Safety Reports Series

No. 99

# Periodic Safety Review for Research Reactors

IAEA
International Atomic Energy Agency

# IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

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# PERIODIC SAFETY REVIEW FOR RESEARCH REACTORS

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SAFETY REPORTS SERIES No. 99

# PERIODIC SAFETY REVIEW FOR RESEARCH REACTORS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2020

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www.iaea.org/publications



Printed by the IAEA in Austria
November 2020
STI/PUB/1889

**IAEA Library Cataloguing in Publication Data**

Names: International Atomic Energy Agency.
Title: Periodic safety review for research reactors / International Atomic Energy Agency.
Description: Vienna : International Atomic Energy Agency, 2020. | Series: Periodic safety review for research reactors, ISSN 1020–6450 ; no. 99 | Includes bibliographical references.
Identifiers: IAEAL 20-01330 | ISBN 978–92–0–106819–4 (paperback : alk. paper) 978–92–0–162619–6 (pdf)
Subjects: Nuclear power plants — Safety measures. | Industrial safety. | System safety.
Classification: UDC 621.039.58 | STI/PUB/1889

# FOREWORD

Routine safety reviews of operating research reactors include reviews of modifications, safety significant events and resulting corrective actions, and the update of safety and operating documents to comply with regulatory requirements and licensing conditions.

Operators of research reactors may also conduct special safety reviews and assessments, such as the safety reassessment for research reactors taking into consideration the available experience from the Fukushima Daiichi nuclear power plant accident.

While routine safety reviews and assessments ensure safety within the design basis, there is a need to take into account the cumulative effects of ageing, modifications, operating experience, changes in the standards and technical developments. The review of such aspects can be achieved through a dedicated systemic safety review against the current standards, taking all applicable factors into account at defined intervals. This periodic safety review complements routine safety reviews, but does not replace them.

IAEA Safety Standards Series No. SSG-25, Periodic Safety Review for Nuclear Power Plants, provides guidance on the periodic safety review of nuclear power plants; however, it does not address the specificities of research reactors and experimental facilities. Given that research reactors do not have a designated lifetime and are expected to operate for reasonably long periods, periodic safety review is an effective way of ensuring that life limiting features are identified in a timely manner to preserve the overall safety of the facility and identify corrective actions and safety improvements.

Member States are increasingly requiring operating organizations to conduct periodic safety reviews for research reactors. This publication is intended to support operating organizations in their conduct of, and regulatory bodies in their assessment of, periodic safety reviews.

The IAEA wishes to thank all those who contributed to the development of this publication, including the Australian Nuclear Science and Technology Organisation and Hungarian Atomic Energy Authority for providing annex materials. The IAEA officers responsible for this publication were D. Rao and A.M. Shokr of the Division of Nuclear Installation Safety.

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# 1. INTRODUCTION

## 1.1. BACKGROUND

Requirement 5 of IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors [1], states:

> "**The safety assessment shall be continued throughout all the stages of the reactor's lifetime (in periodic safety reviews) and shall be conducted in accordance with the potential magnitude and nature of the hazards associated with the particular facility or activity.**"

Paragraph 4.24 of Ref. [1] states that "The safety assessments (and periodic safety reviews) shall be documented to facilitate their evaluation."

Paragraph 4.25 of Ref. [1] states:

> "Systematic periodic safety reviews of the research reactor in accordance with the regulatory requirements shall be performed throughout its operating lifetime, with account taken of operating experience, the cumulative effects of ageing, applicable safety standards and safety information from all relevant sources. The operating organization shall verify by analysis, surveillance, testing and inspection that the physical state of the reactor facility, including experimental devices and facilities, is as described in the safety analysis report and other safety documents, and that the facility is commissioned and operated in accordance with safety requirements and the safety analysis and operational limits and conditions."

Paragraph 4.26 of Ref. [1] (footnote omitted) states:

> "Activities for systematic periodic safety reassessments include, among others, periodic safety reviews such as self-assessments and peer reviews to confirm that the safety analysis report and other selected documents (such as documentation for operational limits and conditions, maintenance, training and qualification) for the facility remain valid in view of current regulatory requirements, or, if necessary, to update or make improvements to the extent practicable. In such reviews, changes in the site characteristics, changes in the utilization programme, cumulative effects of ageing and modifications, changes to procedures, the use of feedback from operating experience and technical developments shall be considered. It shall be verified that selected

structures, systems and components and software comply with the design requirements."

Paragraph 7.121 of Ref. [1] states that "On the basis of the results of the periodic safety review, the operating organization shall take any necessary corrective actions and shall consider making justified modifications to enhance safety".

Paragraph 7.122 of Ref. [1] states that "The operating organization shall report to the regulatory body as required, in a timely manner, the confirmed findings of the periodic safety review that have implications for safety."

The IAEA's Code of Conduct on the Safety of Research Reactors [2] states:

> "The regulations and guidance established by the State or the regulatory body according to national arrangements should…. Require the operating organization to undertake periodic safety reviews at intervals determined by the regulatory body and to make proposals for upgrading and refurbishment arising from such reviews as necessary."

Paragraph 22(a) of Ref. [2] states:

> "The operating organization should…carry out safety reviews at appropriate intervals throughout its life, including in relation to modifications, changes in utilization and significant experimental activities and the management of ageing. The safety assessments and periodic safety reviews should include all technical, operational, personnel and administrative aspects of safety related operations. The assessments and reviews should be well documented, subsequently updated in light of operating experience and significant new safety information and reviewed under the authority of the regulatory body."

Paragraph 4.8 of IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [3], states:

> "The frequency at which the safety assessment shall be updated is related to the radiation risks associated with the facility or activity, and the extent to which changes are made to the facility or activity. As a minimum, the safety assessment shall be updated in the periodic safety review carried out at predefined intervals in accordance with regulatory requirements. Continuation of operation of such facilities or conduct of such activities is subject to being able to demonstrate in the reassessment, to the satisfaction of the operating organization and the regulatory body, that the safety measures in place remain adequate."

Many regulatory bodies in Member States require that research reactors conduct periodic safety reviews (PSRs). The scope of these reviews varies based on national regulations. IAEA Safety Standards Series No. SSG-25, Periodic Safety Review for Nuclear Power Plants [4], provides recommendations regarding PSR for nuclear power plants. Some Member States have applied SSG-25 [4] to research reactors, using a graded approach. Considering the specificities of different research reactors (experimental facilities, isotope production) and the variations in their design and type, there is a need to provide suitable technical information for the conduct of PSR for research reactors. The resources available in many research reactors and regulatory bodies are limited, putting a constraint on undertaking such a resource intensive exercise. This publication aims to fulfil the need for suitable guidance for PSR for research reactors.

## 1.2. OBJECTIVE

The main objective of this publication is to provide technical information and practical examples on the conduct of PSR for research reactors to operating organizations and on the assessment of PSRs to regulatory bodies.

The specific objectives of the publication are to provide information to research reactor operating organizations on the preparation, frequency and tasks required for the review of various applicable safety factors and the performance of a global assessment of the safety of the research reactor. This publication provides information to research reactor operating organizations on identifying safety improvements or corrective actions as a result of PSR. It also provides information to regulatory bodies on the assessment of PSR submissions from research reactors for the renewal of operating licences or continuation of facility operation. Guidance provided here, describing good practices, represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

## 1.3. SCOPE

This publication covers PSR for an operating research reactor, including the definition of the PSR project; the conduct of PSR; and the review of applicable safety factors relating to the facility, safety analysis, performance and feedback of experience, management and radiological considerations. The publication presents the methodology for the review of safety factors and the safety assessment of the facility for the period until the next PSR. The publication also provides details on the review process and finalization of an integrated

implementation plan for maintaining and improving the safety of the research reactor facilities.

The publication is intended for use by operators of research reactors of all types, designs and ages, and can be used by research reactor operating organizations, regulatory bodies that oversee the safety of research reactors, technical support organizations and other stakeholders associated with research reactors.

### 1.4. STRUCTURE

Section 2 provides general considerations for PSR for research reactors, including the general methodology for their conduct and the review process. Section 3 presents information on the conduct of PSR by the operating organization, including the review of safety factors applicable to research reactors under five topical areas, as well as information on the global assessment of the facility based on the findings from the review of safety factors, and the development of the integrated implementation plan. It also briefly describes the documentation of the PSR. Section 4 provides information on the review process of the PSR by the regulatory body, and Section 5 provides details on post-review activities.

The Appendix provides information on associated documentation. Annex I provides typical sources of input information for each of the safety factors and the expected output from the review. Annexes II and III provide examples of PSRs conducted at the Open Pool Australian Lightwater reactor and at the Budapest Research Reactor, respectively.

## 2. GENERAL CONSIDERATIONS

This section outlines the general considerations associated with performing a PSR for a research reactor. It includes the general practical information applicable to this task as well as the benefits that may be obtained in addition to those associated with regulatory compliance and safety assurance.

A PSR provides an overall view of current facility safety and the quality of a facility's safety documentation. It also determines reasonable and practical corrective actions to ensure safety or to identify measures to improve safety to an appropriately high level. To achieve this, any life limiting features at the research

reactor need to be identified during the PSR in order to plan future modifications and determine the timing of future reviews.

Performing a PSR provides additional benefits, including potential improvements to the organization and operation of the reactor facility. A PSR also provides confidence to other stakeholders (including funding bodies, senior management, regulators and the public) as to the continued fitness for purpose of the research reactor for ongoing operation.

Based on international experience, it is reasonable and practical that a research reactor PSR be performed within ten years of the start of facility operation and that subsequent reviews be undertaken at intervals of ten years until the end of operation. For facilities that have been in operation for a longer time and have not been subjected to PSR, this activity needs to be initiated as early as possible. An interval of ten years is considered appropriate for such reviews in view of the following possible developments:

(a) Changes in IAEA and applicable national safety standards;
(b) Changes in operating practices and technology;
(c) The availability of new scientific knowledge or analytical techniques;
(d) Cumulative effects of facility modifications that have the potential to adversely affect safety;
(e) The obsolescence of the safety and operating documentation;
(f) The identification of ageing effects or trends that are significant;
(g) The accumulation of relevant operating experience;
(h) Changes in the utilization of the facility;
(i) Changes in the site characteristics in the vicinity of the facility;
(j) Changes in human resources or in the experience of staff;
(k) Changes in the management systems of the facility or operating organization.

Ten years is also considered a reasonable period between PSRs to identify important safety issues and to maintain continuity of direct knowledge and experience gained in previous reviews. The time taken for the review process depends on the availability of relevant information and the management system of the operating organization. The first PSR has to be completed within three years. This period is normally shorter for subsequent PSRs. It is recognized that for the first PSR, particularly for research reactors with inadequate or limited documentation, the design basis may have to be reconstituted and missing information may need to be created from other available documentation.

Some Member States have alternative arrangements and programmes that, if applied appropriately, can achieve the same results as PSR. This publication is not intended to discourage alternative arrangements and programmes that achieve similar outcomes to PSR. However, it is important that any alternative approach

followed meet the PSR objectives as well as other relevant requirements of licensing, regulation and operating processes.

## 2.1. OBJECTIVES OF PERIODIC SAFETY REVIEW

Paragraph 2.9 of Ref. [4] states:

"The objective of PSR is to determine by means of a comprehensive assessment:

- The adequacy and effectiveness of the arrangements and the structures, systems and components (equipment) that are in place to ensure plant safety until the next PSR or, where appropriate, until the end of planned operation…;
- The extent to which the plant conforms to current national and/or international safety standards and operating practices;
- Safety improvements and timescales for their implementation;
- The extent to which the safety documentation, including the licensing basis, remains valid."

Most research reactors were built to earlier standards and a design life was not prescribed. PSR serves to determine the facility's safety status and the status of its safety documentation against the current standards as well as the actions needed to correct the identified deficiencies. A PSR is normally used in support of the decision making process for operational licence renewal or for continued safe operation [5].

## 2.2. ROLES AND RESPONSIBILITIES

This section addresses the roles and responsibilities of the various parties involved in performing a PSR for a research reactor. In particular, it identifies the roles and responsibilities of the operating organization, the regulatory body and other stakeholders, including technical support organizations, consultants and other contractors. All parties involved need to have sufficient technical competence to perform their PSR responsibilities [6].

If the operating organization or regulatory body does not have the resources (technical or human) to fulfil its roles and responsibilities, then alternatives may be adopted, including the use of consultants to perform the PSR [7]. The use of

consultants may include the use of experts from other research reactors, possibly as part of collaborative agreements or through international organizations.

### 2.2.1. Operating organization

The responsibility for developing the PSR basis document (including agreement on this document with the regulatory body), conducting the PSR, reporting its findings and implementing the resultant measures lies solely with the operating organization of the facility, although some aspects of the review may be contracted to external parties. The operating organization needs to have the competence to manage effectively any contracted work (e.g. from consultants or technical support organizations) and to assess the outputs produced.

The operating organization has to report all safety significant findings from the PSR to the regulatory body, subject to national regulations. The operating organization is expected to provide all required documentation and information sufficient to allow the reviewer (i.e. review team(s), regulator or technical support organization(s)) to complete the PSR.

The main roles involved in managing the PSR project are described in the following:

(a) Project manager: The project manager in the operating organization leads the conduct of the PSR and is responsible for delivering the PSR to the appropriate level of quality, and within the agreed timescale and budget. As such, the project manager has to be a senior person of appropriate authority with broad technical knowledge and, preferably, past experience with PSR. Organizational arrangements may differ depending on the size of the reactor and the organizational structure of the operating organization.

