellado, I.; *Sweden*: Jende, E.; *Switzerland*: Aeberli, W.; *Thailand*: Tanipanichskul, P.; *Turkey*: Alten, S.; *United Kingdom*: Hall, A.; *United States of America*: Newberry, S.; *European Commission*: Schwartz, J.-C.; *IAEA*: Bevington, L. (Co-ordinator); *International Organization for Standardization*: Nigon, J.L.; *OECD Nuclear Energy Agency*: Hrehor, M.

Radiation Safety Standards Committee

Argentina: Rojkind, R.H.A.; *Australia*: Mason, C. (Chairperson); *Belarus*: Rydlevski, L.; *Belgium*: Smeesters, P.; *Brazil*: Amaral, E.; *Canada*: Utting, R.; *China*: Yang, H.; *Cuba*: Betancourt Hernandez, A.; *Czech Republic*: Drabova, D.; *Denmark*: Ulbak, K.; **Egypt*: Hanna, M.; *Finland*: Markkanen, M.; *France*: Piechowski, J.; *Germany*: Landfermann, H.; *Hungary*: Koblinger, L.; *India*: Sharma, D.N.; *Ireland*: McGarry, A.; *Israel*: Laichter, Y.; *Italy*: Sgrilli, E.; *Japan*: Yonehara, H.; *Korea, Republic of*: Kim, C.; **Madagascar*: Andriambololona, R.; **Mexico*: Delgado Guardado, J.L.; *Netherlands*: Zuur, C.; *Norway*: Saxebol, G.; *Peru*: Medina Gironzini, E.; *Poland*: Merta, A.; *Russian Federation*: Kutkov, V.; *Slovakia*: Jurina, V.; *South Africa*: Olivier, J.H.L.; *Spain*: Amor, I.; *Sweden*: Hofvander, P.; Moberg, L.; *Switzerland*: Pfeiffer, H.J.; **Thailand*: Pongpat, P.; *Turkey*: Buyan, A.G.; *Ukraine*: Likhtarev, I.A.; *United Kingdom*: Robinson, I.; *United States of America*: Paperiello, C.; *European Commission*: Janssens, A.; Kaiser, S.; *Food and Agriculture Organization of the United Nations*: Rigney, C.; *IAEA*: Bilbao, A.; *International Commission on Radiological Protection*: Valentin, J.; *International Labour Office*: Niu, S.; *International Organization for Standardization*: Perrin, M.; *International Radiation Protection Association*: Webb, G.; *OECD Nuclear Energy Agency*: Lazo, T.; *Pan American Health Organization*: Borras, C.; *United Nations Scientific Committee on the Effects of Atomic Radiation*: Gentner, N.; *World Health Organization*: Kheifets, L.

Transport Safety Standards Committee

Argentina: López Vietri, J.; *Australia*: Colgan, P.; **Belarus*: Zaitsev, S.; *Belgium*: Cottens, E.; *Brazil*: Bruno, N.; *Bulgaria*: Bakalova, A.; *Canada*: Viglasky, T.; *China*: Pu, Y.; **Denmark*: Hannibal, L.; **Egypt*: El-Shinawy, R.M.K.; *France*: Aguilar, J.; *Germany*: Rein, H.; *Hungary*: Sáfár, J.; *India*: Nandakumar, A.N.; *Ireland*: Duffy, J.; *Israel*: Koch, J.; *Italy*: Trivelloni, S.; *Japan*: Hamada, S.; *Korea, Republic of*: Kwon, S.-G.; *Netherlands*: Van Halem, H.; *Norway*: Hornkjøl, S.; **Peru*: Regalado Campaña, S.; *Romania*: Vieru, G.; *Russian Federation*: Ershov, V.N.; *South Africa*: Jutle, K.; *Spain*: Zamora Martin, F.; *Sweden*: Pettersson, B.G.; *Switzerland*: Knecht, B.; **Thailand*: Jerachanchai, S.; *Turkey*: Köksal, M.E.; *United Kingdom*: Young, C.N. (Chairperson); *United States of America*: Brach, W.E.; McGuire, R.; *European Commission*: Rossi, L.; *International Air Transport Association*: Abouchaar, J.; *IAEA*: Pope, R.B.; *International Civil Aviation Organization*: Rooney, K.; *International Federation of Air Line Pilots' Associations*: Tisdall, A.; *International Maritime*

Organization: Rahim, I.; *International Organization for Standardization*: Malesys, P.; *United Nations Economic Commission for Europe*: Kervella, O.; *World Nuclear Transport Institute*: Lesage, M.

Waste Safety Standards Committee

Argentina: Siraky, G.; *Australia*: Williams, G.; **Belarus*: Rozdyalovskaya, L.; *Belgium*: Baekelandt, L. (Chairperson); *Brazil*: Xavier, A.; **Bulgaria*: Simeonov, G.; *Canada*: Ferch, R.; *China*: Fan, Z.; *Cuba*: Benitez, J.; **Denmark*: Øhlenschlaeger, M.; **Egypt*: Al Adham, K.; Al Sorogi, M.; *Finland*: Rukola, E.; *France*: Averous, J.; *Germany*: von Dobschütz, P.; *Hungary*: Czoch, I.; *India*: Raj, K.; *Ireland*: Pollard, D.; *Israel*: Avraham, D.; *Italy*: Dionisi, M.; *Japan*: Irie, K.; *Korea, Republic of*: Sa, S.; **Madagascar*: Andriambololona, R.; *Mexico*: Maldonado, H.; *Netherlands*: Selling, H.; **Norway*: Sorlie, A.; *Pakistan*: Qureshi, K.; **Peru*: Gutierrez, M.; *Russian Federation*: Poluektov, P.P.; *Slovakia*: Konecny, L.; *South Africa*: Pather, T.; *Spain*: O'Donnell, P.; *Sweden*: Wingefors, S.; *Switzerland*: Zurkinden, A.; **Thailand*: Wangcharoenroong, B.; *Turkey*: Kahraman, A.; *United Kingdom*: Wilson, C.; *United States of America*: Greeves, J.; Wallo, A.; *European Commission*: Taylor, D.; Webster, S.; *IAEA*: Hioki, K. (Co-ordinator); *International Commission on Radiological Protection*: Valentin, J.; *International Organization for Standardization*: Hutson, G.; *OECD Nuclear Energy Agency*: Riotte, H.