(b) PSR project management team: The members of the project management team provide oversight of the work in their area of responsibility and ensure that the review documentation, including that produced by the specialists, meets the PSR objective and that the review reports are delivered on time in accordance with the project plan. This team also acts as the central coordinating body to collate the review outputs from individual review teams into a single coherent PSR.
The team should ideally consist of the following:

- Representatives of the facility who are familiar with research reactor operation;
- Safety experts with broad knowledge of safety issues and how they interact;

— Specialists from within the operating organization, as necessary, for review of each safety factor (e.g. engineer(s) with experience of implementing facility modifications);
— External experts as necessary for specific review areas.

In the review of some of the safety factors, engagement of independent consultants provides an impartial and objective review. As an example, the review of aspects relating to the management system, organizational matters, safety culture and human factors benefits from the perspective of consultants external to the operating organization. This has to be considered when forming the review team, and the safety factors to be reviewed by consultants have to be identified.

### 2.2.2. Regulatory body

Depending on national regulations [8], the following are often the responsibility of the regulatory body:

(a) Establishing the requirements for the PSR;
(b) Reviewing the PSR basis document and agreeing on it with the operating organization;
(c) Reviewing the scope of the project plan, the conduct and findings of the PSR, the resultant corrective actions or safety improvements and their associated implementation plans;
(d) Verifying the prospects for safe operation of the facility for the period until the next PSR;
(e) Taking appropriate licensing actions based on the findings of the PSR;
(f) Reviewing and approving corrective actions or safety improvements proposed by the operating organization;
(g) Informing relevant stakeholders such as the government and the general public about the results of the PSR.

The main prerequisite to performing a PSR is the agreement, in the form of a basis document, between the operating organization and the regulatory body on the scope, level of detail and objectives of the PSR, including current national and international standards and codes to be used.

### 2.2.3. Communication

A formal communication protocol has to be established to govern communications within and between the following groups:

(a) Within the organization's PSR project team, to maintain consistency in the review and to avoid duplication of work;
(b) Between the organization's PSR project team and the consultants or contractors who are part of the PSR team;
(c) Between the PSR project management team of the operating organization and the regulatory body during the conduct of the PSR;
(d) Within the regulatory body, among the review and assessment team members.

## 2.3. PHASES OF A PERIODIC SAFETY REVIEW PROJECT

A PSR consists of the following four phases, which may overlap or be further subdivided as appropriate:

(1) Preparation of the PSR project: This includes establishing a project team and an agreement between the operating organization and the regulatory body in the form of a PSR basis document with regard to the scope, level of detail and timing of the review, and the codes and standards that will be used. There are significant benefits to this agreement such as reduced need for additional iterations of the PSR, and the resource demands required by these iterations, for both the operating organization and the regulatory body.
(2) Conduct of the PSR: In this phase, the operating organization has to conduct the review in accordance with the agreed basis document for the PSR. The review includes identifying positive findings (strengths) or negative findings (deviations) and a global assessment of the facility. Negative findings may lead to proposals for corrective actions or safety improvements.
(3) Regulatory review: The regulatory body reviews and assesses the PSR report prepared by the operating organization and the proposed corrective actions or safety improvements. The regulatory body identifies any safety issues it wishes to raise (e.g. categorization and prioritization of corrective actions), reviews the proposed integrated implementation plan and verifies that the licensing basis for the research reactor remains valid.
(4) Finalization of the integrated implementation plan: The integrated implementation plan has to contain corrective actions and reasonable and

practicable safety improvements, as needed, together with a schedule approved by the regulatory body.

The phase following the PSR in which the safety improvements or corrective actions are implemented is not considered an activity of PSR and so is not addressed in detail in this publication.

## 2.4. PERIODIC SAFETY REVIEW METHODOLOGY

This section outlines guidance on the PSR methodology and the review process when performing a PSR for a research reactor. In particular, it outlines a suggested overall approach to the PSR that implements a graded approach to the application of safety requirements and reflects a wide range of research reactor designs and operating regimes.

The PSR basis document is an essential instrument that governs the conduct of the PSR and the regulatory review of the PSR results. It outlines the process to be followed in carrying out the PSR so as to ensure a complete, comprehensive, consistent and systematic approach. The PSR basis document has to include the following:

(a) A project plan that identifies all the activities to be performed during the review and an associated schedule;
(b) Project and quality assurance processes;
(c) Applicable national and international standards, codes and practices;
(d) The scope (safety factors and level of detail);
(e) Major milestones, including the cut-off date (beyond which changes to codes and standards and new information will not be considered);
(f) The methodology of the PSR;
(g) The structure of the documentation;
(h) Criteria for categorizing, prioritizing and resolving findings;
(i) A list of supporting documents.

Experience has shown that it is easier to perform a PSR in facilities that have a good management system [6]. In particular, the quality of the safety documentation and its updating to reflect the current status of the facility play a significant role in the conduct of a PSR. It is important that the safety documentation (e.g. the safety analysis report) account for up to date modifications, modernizations and refurbishments carried out in the facility, as well as changes to operational programmes such as maintenance, periodic testing and inspection, and other practices.

Paragraph 4.18 of Ref. [4] states:

> "The safety factors should be reviewed for all relevant operating and accident conditions, using current national and applicable international safety standards and operating practices as identified in the PSR basis document. The review method applied should be systematic and independent of the ongoing regulatory oversight of the plant."

This approach is valid for PSR for research reactors, and accident conditions include design extension conditions.

As part of the review of each safety factor, all the documents listed in the PSR basis document need to be checked for completeness. If the documentation is incomplete or does not contain necessary information, it is advisable to establish a set of databases for the review of all the safety factors early in the review process.

In order to minimize duplication, the results of various safety reviews and other relevant activities (e.g. relating to licensing, compliance or operations) have to be used, as appropriate, as inputs to the PSR. The origins of all information used have to be referenced appropriately together with an explanation of how each reference has been used.

Reviews of safety factors result in findings, which can be positive or negative. Positive findings (strengths) are where the practices followed at the facility are equivalent to good practices and exceed expectations as established in the codes and standards. Negative findings (deviations) are where practices followed fall short of the requirements established in the current codes and standards, or do not comply with the licensing basis, or are inconsistent with facility safety and operating documents.

Negative findings from the reviews of safety factors have to be evaluated in terms of resulting corrective actions and safety improvements. Corrective actions are those that need to be undertaken in order to maintain facility safety. Safety improvements are those that would further improve safety. Findings that identify an immediate and significant risk to the environment, or the health or safety of workers or the public, have to be addressed urgently by the operating organization and need not await completion of the PSR process. In such cases, corrective actions have to be determined by the operating organization and, where necessary, the regulatory body's agreement or approval has to be sought. For other corrective actions and safety improvement plans, the timing of the proposed safety improvements has to be determined. The proposed plan has to recognize the need to implement reasonable and practicable safety improvements in accordance with the global assessment of safety at the facility.

The level of facility safety is determined by a global assessment. The global assessment takes into account, among other things, the combined effects of all safety factors. The global assessment also considers whether a negative finding (deviation) in one safety factor is compensated for by a positive finding (strength) in another safety factor. The global assessment takes into account all the positive and negative findings from the PSR, as well as the corrective actions or safety improvements proposed, and assesses the overall level of safety that will be achieved at the research reactor following the PSR. Where there are negative findings and improvements cannot reasonably and practicably be made, the global assessment has to provide a justification or compensatory measures have to be taken. The risks associated with any unresolved negative findings have to be assessed and an appropriate justification for continued operation needs to be provided.

Safety improvements have to be implemented in accordance with the integrated implementation plan submitted to the regulatory body for agreement or approval. The results of the review have to be documented by the operating organization and submitted to the regulatory body. The documentation has to include the following:

(a) The report covering the review of each safety factor;
(b) The global assessment report;
(c) An integrated implementation plan that includes the proposed safety improvements and corrective actions.

## 2.5. PERIODIC SAFETY REVIEW PROCESS

The overall process for undertaking the PSR for a research reactor is shown in Fig. 1. A graded approach has to be used in determining the scope, level of detail and depth of the review based on the type, size, design and hazard potential of the research reactor.

The scope of the PSR, including the period of time covered by the review, is defined in the PSR basis document. Facilities where the PSR is conducted for the first time have to cover the entire period since commissioning; subsequent PSRs could be conducted at the frequency required by national regulations.

### 2.5.1. Preparation of the PSR project

The process for the preparation of the PSR project within the operating organization is shown in Fig. 2. The first task is to establish an appropriate project management team and a reasonable project schedule at the start of the project.

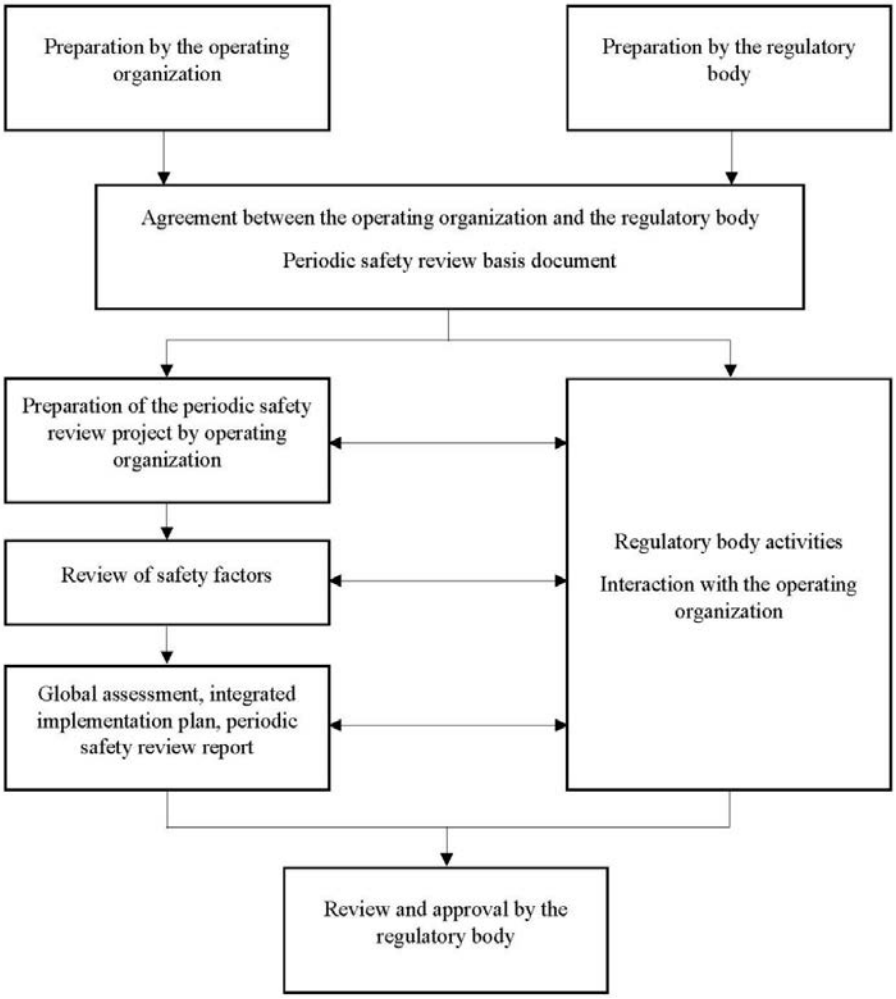


*FIG. 1. The overall process for a PSR of a research reactor.*

This is necessary in order to complete the PSR within the agreed time schedule. The schedule needs to take into account the iterative nature of the review of safety factors and interfaces between the various safety factors.

An overall budget for the PSR has to be determined. The budget takes into account the scope of the review and other relevant factors such as organizational aspects, the schedule and the need to employ external organizations. Resource intensive activities, in particular, have to be identified and their scope and depth have to be taken into account in the overall budget. The budget and schedule

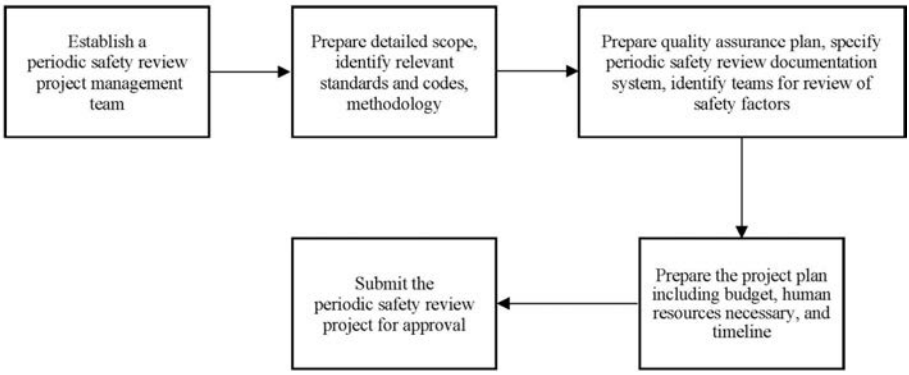


*FIG. 2. The process for the preparation of a PSR project.*

have to be approved by the senior management of the operating organization before commencement of the review.

A PSR is typically performed by a number of review teams that work in parallel. It is important that all reviewers follow a consistent approach. A document that provides guidance to the individual review teams on how to review the different safety factors has to be prepared. The guidance document has to elaborate on the scope of the PSR in a way that is consistent with the PSR basis document, so as to ensure a comprehensive, consistent and systematic approach.

Paragraph 8.9 of Ref. [4] states:

> "To ensure the appropriate quality and format of the PSR documents, a quality assurance plan should be prepared that, among other things, defines the requirements for the preparation and verification of the PSR documentation. The quality assurance plan should also ensure that all reviewers use the same input data to maintain consistency across all areas of the review."

A PSR is not routine work for many of the staff of operating organizations or for external technical support organizations. In order to ensure that the PSR is completed in an effective and efficient way, training for the review team has to be carried out. As many safety factors are interrelated, close coordination among various review teams has to be maintained to avoid duplication or missing areas.

### 2.5.2. Review of safety factors

Figure 3 shows the process for reviewing the safety factors. To ensure efficiency and consistency, it is necessary that the reviewers use consistent data,

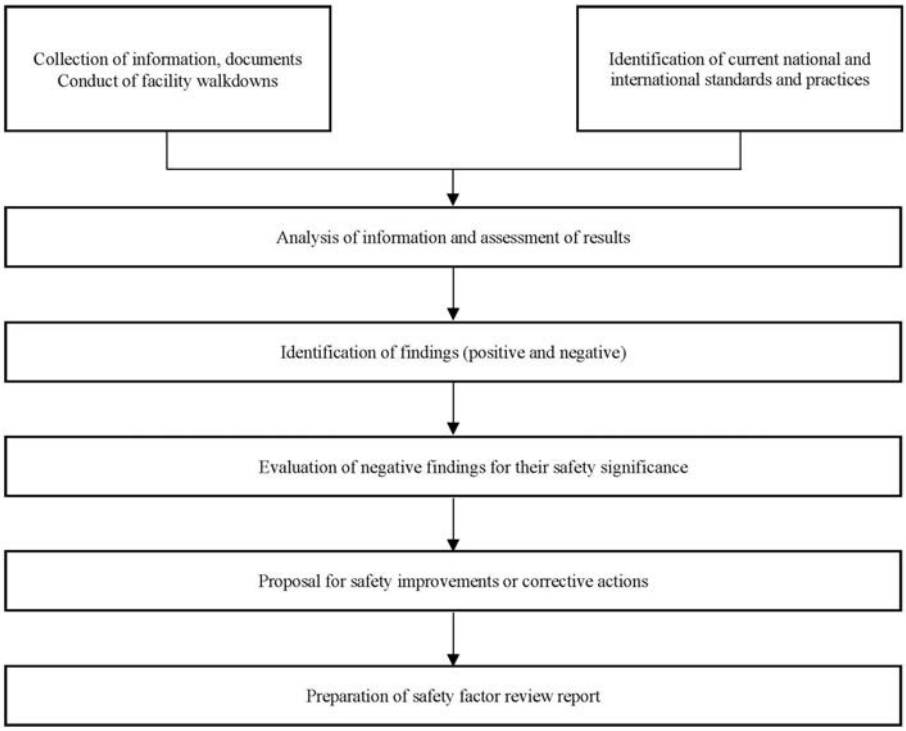


*FIG. 3. The process for the safety factor review in the operating organization.*

and this has to be done by assembling all the required information into a single database. Most of the information may already exist, such as data from the ageing management programme. It is important that all such sources of data be identified and that reviewers use the same information. The database to be used for the PSR may include information from various sources such as updated safety analysis reports; facility operational data; relevant design basis information; data from the ageing management programme; results from the maintenance, periodic testing and inspection programmes; and radiological data. These databases may also contain predictions of the future operation and residual service lives of structures, systems and components (SSCs) important to safety [5]. Where it is not possible to include all the input information needed for PSR in such databases, the sources of such input information have to be identified and documented.

Paragraph 8.13 of Ref. [4] states:

> "A review of each safety factor should be carried out…for all relevant operational states and accident conditions, and an assessment for each

safety factor should be made against current safety standards and operating practices (for example, using information from operating experience or plant walkdowns)."

The safety significance of all positive and negative findings has to be identified and evaluated using a deterministic approach. Probabilistic methods could be used as a complementary tool for the deterministic approach if a probabilistic safety assessment (PSA) is available or required by national regulations [1]. Corrective actions and safety improvements need to be identified in the case of negative findings. If a safety improvement that is reasonable and practicable cannot be identified for any negative finding, a justification needs to be provided or compensatory measures need to be taken. A report has to be prepared for each safety factor. Findings that fall under para. 8.15 of Ref. [4], quoted below, have to be promptly reported to the regulatory body.

Paragraph 8.15 of Ref. [4] states:

"If the operating organization identifies a finding that poses an immediate and significant risk to the health and/or safety of workers or the public or to the environment, implementation of safety improvements should not await completion of the PSR; rather, prompt corrective actions should be taken."

### 2.5.3. Global assessment

The global assessment in the PSR provides an overall view of the safety of the facility. It is a consolidation exercise of the review of all safety factors. A small group of experts who have knowledge of the facility and its safety documents performs the global assessment based on the review of each safety factor.

The global assessment provides an overall view of the risk associated with continued operation of the facility, taking into account commitments for corrective actions and safety improvements, and dispositions for issues for which there is no corrective action. (See also Section 3.6.) An expected outcome of the global assessment is a categorization, ranking and prioritization of corrective actions or safety improvements to address negative findings based on the criteria and methods established in the PSR basis document.

The conclusion of the global assessment has to be carefully documented to provide an auditable trail for future reference, and the results need to be recorded in the global assessment report. Sometimes it may be necessary to revise the safety factor reports to take into account changes arising from the global assessment. The final PSR report includes the global assessment summary. The process for the operating organization following the global assessment is shown in Fig. 4.

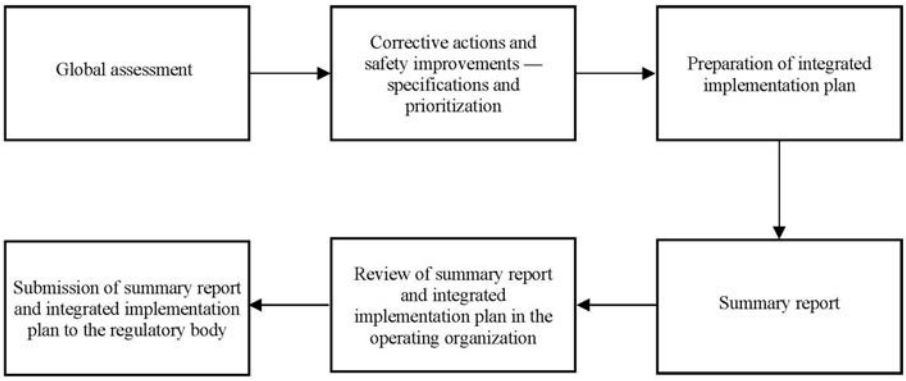


*FIG. 4. The review of PSR in the operating organization.*

## 2.6. USE OF A GRADED APPROACH

Considering that research reactors have a variety of designs, types and power levels, a graded approach needs to be used for all activities relating to PSR, depending on the potential hazard level of the facility and activities [9]. In relation to PSR, a graded approach could be used for the following[1]:

(a) The number of safety factors to be reviewed. In some facilities, the number of safety factors could be reduced by combining safety factors (e.g. actual condition of SSCs, equipment qualification and ageing could be reviewed together in a single safety factor).
(b) The level and detail of the tasks to be undertaken for the review of each safety factor.
(c) The composition of the review teams (in smaller facilities, one team could review several safety factors).
(d) The details of documentation.
(e) The number of meetings or interactions between the operating organization and regulators.
(f) The review of the management system. In some facilities, the same group of personnel might perform multiple functions (e.g. operators might also perform maintenance activities).
(g) The regulatory review of the PSR reports (e.g. if significant safety margins are available in the safety analysis, independent analysis by the regulatory body may not be necessary).

[1] Any simplification of the PSR following the use of a graded approach has to be justified and documented, and approved by the regulator.

(h) The categorization and prioritization of safety improvements or corrective actions (if the identified improvements are small in number, practical and reasonable to implement, no categorization may be needed).
(i) The prioritization of implementing PSR for countries with multiple research reactors (reactors with a higher potential hazard could be selected first).

# 3. REVIEW PROCESS OF THE OPERATING ORGANIZATION

Sections 3.1–3.6 provide information on individual safety factors and how to perform the review of these safety factors. The safety factors that apply to a research reactor are as follows:

*Safety factors relating to the facility*

(1) Facility design;
(2) Actual condition of SSCs important to safety;
(3) Equipment qualification;
(4) Ageing;
(5) Utilization.

*Safety factors relating to safety analysis*

(6) Deterministic safety analysis including hazard analysis;
Probabilistic safety assessment (not a requirement for research reactors).

*Safety factors relating to operating experience*

(7) Operating experience;
(8) Use of experience from other facilities and research findings.

*Safety factors relating to organizational effectiveness*

(9) Organization, the management system and safety culture;
(10) Procedure management;
(11) Human factors;
(12) Emergency planning.

*Safety factors relating to radiological safety*

(13) Operational radiation protection;
(14) Radiological impact on the environment.

The overall intent of this approach is to rationalize the structure of the safety factors so as to simplify performance of a PSR for a research reactor in accordance with the use of a graded approach [9].

## 3.1. SAFETY FACTORS RELATING TO THE FACILITY

### 3.1.1. Safety factor 1: Facility design

Requirement 9 of Ref. [1] states:

> "**The design of a research reactor facility shall ensure that the reactor facility and items important to safety have the appropriate characteristics to ensure that the safety functions can be performed with the necessary reliability, that the research reactor can be operated safely within the operational limits and conditions for its entire lifetime and can be safely decommissioned, and that impacts on the environment are minimized.**"

Facility SSCs important to safety need to be designed and configured in such a way that there is a high degree of confidence that they will meet the requirements for safe operation of the facility and for performance in compliance with design characteristics, including the prevention and mitigation of events that could jeopardize safety (i.e. fulfilment of their safety functions). Adequate design information, including information on the design basis, needs to be made available to provide for the safe operation and maintenance of the facility and to facilitate modifications of the facility.

*Objective*

The objective of the review of this safety factor is to assess the adequacy of the design and design documentation of the facility against the current licensing basis and international standards and practices.

*Scope and tasks*

Review is needed to verify that the design and other characteristics are appropriate to meet the requirements for facility safety and performance for all facility conditions and the applicable period of operation. The main tasks for review are detailed below:

— Review of the list of SSCs important to safety for completeness and adequacy;
— Review of codes and standards used for the design of the facility against current versions of codes and standards, to identify significant changes that may have an impact on the safety of the facility;
— Identification of differences between the design of SSCs important to safety and the requirements of current standards, and assessment of the safety significance of those differences;
— Review of the cumulative effects of all modifications on the design;
— Review of relevant documentation (e.g. safety analysis report, design basis documentation) to determine if it is adequate and has been updated to reflect the modifications made to the facility;
— Review of the process for design changes;
— Review of SSCs important to safety for their design characteristics, layout and segregation to ensure that they meet the current requirements for facility safety and performance, including the prevention and mitigation of events that could be detrimental to safety;
— Review of the changes to the site characteristics where they have the potential to have an impact on the reactor (e.g. new nuclear or non-nuclear facilities, changes to existing adjacent facilities, changes to site infrastructure).

*Methodology*

The first step of the review is to determine if sufficient information is available to define the design basis. For older reactors, the first PSR may lead to reconstitution of the design basis. The list of SSCs important to safety needs to be checked for completeness. If such a list is not available, it needs to be developed as part of the PSR.

The design of each SSC important to safety has to be reviewed against the current standards, including design codes identified in the PSR basis document. Any deviations have to be identified and their safety significance has to be determined. Changes in the requirements and standards from the versions used for the original design need to be evaluated to assess the impact of changes on facility safety. The review needs to be performed systematically by means of a

clause-by-clause review of national and international requirements and standards listed in the PSR basis document and other requirements and standards identified as relevant during the course of the review.

Paragraph 5.23 of Ref. [4] states:

> "The review should consider the adequacy of defence in depth in the plant design. This should include an examination of:
>
> — The degree of independence of the levels of defence in depth;
> — The adequacy of delivery of preventive and mitigatory safety functions;
> — Redundancy, separation and diversity of SSCs important to safety;
> — Defence in depth in the design of structures (for example, review of the integrity of fuel, cooling circuit and containment building)."

The review has to consider, inter alia, the independence of the control and protection functions, the application of the single failure criterion and the potential for common cause failures. The review has to demonstrate that relevant documentation has been updated to reflect modifications made to the facility or operation. The modifications carried out in the facility have to be studied for their cumulative effect on the design. In some cases, where the design information is inadequate or there is uncertainty about whether an SSC important to safety would be able to perform its safety function, a design re-evaluation has to be undertaken.

Reference [1] establishes the requirements for the design of research reactors, and Ref. [10] establishes the requirements for site evaluation of nuclear installations. Reference [11] provides further guidance on the safety assessment for research reactors.

### 3.1.2. Safety factor 2: Actual condition of SSCs important to safety

The actual condition of SSCs important to safety is a significant factor in the review of the safety of the facility. The condition of each SSC important to safety has to be thoroughly documented. The review of this safety factor is closely associated with the review of ageing management. Knowledge of any existing or anticipated obsolescence of facility systems and equipment has to be considered as a part of the review of this safety factor.

*Objective*

The objective of the review of this safety factor is to assess the actual condition of SSCs important to safety in order to determine whether they meet their design requirements, to confirm that the condition of SSCs is adequately documented and to review the ongoing maintenance, periodic testing and inspection programmes [12], as applicable.

*Scope and tasks*

The review of this safety factor includes a review of the actual condition of the SSCs important to the safety of the facility. Aspects that need to be examined for each include the following:

(a) The results of inspections, including walkdowns of the SSC;
(b) The maintenance and validity of records which represent the actual condition of the SSC;
(c) The operating history of the SSC and its evaluation;
(d) The actual state of the SSC against its design basis to verify that ageing has not significantly affected its conformity with the design basis assumptions;
(e) The current state of the SSC, particularly with regard to its obsolescence;
(f) Possible degradation of the SSC by corrosion;
(g) Ongoing facility programmes that provide confidence in the condition of the SSC;
(h) Operational limits and conditions;
(i) Significant findings from the functional capability tests of the SSC.

*Methodology*

The actual condition of SSCs important to the safety of the facility has to be reviewed using knowledge of any existing or anticipated ageing processes or of obsolescence (e.g. unavailability of spares in the near future) of facility systems and equipment, modification history and operating history. (Input is needed from the review of safety factor 4.)

The implications of changes to design standards since the facility was designed, or since the last PSR was performed, have to be examined during the review of the facility condition. Inputs to the review of this safety factor may be made available from any ageing management programme the operating organization may have.

In addition to other inspections, walkdowns are an effective way to assess the condition of SSCs (photographic records are beneficial). Observations on housekeeping have to be included in the walkdowns.

Where sufficient data are not available, they have to be generated or derived; such data can be obtained by performing special tests, facility walkdowns and inspections, as necessary. The existing records need to be checked for their validity to ensure that they represent the actual condition of SSCs important to safety. Any significant findings from ongoing maintenance, periodic testing and inspection programmes have to be taken into account.

Paragraph 5.35 of Ref. [4] states:

> "After determining the actual condition of the SSCs important to safety, each SSC should be assessed against the current design basis (or updated design basis: see safety factor 1) to confirm that design basis assumptions have not been significantly challenged and will remain so until the next PSR."

This ensures that SSCs are fit for purpose and that, if a shortfall is noted, a corrective action is considered. Instances where it is not possible to determine the actual condition of SSCs — owing to, for example, facility layout or inaccessibility — have to be clearly documented and the safety significance of such uncertainty needs to be determined. Experience from other facilities or knowledge of relevant ageing processes could be used to reduce some uncertainties.

### 3.1.3. Safety factor 3: Equipment qualification

Facility equipment important to safety has to be qualified to ensure its capability to perform its designated safety function throughout its service life and under postulated service conditions (including fault conditions and environmental conditions) as well as during and after accident conditions [1, 11, 12]. A graded approach has to be used for the review of the qualification of SSCs based on the safety classification of the SSCs [9].

*Objectives*

The objectives of the review of this safety factor are to determine whether equipment important to safety is qualified to perform its designated safety function and to determine whether this qualification is being maintained through an adequate programme of maintenance, inspection and testing that provides confidence in the delivery of safety functions until at least the next

PSR (e.g. equipment that is required to perform in response to a seismic event remains qualified).

*Scope and tasks*

The PSR has to verify that a formal process for equipment qualification exists that includes documentation and evidence that equipment would perform its safety function while subject to the environmental conditions that could exist during both normal conditions and predicted accident conditions. These may include seismic conditions, vibration, temperature, pressure, jet impingement, electromagnetic interference, irradiation, corrosive atmosphere and humidity, fire and combinations thereof, as well as other anticipated events.

The review has to examine the following:

(a) Whether the design identifies a list of SSCs requiring qualification together with the conditions under which they are required to perform a safety function;
(b) Whether installed SSCs meet the qualification requirements;
(c) Whether the records of equipment qualification are adequate;
(d) Whether procedures to update and maintain qualification are adequate for the service life of the equipment;
(e) Whether procedures to ensure that modifications or additions to SSCs important to safety are adequate and do not compromise their qualification;
(f) Whether surveillance programmes exist for ensuring that ageing degradation does not affect qualified equipment significantly;
(g) Whether monitoring of actual environmental conditions includes identification of 'hot spots' of high dose rate or temperature;
(h) Whether qualified equipment remains protected from adverse environmental conditions and non-qualified equipment does not impact it adversely.

*Methodology*

The PSR has to verify that the use of the standards and requirements for equipment qualification at the facility remains valid.

Paragraph 5.42 of Ref. [4] states:

"The review should also include assessment of the following:

— Changes in the equipment classification resulting from design modifications;
— Qualification for all designed environmental conditions;

— The availability of equipment that is required to fulfil safety functions;
— Quality management provisions that ensure that an effective qualification programme is in place."

Paragraph 5.43 of Ref. [4] states:

"The review of equipment qualification should determine:

— Whether adequate assurance of the required equipment performance was initially provided;
— Whether current equipment qualification specifications and procedures are still valid (for example, initial assumptions regarding the service life of equipment and the environmental conditions);
— Whether equipment performance has been preserved by ongoing application of measures such as scheduled maintenance, condition monitoring, testing and calibration and whether such programmes have been properly documented."

The review of this safety factor has to take into consideration the originally assumed service conditions for the equipment to verify that service conditions such as temperature, humidity and seismic conditions remain valid and will remain valid until the next PSR, and that the equipment will perform under the required conditions.

The review has to evaluate the results of facility tests, inspections and walkdowns, and other investigations carried out to assess the current condition of installed qualified equipment (see safety factor 2). It needs to identify any differences from the qualified configuration (e.g. equipment support, damaged electrical insulation). The walkdowns and inspections provide an input to the review of the adequacy of the facility's procedures for maintaining equipment qualification.

In many research reactor facilities, the equipment qualification is covered under the maintenance, periodic testing and inspection programme. Further guidance is provided in Ref. [12].

### 3.1.4. Safety factor 4: Ageing

Ageing is a very important issue for research reactor safety. Ageing has to be managed in a timely and effective manner through an established programme [5] covering, inter alia, maintenance, periodic testing and in-service inspections [12] as well as limitation on service life. Ageing management also covers obsolescence management and the ageing of operating staff.

An ageing management programme usually demonstrates how to detect and predict ageing degradation that may affect the safety functions and lifetime of SSCs and identifies appropriate measures for their maintenance. Ageing management programmes usually include the following:

— Screening of SSCs for ageing management review;
— Identification and understanding of degradation mechanisms;
— Minimization of ageing effects;
— Detection, monitoring and trending of ageing effects;
— Mitigation of ageing effects;
— Acceptance criteria;
— Corrective actions;
— Continuous improvement of the ageing management programme;
— Record keeping.

*Objective*

The objective of the review of this safety factor is to determine whether a systematic and effective ageing management programme is in place and whether ageing in a research reactor is being effectively managed in order that required safety functions can be performed on demand.

*Scope and tasks*

The review of this safety factor includes the ageing management programme implemented at the research reactor, including its experimental facilities. The evaluation includes review the following aspects of the ageing management programme:

(a) The programme and procedures for understanding the ageing mechanism of SSCs and timely detection of ageing effects;
(b) The measures for minimization or mitigation of ageing degradation of SSCs;
(c) The comprehensiveness of the programme (i.e. whether the programme addresses all SSCs important to safety);
(d) The effectiveness of policies and procedures for replacement of replaceable components affected by ageing degradation;
(e) Potential ageing degradation of SSCs important to safety that may affect their safety functions;
(f) Management of the effects of ageing on those parts of the facility that will be required for safety when the research reactor has ceased operation, for example the spent fuel storage facilities;

(g) Record keeping and availability of data for evaluating ageing degradation, including baseline data for SSCs important to safety and their operating and maintenance histories.

The review has to include verification of the adequacy and validity of the following:

(i) Acceptance criteria for SSCs important to safety with respect to the required safety margins;
(ii) Methods for monitoring ageing and for minimizing and mitigating ageing effects;
(iii) The physical condition of SSCs important to safety and provisions aimed at preventing any features that could limit their service life;
(iv) Control of ageing of all materials (including consumables with a limited shelf life such as lubricants and polymers) and SSCs that could impair the performance of their safety functions;
(v) Obsolescence management of technologies used in the facility.

*Methodology*

A review is conducted of the existing ageing management programme that includes the results of maintenance, inspection and periodic testing activities; the validity of standards against which these activities are conducted; the operating history, with the aim of evaluating ageing degradation; and the planned or completed refurbishment or modernization of SSCs.

The review has to demonstrate the following (further guidance on review of this safety factor is provided in Ref. [5]):

(a) A systematic and effective ageing management programme exists for the facility.
(b) The ageing management programme covers SSCs important to safety as well as any non-safety related SSCs whose failure might affect SSCs important to safety or adversely affect a safety function.
(c) All ageing degradation mechanisms are identified, and adequate measures are taken to monitor, trend and control ageing degradation.
(d) The comprehensive ageing management programme ensures continued safe operation until the next PSR.

### 3.1.5. Safety factor 5: Utilization

The safety of experiments and experimental devices is important to overall research reactor safety and performance. Design and safety provisions for research reactor utilization have to include the categorization of experiments according to their safety significance, robust procedures for the safety analysis of experiments, commensurate approval of experiments by management and operating personnel according to safety significance, and installation and formal commissioning programmes for experiments with major safety significance [13, 14].

*Objective*

The objective of the review of this safety factor is to determine whether the existing arrangements are adequate to ensure the safety of experiments and research reactor utilization, and the effects of experiments on reactor safety, as well as whether changes in the utilization are adequately addressed.

*Scope and tasks*

The review of this safety factor includes all experimental and utilization facilities at the research reactor. The evaluation includes review of the following:

(a) Ongoing utilization and any foreseeable changes;
(b) The adequacy of existing procedures for utilization;
(c) The adequacy of arrangements for use and control of utilization activities;
(d) The review and approval process for use and control of utilization activities;
(e) Changes in the facility documentation with respect to utilization;
(f) The influence of experiments and utilization on reactor safety;
(g) The assessment of special operational limits and conditions that may be required for an experiment;
(h) Ageing management of experimental devices;
(i) The qualification of personnel associated with experiments and utilization.

*Methodology*

The review of this safety factor has to determine the following:

(a) Whether adequate assurance of the safety and performance of experimental devices was initially provided;

(b) Whether current experimental device qualifications, specifications and procedures are still valid (e.g. regarding service life) with reference to current standards;
(c) Whether the safety of experimental devices has been preserved by ongoing application of programmes such as scheduled maintenance, condition monitoring, testing and calibration, and whether such programmes have been properly documented;
(d) Whether the effects on reactor safety of any changes in the operation of experimental devices (e.g. the use of a new design of device) have been assessed and documented.

The review has to evaluate the adequacy of the arrangements with regard to the following (further guidance on review of this safety factor is provided in Refs [13–15]):

(i) The review and approval of new utilization;
(ii) Changes in the existing utilization;
(iii) The use of operating experience for utilization (root cause analysis of prior incidents and lessons related to utilization) to establish experimental procedures for design, construction and commissioning;
(iv) The training and qualification of experimenters;
(v) The quality of procedures;
(vi) Records of radiation doses and radioactive releases due to operation of experiments;
(vii) Categorization criteria and the associated routes of approval according to the safety significance of the experimental utilization;
(viii) Storage conditions and disposal of experimental devices.

## 3.2. SAFETY FACTORS RELATING TO SAFETY ANALYSIS

### 3.2.1. Safety factor 6: Deterministic safety analysis including hazard analysis

Deterministic safety analysis has to be available for each research reactor in order to confirm the design basis for SSCs important to safety and to evaluate the facility's behaviour in response to a postulated initiating event [11]. A deterministic safety analysis has to be completed for the facility for the PSR, if one is not already available, using deterministic methods (e.g. validated tools and methods).

*Objective*

The objective of the review of this safety factor is to assess the extent to which the facility's deterministic safety analysis is complete and remains valid, taking into account the following aspects:

(a) The adequacy of the identified postulated initiating events, including internal and external hazards, with account taken of the facility design and site characteristics for the period covered by the PSR, and current analytical methods (modern, validated computer codes), safety standards and knowledge;
(b) The actual facility design together with all modifications of SSCs, including experimental facilities, since the last update of the safety analysis report or the last PSR;
(c) The current operating modes, facility utilization and fuel management [16];
(d) The applicable safety standards and knowledge (including any new findings from research and development);
(e) The adequacy of safety margins and any uncertainties.

*Scope and tasks*

A deterministic safety analysis evaluates the following:

(a) The functional adequacy and reliability of SSCs;
(b) The impact on safety of internal and external events;
(c) Equipment failures and human errors;
(d) The adequacy and effectiveness of engineered safety features;
(e) Administrative measures to prevent and mitigate accidents.

A review of the deterministic safety analysis has to include the following tasks:

(i) A review of the list of postulated initiating events forming the design basis that may affect the safety of the facility for completeness, validity and relevance. If new postulated initiating events are identified, they have to be included.
(ii) A review of the application of analytical methods, computer codes and guidelines used in the deterministic safety analysis.
(iii) A comparison of the assumptions, conduct and results of the facility's deterministic safety analysis with current standards and requirements.

(iv) An examination of whether the assumptions made in the existing deterministic safety analysis remain valid, taking into account the actual condition of the facility.
(v) An examination of whether the assumptions made in the deterministic safety analysis are in accordance with current regulations, and national and international standards and practices.
(vi) An evaluation of whether the actual operational conditions of the facility meet the acceptance criteria for the design basis.
(vii) A review of the application of the concept of defence in depth, including the independence of each level.
(viii) A review of operational limits and conditions for their continued validity as derived from the safety analysis [17].

*Methodology*

The facility's deterministic safety analysis has to be reviewed to check that the postulated initiating events identified in the safety analysis are valid. The review needs to verify that the design basis for SSCs important to safety is correct when reviewed against the current regulations and national and international standards. The review also has to verify that facility behaviour for postulated initiating events meets with current standards. It has to be demonstrated that the facility in its current state is capable of meeting the regulatory requirements and expectations for normal operation and accident conditions.

The analytical methods, national and international safety standards and information used for the safety analysis have to be up to date and valid. If this is not the case, the analysis has to be repeated or revised as necessary. The analytical methods have to account for the facility design, site characteristics, condition of SSCs important to safety (both at present and predicted for the end of the period covered by the PSR) and relevant international practice. Changes in facility design or changes in site characteristics such as additional nuclear and non-nuclear facilities, the prevailing climate, the potential for floods and earthquakes, transport and industrial activities, and combinations of such changes need to be considered.

When considering the risk of particular hazards, knowledge gained from actual events, in particular those that have occurred at research reactors, has to be utilized. Any experience from managing such events (e.g. external floods, seismic events, tornadoes), including design extension conditions and combinations of such external events, has to be used to improve the existing safety at the facility.

If it becomes necessary to repeat the analysis, current valid computer codes with observed data and records have to be used. If the earlier analysis method is still used, its validity has to be verified to include the assumptions used, the

uncertainties in the analysis and the degree of conservatism. The operational limits and conditions need to be reviewed taking into consideration the updated safety analysis, the actual condition of SSCs and relevant operating experience.

A list of postulated initiating events relevant for the review of deterministic safety analysis is provided in Ref. [1] and further information is provided in Refs [11, 18, 19]. Depending on the reactor design, modifications and changes in site characteristics, new postulated initiating events could be added.

*Probabilistic safety assessment*

The facility safety assessment needs to be based on the deterministic approach. However, if the national regulations require the facility to conduct a probabilistic safety assessment, then it can be included in the PSR as an additional safety factor. The objective, scope, related tasks, review methodologies and evaluation criteria have to be defined consistently with all other safety factors. Additional guidance is provided in Ref. [4].

## 3.3. SAFETY FACTORS RELATING TO OPERATING EXPERIENCE

### 3.3.1. Safety factor 7: Operating experience

Safety performance related to operating experience is determined from the assessment of operation, maintenance, surveillance, ageing and radiation protection, including, for example, safety related events, records of the unavailability of safety systems, radiation doses, radiological releases to the environment and waste management.

*Objectives*

The following are the objectives of the review of the safety factor for operating experience:

(a) To determine whether there is any need for corrective actions or safety improvements based on the facility's safety performance and records of operating experience, including root cause analysis of facility events;
(b) To determine the adequacy of the programme for the collection and analysis of operating experience.

*Scope and tasks*

The review of operating experience covers whether the facility has an adequate programme and set of procedures for the recording of safety related operating experience and its evaluation, including its recording of the following:

(a) Safety related events, low level events, precursors and near misses;
(b) Safety related operational information;
(c) Maintenance, inspection and periodic testing information;
(d) Replacement of SSCs important to safety owing to failure, ageing or obsolescence;
(e) Modifications to SSCs important to safety (temporary or permanent);
(f) Unavailability of safety systems;
(g) Compliance with regulatory requirements and operational limits and conditions.

The review of operating experience is closely related to the use of experience from other facilities and research findings (safety factor 8). However, the evaluation under this safety factor has to be primarily focused on operating experience at the facility being reviewed.

The review needs to examine any records of operating experience from the review period that are relevant to safety, taking into consideration the effectiveness of the processes and methodology used to evaluate and assess operating experience and trends. The review needs to also take into account the findings of the reviews of other safety factors when performing this task.

*Methodology*

The review of operating experience has to evaluate the adequacy of the following:

(a) Identification of safety related events and their classification;
(b) Root cause analysis of events and feedback from lessons learned, including implementation of corrective actions following events;
(c) Methods used for the selection of safety related operational data, including maintenance, inspection and periodic testing data;
(d) Trend analyses of safety relevant operational data;
(e) Trend analyses regarding replacements of components owing to failures, ageing or obsolescence;
(f) Use of safety related operational data in facility programmes (e.g. for revising procedures or for training purposes);

(g) Programmes in place for ensuring continuous improvement, including self-assessment and independent assessment.

The trend analysis since the previous PSR has to be reviewed, in particular to identify potential safety concerns (e.g. precursors to safety significant events) or deteriorating safety performance. Where relevant, the results of the previous PSR and operating experiences also have to be examined to identify trends in deteriorating safety performance.

The review has to consider changes or modifications in SSCs or operating procedures and their effects on safety performance (e.g. new core, equipment of new design or changes in the maintenance schedule). Use of the safety performance indicators aids in the review of this safety factor. Further guidance for review of this safety factor is provided in Ref. [20].

### 3.3.2. Safety factor 8: Use of experience from other facilities and research findings

Experience from other research reactors, from nuclear power plants or from non-nuclear facilities, as well as research findings or relevant information from international organizations such as the IAEA, can reveal previously unknown safety weaknesses or can help solve existing problems.

*Objective*

The objective of the review of the use of experience from other facilities and research findings is to determine the adequacy of the process established at the facility to collect such information. The review determines whether this information is used at the facility or in the operating organization to introduce applicable safety improvements.

*Scope and tasks*

The review has to identify information, including operating experience reports, that may be important to safety at other facilities within the operating organization, together with relevant experience and national and international research findings from other nuclear and non-nuclear facilities. The review has to verify that the facility's routine evaluation process determines when information from outside organizations is relevant and that this information is properly considered for appropriate action within its organization. The review of the use of experience from other facilities and research findings has to ensure that good

practices and lessons learned elsewhere, and improved knowledge derived from research, are properly utilized to improve safety.

*Methodology*

The review of the use of experience from other facilities and the nuclear industry in general has to include the following:

(a) Verification that the facility has arrangements in place for collecting relevant operating experience feedback from other research reactors, which may include regional and bilateral collaborations with nuclear and non-nuclear facilities, and from other relevant research findings;
(b) Review of the effectiveness of such arrangements, including how the facility is using such experience for the timely implementation of safety improvements;
(c) Review of the facility processes for assessing and, if relevant and necessary, for implementing findings from operating experience and research findings relevant to safety.

Many facilities may have well established arrangements for using operating experience from other facilities; however, similar arrangements may not be so well established for the dissemination of research findings. The PSR therefore has to pay special attention to whether the arrangements are adequate for timely feedback of research findings.

The Incident Reporting System for Research Reactors, which is operated by the IAEA, is an important tool for the international exchange of operating experience feedback for research reactors. The operating organization needs to have a process in place for receiving, analysing and acting upon such operating experience. The PSR has to provide a summary of the findings from this process and evaluate the effectiveness of the process. Where the review of effectiveness indicates significant shortcomings in the process, appropriate measures have to be taken, including a repeat review of relevant events and information. Further information for the review of this safety factor is provided in Refs [21, 22].

## 3.4. SAFETY FACTORS RELATING TO ORGANIZATIONAL EFFECTIVENESS

### 3.4.1. Safety factor 9: Organization, the management system and safety culture

The operating organization's management system ensures that policies and objectives are implemented in such a way that safety is given the highest priority and that processes are effective and efficient. The management system has to promote a strong safety culture in the organization to ensure that duties important to safety are carried out by qualified individuals correctly and with due diligence and a proper sense of accountability.

*Objective*

The objective of the review of this safety factor is to determine whether the organization's management system and safety culture are effective and adequate to ensure the safe operation of the research reactor.

*Scope and tasks*

Paragraph 5.113 of Ref. [4] states:

"The review of the organization and management system should include a review of the following elements or programmes against national and international standards:

- Policy statements of the operating organization;
- The documentation of the management system;
- The adequacy of arrangements for managing and retaining responsibility for activities or processes important to safety that have been outsourced (for example, maintenance and engineering services and safety analysis);
- The roles and responsibilities of individuals managing, performing and assessing work;
- The processes and supporting information that explain how work is to be specified, prepared, reviewed, performed, recorded, assessed and improved."

The review of the organization and management system, as applicable based on the staffing at the facility, has to verify the following:

(a) That processes for managing organizational change are adequate;
(b) That a human resource management process is in place to ensure the availability of adequate and qualified human resources, and to address succession planning;
(c) That the control of documents and records is adequate, and these are readily retrievable;
(d) That the change control processes and configuration management of both the facility and associated documentation are effective;
(e) That the control of procurement of equipment and services is adequate, especially for items that affect facility safety;
(f) That processes to check the quality of suppliers' management systems are adequate to ensure that items and services supplied to the research reactor are of sufficient quality and fit for purpose, and that processes are effective and efficient;
(g) That training and retraining programmes are adequate for staff at all levels;
(h) That responsibilities and levels of authority are clearly defined and understood.

The review of the culture for safety has to verify the following:

(i) That the safety policy clearly states that safety takes precedence over the facility's other commitments and that this policy is implemented effectively;
(ii) That procedures to ensure nuclear and radiation safety are properly controlled and well understood by the people who implement them, and that all staff take appropriate and consistent measures;
(iii) That a questioning attitude and conservative decision making exist in the organization;
(iv) That there is a strong drive to ensure that all events with lessons to be learned are reported, that these events are investigated to analyse root causes and that action is taken to provide timely feedback to appropriate staff on findings as well as remedial actions;
(v) That unsafe conditions and acts are identified and challenged as and when they are encountered by facility employees and also by external staff (contractors, users);
(vi) That the organization has and continuously promotes a learning culture, and that improvements and new ideas are constantly encouraged;
(vii) That interactions between human, technical and organizational factors are adequately addressed;

(viii) That an adequate programme for training in safety culture for staff at all levels is in place.

The requirements established in Ref. [6], guidance provided in Refs [23, 24] and information in Ref. [25] have to be considered when carrying out the tasks listed above.

*Methodology*

A review of the management system has to be conducted to ensure that the safety policies, goals and objectives of the organization are aligned and being met as required. This review has to include an evaluation of how tasks related to the review of culture for safety are being undertaken and completed.

The review has to examine whether weaknesses and obstacles can be identified, and whether such weaknesses and obstacles are evaluated and remedied in a timely manner via the management system. It also has to determine whether the management system can identify the need to make appropriate changes or improvements to the organization's objectives, goals, strategies, policies, plans and processes.

The review also has to examine whether regular management system reviews are conducted at sufficient intervals and whether they address the results of audits and other safety issues, non-conformances, lessons learned from other operating organizations and improvement opportunities. Where the review shows that the management system has not addressed any of these aspects, the PSR needs to undertake a detailed review of the omitted tasks.

A key indicator of the health of the training programme would be the number of training events organized and the number missed by staff. Culture for safety assessment includes interviews with personnel in the operating organization at all levels, as well as personnel providing support services. This aspect of the review is best conducted by external experts such as behavioural scientists. The outcome of audits and peer reviews, and actions taken in response to their findings should also be reviewed.

### 3.4.2. Safety factor 10: Procedure management

Procedures important to the safety of the research reactor have to be subject to management control and they have to be appropriately validated, formally reviewed and approved, and distributed. The procedures have to be unambiguous and not subject to individual interpretation or judgement, and have to be in accordance with the current state of the facility. Procedures have to consider human factor aspects (for example, they have to be user-friendly).

*Objective*

The objective of the review of procedure management is to assess whether the operating organization's processes for procedure management are adequate for the development and implementation of and adherence to operating procedures, and to assess whether the facility complies with regulatory requirements, operational limits and conditions, and ensures facility safety in an effective way.

*Scope and tasks*

The review has to verify that the facility has established an effective formal process for the development, approval and documentation of all safety related procedures, including modification of any procedure. The following types of procedures have to be reviewed:

(a) Operating procedures for normal and accident conditions;
(b) Emergency procedures including design extension conditions;
(c) Maintenance, periodic testing and inspection procedures;
(d) Work permit procedures;
(e) Procedures for controlling modifications;
(f) Procedures for configuration control;
(g) Radiation protection and waste management procedures.

*Methodology*

The review of procedure management has to include the following:

(a) Verification that a formal process is in place for the approval and documentation of all safety related procedures and that the process is effective;
(b) Verification that the formal system covers the development, modification, distribution and appropriate controls of any safety related procedure;
(c) Evaluation of self-assessments, audits, safety performance and events to assess whether there is adequate understanding of these procedures by operating personnel;
(d) Determination of the adequacy of the arrangements in place for regular review of the procedures;
(e) Evaluation of the processes in place to update procedures in response to changes in the assumptions made regarding safety analysis, facility design or operating experience;

(f) Verification that the procedures are categorized in accordance with their safety significance;
(g) Verification that the staff who will use the procedures are involved in their development;
(h) Verification that the procedures adequately address the human–machine interface;
(i) Verification that only the latest approved version of the procedure is used and that there is adequate control over the distribution process, in particular to ensure that obsolete versions of procedures are removed.

Reference [1] establishes the requirements for operating procedures and Ref. [17] provides relevant recommendations and guidance.

### 3.4.3. Safety factor 11: Human factors

Human factors influence all aspects of the safety of a research reactor. The review has to examine whether human factors are taken into account in the facility's safety management and whether this corresponds to accepted good practices. In particular, it is important that human factors do not present an unacceptable contribution to risk and that the operator actions necessary for safety can be carried out and are properly supported.

*Objective*

The objective of the review of this safety factor is to determine how the various human factors could affect the safe operation of the research reactor and to identify reasonable and practicable corrective actions or improvements. The review has to establish the extent to which a set of culture for safety attributes and attitudes exists in individuals and in the organization.

*Scope and tasks*

The review of human factors has to consider the processes and procedures in place at the research reactor to ensure the following:

(a) The resources devoted to safety are adequate and appropriate.
(b) Staffing levels are adequate for operating the facility, with due consideration of shift work, absences and restrictions on overtime.
(c) Qualified staff as required by the facility procedures are available and on duty at all times.

(d) The training programmes in place for initial training, retraining and upgrading training are adequate, including training for emergency situations.
(e) The operator actions that are needed for safe operation are assessed to confirm that assumptions made in safety analyses are valid.
(f) Human factors for maintenance activities prevent errors in execution of work.
(g) The competence requirements are adequate for operating personnel, including maintenance, technical and managerial staff.
(h) The management's attitude, system of rewards and sanctions, and communication with individuals motivate the staff and develop good attitudes among staff members.
(i) The staff selection methods ensure that people with the right aptitudes, knowledge and skills are recruited.
(j) Fit for duty guidelines, as applicable to the research reactor, exist relating to types and patterns of work, hours, good health and substance abuse.
(k) Human–machine interfaces are addressed.

*Methodology*

The review of human factors has to include the above tasks and take into account national and international good practices. The review may require the assistance of qualified specialists. In order to provide an independent and objective review of the performance of the facility's staff, the operating organization may decide that specific elements of the review need to be carried out by external experts. The review has to include key human performance indicators, for example, procedural deviations or violations, reportable events, maintenance and operator induced errors, and lost time due to injuries or accidents. The review of the human–machine interface has to examine the current condition of the facility using, for example, facility walkdowns by specialists. Further recommendations and guidance on the assessment of the recruitment, training and qualifications of personnel for research reactors can be found in Ref. [26].

### 3.4.4. Safety factor 12: Emergency planning

The design and operation of a research reactor is required to prevent, minimize or mitigate the radiation risks to workers, the public and the environment. Emergency preparedness to mitigate the consequences of accident conditions, including design extension conditions, is necessary for the operating organization and may involve other stakeholders such as local and national authorities [27].

*Objective*

The objective of the review of emergency preparedness is to assess whether the plans, staff, facilities and equipment in place within the operating organization are adequate for dealing with emergencies; whether the coordination of the operating organization with local and national authorities is adequate; and whether regular exercises are implemented to ensure these elements remain adequate.

*Scope and tasks*

The PSR has to include an overall review to assess whether emergency planning and preparedness at the facility is satisfactory and in accordance with current safety analyses, including accident mitigation, and conforms to current national and international standards and good practice.

The PSR has to verify that the operating organization has considered any significant changes at the site of the research reactor or significant changes in its use, organizational changes with respect to emergency response at the facility, and developments around the site that could influence planning and preparedness for potential emergency situations.

The review of emergency planning has to include the following:

(a) Verification of the comprehensiveness and documentation of the on-site emergency plan and verification that procedures for implementing the emergency plan are regularly exercised and tested;
(b) Evaluation of the adequacy of the structure of the emergency response organization and the clarity of shared responsibilities for various response tasks;
(c) Verification that on-site equipment and facilities for emergencies are adequate;
(d) Evaluation of the adequacy of on-site emergency support centres;
(e) Verification that communications within the operating organization and interactions with outside organizations in the event of an emergency are effective;
(f) Assessment of records of emergency training and exercises, and experience gained from such exercises;
(g) Verification that arrangements are in place to regularly review and update emergency plans and procedures, and that such arrangements are effective and efficient;
(h) Examination of whether emergency equipment is properly stored and maintained in an operable condition;

(i) Evaluation of the effects of changes in the site's vicinity, such as new residential or industrial developments around the site.

*Methodology*

The review of emergency planning has to include the current procedures for maintaining and updating the emergency plan to incorporate changes in national and international requirements, experiences from exercises and lessons from real emergencies in a timely manner.

The review of this safety factor also has to include the review of records of emergency exercises to assess the operating organization's staff response, their competence and effectiveness, their interactions with off-site (emergency) organizations and the adequacy of emergency planning. The review has to include a check of records of the adequacy and functional capability of equipment necessary for dealing with emergencies, including communications equipment. The review also has to verify whether shortcomings are identified in the exercises and corrective actions are implemented as a result.

The operating organization's interaction arrangements with relevant off-site organizations such as the government, regulatory bodies, hospitals, ambulance services, police, fire departments, local authorities, public welfare authorities and the media have to be evaluated. The review of the adequacy of equipment and facilities for emergencies both on-site and off-site has to include walkdowns of the relevant areas on and off the facility site.

Records of emergency training and exercises have to be reviewed for their effectiveness. This has to include, inter alia, the frequency of such exercises, observations made during the exercises, deficiencies noted and actions taken. These can be compared with current national and international guidelines and good practices.

References [1] and [27] establish the requirements and Ref. [28] provides relevant recommendations and information for emergency preparedness for, and response to, a nuclear or radiological emergency.

## 3.5. SAFETY FACTORS RELATING TO RADIOLOGICAL SAFETY

### 3.5.1. Safety factor 13: Operational radiation protection

The operational radiation protection programme is established to ensure monitoring of the radiation dose to workers, radiation and contamination levels in and around the facility, and the discharge of radioactive effluents, as well as the generation of radioactive waste in the facility.

*Objective*

The objective of the review of this safety factor is to determine the adequacy and effectiveness of the operational radiation protection programme, current procedures and practices, and measures for minimizing the radiation risk and doses to workers and releases to the environment, including from waste management activities at the facility.

*Scope and tasks*

The review needs to evaluate whether the operational radiation protection programme is adequate and effective, including the assessment of the following:

(a) The policy on operational radiation safety and protection;
(b) The policy on radioactive waste management (generation and treatment);
(c) The radiation protection and on-site monitoring programme, including instrumentation and equipment, radiological monitoring and surveys, and decontamination;
(d) Potential sources of radiological exposure and other radiological impacts such as shielding, hot spots and the categorization of premises;
(e) The applicable limits and reference levels for exposure and emissions against current national and international standards and good practice;
(f) Radiation doses (to personnel, users, visitors and contractors), including dose constraints;
(g) On-site and off-site contamination and radiation levels;
(h) Discharges of radioactive effluents;
(i) Generation and interim storage of radioactive waste.

*Methodology*

The applicable limits and reference levels for exposure and emissions are reviewed to ensure compliance with the current national and international standards and good practice. Records of radiation doses and radioactive effluents are reviewed to determine whether these are within prescribed limits and are as low as reasonably achievable. Although radiation risks have to be considered in all safety factors, the review of this safety factor examines data on radiation doses and radioactive effluents and the overall effectiveness of the radiation protection programme.

The availability of adequate radiation protection equipment including area radiation monitors, stack monitors, portable monitors and contamination monitors, and their maintenance and calibration records, has to be reviewed.

Data on the generation of radioactive waste have to be reviewed to determine whether operation of the facility is being optimized to minimize the quantities of waste being generated and accumulated, taking into account the national policy on radioactive discharges and international treaties, standards and criteria. The waste storage capacity at the facility has to be reviewed, including changes in the background levels, hot spots and the need for additional shielding. Trends in radiation doses (collective and individual) have to be monitored. Similarly, discharges to the environment have to be trended and ways to optimize the discharges have to be addressed.

IAEA Safety Standards Series No. NS-G-4.6, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors [29], provides guidance for a radiation protection programme, including guidance on the assessment of occupational exposure and on the management of radioactive waste and effluents arising from the operation of a research reactor. IAEA Safety Standards Series No. WS-G-6.1, Storage of Radioactive Waste [30], provides additional relevant guidance. These IAEA Safety Guides can be consulted when reviewing records relating to radiation doses, the generation and storage of radioactive waste and the discharge of radioactive effluents.

### 3.5.2. Safety factor 14: Radiological impact on the environment[2]

The operating organization needs to have a programme for effectively monitoring the radiological impact of the facility on the surroundings and the environment.

*Objective*

The objective of the review of this safety factor is to assess the adequacy and effectiveness of the programme for monitoring the radiological impact of the facility on the environment. The review also includes verifying whether releases of radioactive material are properly controlled and efforts are made to keep them as low as reasonably achievable.

*Scope and tasks*

The review has to establish whether the radiological monitoring programme is appropriate and sufficiently comprehensive. In particular, the review has to verify that the radiological impact of the facility on the environment is not

[2] Other risks, such as releases of toxic material and their impact, may be included as required by national regulations.

significant. The review of this safety factor includes the analysis of radiological data and comparison of these data with baseline data or previous PSR data.

*Methodology*

As part of the review, the following have to be verified (Refs [31] and [32] provide further guidance and information on environmental monitoring):

(a) The environmental monitoring programme includes regular monitoring of the concentrations of radionuclides in air, water (including river water, sea water and groundwater), soil, agricultural and marine products, and animals. The monitoring could be done by the operating organization or an independent public organization. The results of such monitoring are trended, and if an abnormal trend is noticed or predetermined levels are exceeded, appropriate corrective actions are taken.
(b) Potential new sources of radiation such as those that arise from facility modifications are identified and their radiological impacts are evaluated by the operating organization.
(c) Sampling and measurement methods are as per current standards.
(d) Records of discharges of effluents are monitored and trended. The discharges are kept within established limits and the facility takes action to keep them as low as reasonably achievable.
(e) The locations and methods selected for on-site monitoring are capable of detecting the release of radioactive material to the environment with a high probability of prompt detection.
(f) Off-site monitoring for radiation levels and contamination levels is adequate, and any release of radioactive material or abnormal radiation levels will be detected. Corrective actions are taken, as necessary, to ensure that such levels are kept as low as reasonably achievable.
(g) Actions are taken to quarantine contaminated areas and clean up contamination where practicable.
(h) Alarm systems are designed and available to respond to any unplanned radioactive material releases from on-site facilities.
(i) The environmental impact of the facility is assessed and appropriate data are published.
(j) Monitoring programmes take into account any changes in the use of areas in the vicinity of the site.

## 3.6. GLOBAL ASSESSMENT

The PSR global assessment is performed to judge the research reactor's suitability for continued operation, taking into account the findings (negative and positive) from the reviews of the individual safety factors. This judgement also takes into account corrective actions or safety improvements that are considered necessary resulting from negative findings (weaknesses), together with the positive findings (strengths) in the global assessment. The global assessment evaluates the impact on safety of findings from all the separate safety factors and therefore needs to be performed after all the individual safety factor reviews have been completed.

The global assessment is performed by an interdisciplinary team with appropriate expertise in the operation, design and safety of the facility, including an appropriate number of participants from the safety factor review teams. The team has to also include members who are independent of the safety factor review teams. Overall conclusions and safety improvements considered reasonable and practicable need to be included in the final PSR report.

The global assessment has to include the following:

(a) Interface issues and overlapping issues between the various safety factor reviews, to ensure that such issues are fully addressed.
(b) An analysis of the interfaces and interactions between the various safety factors. As the findings from the review of a safety factor could be the input for review of another safety factor, communication and regular updates between the review teams is important and needs to be well organized. In particular, findings that are also related to other safety factors have to be provided promptly to the review team concerned.
(c) An examination of supporting information, including documents on the agreed scope and methodology of the PSR, associated regulatory requirements and previously submitted PSR documents, in particular issues raised by and feedback from the regulatory body, peer review missions and any additional reference material.
(d) Consideration of all the findings (positive and negative) from the separate safety factor reviews and whether the safety improvements are reasonable and practicable. Considering any overlaps or omissions between the reviews of the separate safety factors, the global assessment also has to determine whether additional or grouped safety improvements arising from more than one safety factor review are also reasonable and practicable. Identified safety improvements that are judged not to be reasonable and practicable might not be pursued any further, in consultation with the regulatory body.
(e) A clear distinction between corrective actions and safety improvements.

(f) A method for the assessment, categorization, ranking and prioritization of corrective actions or safety improvements to address negative findings based on the criteria and methods established in the PSR basis document. The method has to be based on the safety significance and resulting gains of each proposed safety improvement within the global assessment. The approach adopted has to be based on deterministic safety analysis, PSA (if available), engineering judgement, risk analysis or cost–benefit analysis, or a combination thereof. The corrective actions or safety improvements proposed in the global assessment are included in the integrated implementation plan.

(g) An assessment of risks associated with negative findings, both individually and collectively, and an appropriate justification for continued operation. It is possible that a negative finding following the review of one safety factor is compensated for by a positive finding from the review of another safety factor. The justification has to address short term operation prior to the implementation of identified corrective actions or safety improvements, and long term operation if the global assessment concludes that it is not reasonable and practicable to address some of the negative findings.

(h) The time necessary for corrective actions or safety improvements, together with actual benefit to the facility's safety.

(i) An examination of the overall effect of PSR on the defence in depth and the facility's main safety functions (reactivity control, core cooling and confinement).

## 3.7. INTEGRATED IMPLEMENTATION PLAN

Safety improvements have to be implemented in accordance with an integrated implementation plan submitted to the regulatory body for approval. The safety improvements and the integrated implementation plan, including the categorization and prioritization of the proposed corrective actions and safety improvements, have to be updated after the PSR report has been assessed and approved by the regulatory body.

The completion of the global assessment results in a prioritized list of safety significant findings. On the basis of this list, appropriate corrective actions or safety improvements to address the safety issues are defined and an adequately resourced programme is prepared for their implementation. In some cases, it may be necessary to conduct a preliminary assessment in order to determine the scope of the work required before a committed programme can be declared.

Different approaches exist for the prioritization of corrective actions or safety improvements. Such a judgement process can be based on deterministic

analyses; the application of engineering judgement is also an important factor in this process. First, the potential options for resolving the issue are identified. For each option, both the benefits and disadvantages are listed in order to compare them and to establish the best solution.

Solutions to resolve the various issues may involve a modification of the facility, a modification of procedures, further analysis or a combination of these. It is essential that various potential options for resolving issues be identified to enable the optimization of solutions.

The integrated implementation plan has to consider any interactions between individual corrective actions or safety improvements. The plan also has to specify the schedules for implementation of corrective actions or safety improvements and the necessary resources. It is recognized that the implementation of corrective actions or safety improvements will have different execution times. Corrective actions have to be given higher priority and need to be executed in the short term. The plan also has to include updating of the facility's safety and operating documents, together with safety improvements or corrective actions. A good configuration management process will also ensure that, as a minimum, documentation including the safety analysis report, design basis documents, procedures, operational limits and conditions, maintenance documents, facility drawings, and inspection and test schedules are updated.

The integrated implementation plan is reviewed and approved by senior managers from the operating organization, who commit the necessary human and financial resources to implement the proposed corrective actions or safety improvements according to a schedule that is considered reasonable and practicable. The integrated implementation plan is then submitted to the regulatory body. The regulatory body reviews and, in accordance with national requirements and regulations, accepts or approves the implementation plan.

Implementation of the safety improvement plan is not considered part of the PSR and is subject to normal regulatory oversight. Some improvement plans (e.g. obsolescence management) may go beyond the next PSR.

## 3.8. DOCUMENTATION

For the performance of the PSR, the availability of consistent documentation for the facility is necessary. The documentation for the facility has to be available to the PSR project team at the beginning of the PSR project and be made available to the regulatory body with the final PSR reports.

The documentation of the PSR results has to cover all parts of the PSR, including an introduction, a global assessment of the overall safety status of the facility and an implementation plan for measures resulting from the findings.

The documentation can be one document or can be split into single reports covering the different parts of the PSR. It has to be internally consistent, if references to internal documents of the facility are used; the operating organization has to be ready to hand those to the regulatory body on request. It is important that both the regulatory body and the operating organization set up an auditable system to monitor the status of incoming and outgoing correspondence between them. The Appendix provides details regarding the format of the PSR documentation.

# 4. REVIEW PROCESS OF THE REGULATORY BODY

The requirements for the PSR are established by the regulatory body. The regulatory body has to appoint a project manager for the assessment of the PSR. The project manager acts as the focal point and coordinator for all PSR related activities, and is responsible for communication with the operating organization, external sources (if used) and within the regulatory body.

The regulatory body assesses the PSR basis document provided by the operating organization and has to discuss and agree on the proposed PSR plan with the operating organization. Milestones and time frames provided by the operating organization are to be reviewed and accepted/approved by the regulatory body consistent with the national regulations.

An assessment plan for performing the regulatory assessment of PSR reports then has to be prepared by the regulatory body, including the assessment criteria to be used. The regulatory body has to identify the technical experts who will carry out the regulatory assessments. Appropriate training and briefing of the reviewers has to be carried out to ensure the consistency of the criteria applied by different reviewers and to ensure that the regulatory assessment is completed in an efficient and effective manner.

During the period when PSR is being conducted by the operating organization, the regulatory body has to maintain communication with the operating organization to ensure that PSR is being conducted as agreed in the basis document. This could be achieved through organized meetings between the operating organization and the regulatory body.

After receipt of the PSR report, the regulatory body reviews it and assesses the PSR findings and proposals for corrective actions or safety improvements submitted by the operating organization. This review may involve analysis, verification and validation calculations; the regulatory body may use its own methods, such as alternative computer codes, if available and appropriate. During

the assessment process, the regulatory body has to maintain communication with the operating organization in order to clarify issues, obtain additional information, as necessary, and discuss any additional issues that are identified by the assessor. The results of these interactions need to be documented for future reference.

Assessors prepare reports that include all significant issues to be resolved. Such assessment reports could also provide initial acceptability of safety improvements or corrective actions proposed by the operating organization. The project manager prepares an integrated PSR assessment report using the individual assessment reports.

The integrated PSR assessment report covers, in a concise way, the following:

(a) The regulatory body's position on the adequacy of the PSR based on the reports submitted, including the corrective actions or safety improvements identified or implemented by the operating organization;
(b) The regulatory body's view of the proposed time schedule for the integrated implementation plan.

Paragraph 8.34 of Ref. [4] states:

"In the event that the PSR identifies a finding that poses an immediate and significant risk to the health and/or safety of workers or the public or to the environment, the regulatory body should verify that the operating organization takes prompt action and does not wait until the end of the PSR before taking corrective action or implementing safety improvements."

The regulatory body has to discuss the integrated project report with the operating organization to reach agreement on an updated integrated implementation plan of corrective actions and safety improvements. Depending on the national regulations, the regulatory body has to then take appropriate licensing or other regulatory actions.

Where the PSR is used in decision making for operational licence renewal, the review has to pay particular attention to the documentation and facility programmes that are of significant importance for continued safe operation, including the following:

(a) Facility programmes to support safety factors relating to facility design, the actual condition of SSCs important to safety, equipment qualification and ageing;
(b) The management system;

(c) Safety analyses involving time limiting assumptions relating to the proposed lifetime of the facility;
(d) The programme for promoting the facility's culture for safety.

## 5. POST-REVIEW ACTIVITIES

This section describes post-review activities, that is, those activities carried out after the PSR is completed through the regulatory bodies' approval of an integrated implementation plan. A particularly important activity is the implementation of corrective actions and identified reasonable and practicable safety improvements in a timely manner. Therefore, both the operating organization and the regulatory body have to maintain adequate arrangements for effective implementation of the safety improvement plan after the completion of the PSR. These arrangements have to ensure that the regulatory body is notified of the implementation of the corrective actions and safety improvements or of any significant delays in their implementation.

The completion of the PSR and the associated corrective actions or safety improvements invariably necessitates changes to facility documentation. Such changes may result in the revision of design, operation, safety and licensing documentation to reflect the actual configuration of the facility. In particular, it is anticipated that the safety analysis report will be updated after completion of the PSR to:

(a) Reflect the results of reviews of reference documents and requirements;
(b) Take into account new operating experience;
(c) Incorporate all design changes completed and identified during the course of the PSR;
(d) Incorporate the results of safety analyses performed in support of the PSR;
(e) Reflect the implementation of safety improvements.

The intent is for the actions and activities identified in the implementation plan to be complete prior to the next PSR. However, it is acknowledged that some actions may not even be scheduled for implementation prior to the next PSR (e.g. the anticipated obsolescence of SSCs may be more than ten years from the time of the PSR).

## Appendix

## DOCUMENTATION OF THE PERIODIC SAFETY REVIEW

### A.1. DOCUMENTS PRODUCED BY THE OPERATING ORGANIZATION

The following documents are produced by the operating organization during the conduct of the PSR:

— The basis document for the PSR;
— Safety factor report(s);
— The global assessment report;
— The final PSR report, including the integrated implementation plan.

#### A.1.1. Recommended contents of the PSR basis document

The PSR basis document sets the process for PSR and has to be prepared by the operating organization and reviewed and agreed by the regulatory body. In addition to the content listed below, the PSR basis document has to include criteria for corrective actions and safety improvements for research reactors.

Paragraph II.2. of Ref. [4] states:

"The PSR basis document should include three main parts:

*(1) General*

— The scope and objectives of the PSR and the future operating period that will be considered by the review;
— The cut-off dates to be used, that is, the dates beyond which updates to standards and codes and new information (for example, more recent plant operating experience) will not be considered during this PSR;
— The plant licensing basis at the time of initiating the PSR;
— Relevant regulatory requirements;
— The list of safety factors to be reviewed within the PSR and interfaces between them;
— A description of the systematic review approach to be used to ensure a complete and comprehensive review;
— Processes for identifying, categorizing, prioritizing and resolving negative findings;

— The process for ensuring any immediate and significant risks to the health and/or safety of workers or the public or to the environment identified during the PSR will be addressed without delay;
— The methodology to be used for the global assessment and the planned document structure of the global assessment report;
— Guidance for preparation of the integrated implementation plan of safety improvements;
— The systematic method to be used for recording outputs from the PSR, including the proposed formats of:
    - The safety factor reports;
    - The global assessment report;
    - The final PSR report, including the integrated implementation plan of safety improvements."

Paragraph II.2(2) of Ref. [4] states:

*"(2) Safety factors*

The following information should be provided for each safety factor:

— Objectives and scope of the review;
— The applicable regulatory requirements, national, international and industry safety standards, codes and methods, and operational practices selected as the basis for the safety factor review and, where relevant, their hierarchy;
— The input documents and processes to be reviewed;
— The specific methodologies to be used for the review and a justification for the approach to be followed;
— Expected outputs."

The project plan has to ensure that a sufficient number of trained human resources (either in-house or outsourced) for the period during which PSR is conducted will remain available. Paragraph II.2(3) of Ref. [4] states that the PSR basis document should include three main parts, one of which is the project plan for the PSR with the following contents:

*"(3) Project plan for the PSR*

— Organization of the project, including roles and responsibilities;
— Time schedule including any major milestones and cut-off dates;
— Project and quality management processes;

— Processes for ensuring consistency between separate safety factor reviews, for example, for establishing a common set of technical databases…;
— Training;
— Internal communications;
— The plan for communicating and interfacing with and gaining relevant approvals and agreements from, the regulatory body."

### A.1.2. Recommended contents of each safety factor report

In addition to the below, the safety factor review reports have to include details of the review team, the timeline followed, operating personnel interviewed for collecting information, walkdowns conducted and proposed corrective actions.

Paragraph II.3 of Ref. [4] states:

"The safety factor report should include the results from the review of each safety factor following the approach detailed in the PSR basis document. The findings specific to each safety factor should be documented and ranked according to their safety significance. In some States, the findings on all safety factors are included in a single report; however, multiple reports can be developed. If multiple reports are to be developed, a general template or structure should be provided to maintain consistency and to ensure that all the items required to be reviewed are covered by the different teams performing the PSR."

Paragraph II.4 of Ref. [4] states:

"The following is an example of the structure of a typical safety factor report:

— Title (name of the safety factor);
— Introduction;
— Scope of the review, including a list of the documents and aspects of safety reviewed (for example, organizational capability…);
— Review criteria (reference standards, operating practices, safety assessment criteria, etc.);
— Review methodologies applied;
— Review of performance since the previous PSR;
— Comparison with review criteria and discussion of the results;

— Evaluation of the safety significance of negative findings, together with proposed safety improvements and their prioritization;
— Review of future safety for the period addressed in the PSR;
— Conclusions;
— References;
— Appendices."

### A.1.3. Recommended contents of the global assessment report

In addition to the list below, the global assessment report has to include corrective actions together with safety improvements.

Paragraph II.5 of Ref. [4] states:

"The PSR results for all safety factors should be evaluated through a global assessment, and the following items should be documented:

— Significant PSR outcomes, including positive and negative findings (strengths and deviations);
— Analysis of interfaces, overlaps and omissions between safety factors and between individual negative findings;
— An overall analysis of the combined effects of the positive and negative findings;
— The category, ranking and priority of safety improvements proposed to address negative findings;
— An assessment of defence in depth;
— An assessment of the overall risk;
— Justification for proposed continued operation in both the short term and long term…."

### A.1.4. Recommended contents of the final PSR report

Paragraph II.6 of Ref. [4] states:

"The final PSR report should provide an overview of the PSR and should include the following topics:

— Summary of the outcomes of the safety factor reports;

— Summary of the outcomes of the global assessment report, including:
  - Identification of negative findings arising from deviations between the present state of the plant and current safety standards and operational practices;
  - An evaluation of the safety significance of these negative findings;
  - An overall judgement on the acceptability of continued plant operation;
— The integrated implementation plan, including proposals for resolving negative findings by safety improvements or corrective actions, and their safety significance and priority;
— An assessment of the safety of future plant operation over the period addressed in the PSR."

## A.2. DOCUMENTS PRODUCED BY THE REGULATORY BODY

The following documents are produced by the regulatory body for the assessment of the PSR conducted by the operating organization:

(a) The regulatory guidance document for the operating organization;
(b) The internal management plan for regulatory assessment of the PSR;
(c) The safety factor assessment reports;
(d) The PSR conclusion report.

### A.2.1. Recommended contents of the regulatory guidance document for the operating organization

The regulatory guidance document provides regulatory guidance to the operating organization on general issues while performing the PSR and includes the following:

(a) The legislative background of PSR (reference to all relevant legal items that provide important considerations for the initiation, conduct and evaluation of PSR, and the extension of operational licences);
(b) Relevant regulatory requirements to be considered during the PSR;
(c) Relevant international standards and requirements to be considered during the PSR;
(d) The PSR scope and objectives from the regulatory point of view and general time scale to be considered by all relevant stakeholders (submission deadline

of PSR documents by the operating organization, deadline for issuance of regulatory decisions relating to the PSR);

(e) Guidance to the operating organization for preparation for and conduct of PSR and preparation of the integrated implementation plan for safety improvements.

### A.2.2. Recommended contents of the internal management plan for the regulatory assessment of the PSR

The regulatory body's internal management plan for the regulatory assessment of the PSR has to include the following elements:

(a) Reference to the relevant regulatory requirements and international standards and requirements to be considered during the PSR;
(b) The structure of the regulatory organization for the conduct of the independent assessment of submitted PSR documents;
(c) The identification of safety factors and technical sub-areas where the regulatory body needs external technical support, and identification of the appropriate external technical support organizations to provide the required technical support for the independent regulatory assessment of submitted PSR documents;
(d) The organization of the project, including roles and responsibilities;
(e) A description of the approach to be followed during the regulatory assessment of submitted PSR documentation;
(f) Unified processes to be followed by the regulatory body for identifying, categorizing and prioritizing negative findings that are revealed by both the operating organization during its review process and the regulatory body during its independent assessment;
(g) Internal deadlines and milestones for the regulatory assessment processes;
(h) Unified communication protocols for the regulatory assessment processes;
(i) Ways of interacting with the operating organization during its review process and during the regulatory assessment of PSR documents;
(j) The plan for inspections for verification of statements in the operating organization's PSR documents;
(k) The documentation system (types and purposes of documents and databases);
(l) The general template or structure for the regulatory body's safety factor assessment reports to maintain consistency and to ensure that all items required to be assessed are covered by the different teams performing the assessment of the PSR documents;

(m) A general training programme for the regulatory body about PSR (purpose, regulatory objectives, how to conduct and document independent assessment, use of databases).

### A.2.3. Recommended contents of the safety factor assessment reports

For each safety factor, a safety factor assessment report has to be prepared by the assessment team (within the regulatory body) responsible for the given safety factor. The safety factor assessment report has to include the results from the independent assessment of the safety factor following the approach detailed in the internal management plan. The findings specific to each safety factor have to be documented and ranked according to their safety significance. The following is an example of the structure of a typical safety factor assessment report:

(a) Title (name of the safety factor);
(b) Identification and composition of the regulatory team responsible for the assessment;
(c) Scope of the regulatory assessment, including a list of the documents and topics;
(d) Acceptance criteria (reference requirements and standards, operating practices, safety assessment criteria);
(e) Assessment methodologies applied;
(f) Results of regulatory inspections for verification of statements in the operating organization's safety factor report;
(g) Additional information obtained from the operating organization which is not included in the safety factor review report;
(h) Assessment of the safety significance determination by the operating organization of their positive and negative findings;
(i) Identification of additional positive and negative findings by the regulatory team conducting its independent assessment and their safety significance determination;
(j) Evaluation of the corrective actions and safety improvements and their prioritization as proposed by the operating organization;
(k) Identification of areas where additional corrective actions or safety improvements are to be required by the regulatory body;
(l) Conclusions;
(m) References;
(n) Appendices.

### A.2.4. Recommended contents of the PSR conclusion report

The regulatory body's PSR conclusion report needs to be prepared by the appointed regulatory team. The PSR conclusion report summarizes the safety factor assessment reports and provides an overview of the PSR. Its contents should include the following items:

(a) A summary of the outcomes of the safety factor assessment reports.
(b) A summary of the outcomes of the operating organization's global assessment report, including:
    - The acceptance of positive and negative findings identified by the operating organization arising from deviations of the present state of the facility from current safety standards and operational practices;
    - An assessment of the safety significance determination of findings conducted by the operating organization;
    - A list of additional positive and negative findings identified by the regulatory body including assessment of their safety significance;
    - The regulatory acceptance of the integrated implementation plan, and identification of areas for additional corrective actions or safety improvements to be prioritized and integrated in the implementation plan;
    - An assessment of the safety of future facility operation over the period addressed in the PSR;
    - An overall judgement on the acceptability of continued facility operation;
    - Any licensing action as required by the national regulations.

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## Annex I

## TYPICAL INPUTS, OUTPUTS AND RELEVANT PUBLICATIONS FOR THE REVIEW OF SAFETY FACTORS

This annex provides lists of the input information typically needed for review of each safety factor within the operating organization and the expected outputs (see Tables I–1 to I–14). The content is indicative and it may vary depending on the facility documentation system.

In preparation for the review of safety factors, the information listed in the 'inputs' column of the table is to be collected. A systematic and comprehensive assessment of the input information, records and data is to be conducted. Gaps between the current status and the national and international standards have to be analysed. Appropriate corrective measures need to be identified in order to eliminate the gaps. The results of the assessment, the gap analysis and corrective measures are the outputs for the safety factor.

TABLE I–1. SAFETY FACTOR 1: FACILITY DESIGN

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international requirements and codes and standards on design and site evaluation;<br>— Current national and international good practices in design and site evaluation.<br><br>Facility specific documents:<br><br>— Relevant chapters of the updated safety analysis report;<br>— The updated site evaluation (from the updated safety analysis report or similar safety document);<br>— The list of structures, systems and components (SSCs) important to safety and their safety classification (from the updated safety analysis report);<br>— The documented design basis (original or reconstituted and updated) including the list of postulated initiating events;<br>— The description of the facility design; drawings and layout, systems and equipment (from the updated safety analysis report);<br>— Results of the commissioning tests;<br>— The design specifications of the facility.<br><br>The review of this safety factor may require inputs from other safety factors, for example the following:<br><br>— Results of the safety analysis;<br>— Negative findings from equipment qualification. | Safety factor review report<br><br>The review of the facility design may result in conclusions and findings concerning the following topics:<br><br>— Compliance with current safety and design standards;<br>— Prevention and mitigation of events affecting safety;<br>— Records of the design basis, facility modifications and results of tests;<br>— The facility safety documents (safety analysis report, operational limits and conditions);<br>— Facility modifications.<br><br>The results of this safety factor may provide inputs to other safety factors, for example safety analysis. |

TABLE I–2. SAFETY FACTOR 2: ACTUAL CONDITION OF STRUCTURES, SYSTEMS AND COMPONENTS IMPORTANT TO SAFETY

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international requirements, codes and standards on design;<br>— Appropriate standards on assessment;<br>— Operating experience from similar facilities.<br><br>Facility specific documents:<br><br>— The list of SSCs important to safety and their safety classification;<br>— Descriptions of the actual condition of SSCs important to safety;<br>— Technical specification of SSCs important to safety;<br>— Equipment qualification results;<br>— Findings of facility walkdowns;<br>— Maintenance records;<br>— Inspection results;<br>— Findings of tests demonstrating the functional capability of SSCs important to safety;<br>— Records of modifications.<br><br>The review of this safety factor may require inputs from other safety factors, for example the following:<br><br>— Negative findings from equipment qualification;<br>— Findings from the ageing management programme. | Safety factor review report<br><br>The review of the actual condition of the facility SSCs may lead to findings such as the following:<br><br>— Confirmation that the design basis assumptions have not been significantly challenged and will remain unchallenged until the next periodic safety review (PSR);<br>— Confirmation that the actual condition of the SSCs important to safety of the research reactor is such that the design basis assumptions are not significantly challenged and will not be challenged before the next PSR;<br>— Additional surveillance measures needed to ensure the timely detection of ageing effects;<br>— Maintenance and testing provisions to be improved;<br>— Deficiencies in recording the actual condition of SSCs;<br>— Confirmation that the validity of existing records is sufficient or needs to be improved.<br><br>The results of this safety factor may provide inputs to other safety factors, for example in the following areas:<br><br>— Ageing management of SSCs;<br>— Equipment qualification. |

TABLE I–3. SAFETY FACTOR 3: EQUIPMENT QUALIFICATION

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international requirements and standards on design and site evaluation;<br>— Current national and international good practices in design and site evaluation.<br><br>Facility specific documents:<br><br>— The site evaluation (from the safety analysis report or similar safety document);<br>— The list of SSCs important to safety and their safety classification;<br>— The documented design basis (original and updated) with the list of postulated initiating events;<br>— The list of equipment covered by the equipment qualification programme;<br>— Equipment qualification procedures and reports.<br><br>Operating experience:<br><br>— Operating experience from similar facilities.<br><br>The review of this safety factor may require inputs from other safety factors, for example in the following areas:<br><br>— Facility design;<br>— Safety analysis;<br>— Ageing management. | Safety factor review report<br><br>The review of equipment qualification may lead to findings in some of the following areas:<br><br>— The equipment qualification programme and its validity, procedures (including design extension conditions) and records;<br>— The updated safety analysis report;<br>— Maintenance and ageing management programmes.<br><br>Findings from the review of equipment qualification may include the following:<br><br>— The equipment qualification programme is adequate or justification is necessary.<br>— Additional qualification or protection is needed for components.<br>— There is a need for replacement of SSCs.<br>— There is a need for improvements to the maintenance programme.<br>— There are deficiencies in maintaining the environmental conditions.<br>— There is a need for improvements to the ageing management programme.<br><br>The results of this safety factor may provide inputs to other safety factors, for example in the following areas:<br><br>— Ageing management of SSCs;<br>— Actual condition of SSCs. |

TABLE I–4. SAFETY FACTOR 4: AGEING

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international ageing management standards.<br><br>Facility specific documents:<br><br>— The ageing management programme description;<br>— Relevant guidance on the management of facility ageing and record keeping;<br>— Manuals on ageing management used by the operating organization;<br>— The updated safety analysis report;<br>— Documented criteria for identifying SSCs important to safety covered by the ageing management programme;<br>— The list of SSCs important to safety covered by the ageing management programme;<br>— Maintenance, periodic testing and inspection records of SSCs important to safety;<br>— Time limited ageing analysis records;<br>— The programme for obsolescence management;<br>— Spare parts and maintenance stores records;<br>— Trend analysis data to detect ageing degradation;<br>— Failure data of SSCs important to safety;<br>— Surveillance and monitoring records including water chemistry;<br>— Data for assessing ageing degradation, including baseline data and operating and maintenance histories. | Safety factor review report<br><br>The review of ageing may lead to findings such as the following:<br><br>— The rapidity of the ageing process;<br>— Deficiencies in the ageing management programme;<br>— Deficiencies in the obsolescence management;<br>— Facility design review.<br><br>Examples of outputs include the following:<br><br>— Proposals for replacement of particular SSCs important to safety;<br>— Improvements to the maintenance programme;<br>— Proposals for refurbishment or modernization of SSCs;<br>— Improvements in obsolescence management;<br>— Improvements in spare parts and maintenance stores management;<br>— Reconstitution of time limited ageing analysis;<br>— Improvements to the ageing management programme.<br><br>The results of this safety factor may provide inputs to other safety factors, for example in the following areas:<br><br>— Equipment qualification;<br>— The actual condition of SSCs. |

TABLE I–4. SAFETY FACTOR 4: AGEING (cont.)

| Inputs | Outputs |
|---|---|
| The review of this safety factor may require inputs from other safety factors, for example the following:<br><br>— Results of the actual condition of SSCs;<br>— Results of the equipment qualification;<br><br>Results of the operating history. | |

TABLE I–5. SAFETY FACTOR 5: UTILIZATION

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international standards for the conduct of experiments;<br>— Relevant guidance on the management of ageing and record keeping for experimental devices;<br>— Relevant guidance on the training and qualification of personnel conducting experiments at research reactors.<br><br>Facility specific documents:<br><br>— The processes and procedures, including operational limits and conditions, used by the operating organization for managing and conducting experiments;<br>— The list of current experimental device qualification, specifications and procedures, and records that provide information in support of their importance to safety with reference to current standards;<br>— Data for assessing ageing management of experimental devices, including baseline data and operating and maintenance histories.<br><br>The review of this safety factor may require input from other safety factors, for example in the area of operating experience. | Safety factor review report<br><br>The review of utilization may lead to findings such as the following:<br><br>— The need to update safety analyses for experiments;<br>— The need for changes in the facility documentation with respect to utilization;<br>— The need for new or special operational limits and conditions that may be required for experiments;<br>— The need for ageing management for experimental devices;<br>— The need for new or specialized training for personnel associated with utilization.<br><br>Examples of outputs include the following:<br><br>— Proposals for new or special operational limits and conditions relating to experiments and utilization;<br>— Proposals for replacement of experimental devices or particular SSCs important to safety for experiments;<br>— Improvements to the experiment programme;<br>— Improvements to the ageing management programme for experimental devices;<br>— Proposals for written procedures for use and handling of experimental devices that state the responsibilities for those involved with experiments;<br>— Improvements to procedures for approval of experiments.<br><br>The results of this safety factor may provide inputs to other safety factors. |

TABLE I–6. SAFETY FACTOR 6: DETERMINISTIC SAFETY ANALYSIS

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international standards and guidelines for deterministic safety analysis (e.g. guidelines for application of the single failure criterion, diversity and separation of SSCs important to safety). Probabilistic safety assessment standards and guidelines can be added if included based on the national requirements.<br><br>Facility specific documents:<br><br>— The updated safety analysis report for the facility including design extension conditions;<br>— The list of updated postulated initiating events;<br>— The existing deterministic safety analysis and the assumptions used;<br>— The operational limits and conditions and permitted operational modes of the facility;<br>— The lists of anticipated operational occurrences, including all postulated initiating events that could affect the safety of the facility;<br>— The analytical methods and computer codes used in deterministic safety analysis and comparable current methods including their validation;<br>— The calculated radiation doses and limits on releases of radioactive material for design basis accident conditions.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of the deterministic safety analysis may lead to findings in some of the following areas:<br><br>— The applicable list of initiating events for the facility;<br>— The design basis for SSCs important to safety;<br>— The treatment of design extension conditions;<br>— Facility behaviour for postulated initiating events;<br>— The computer codes and deterministic methods used in safety analysis.<br><br>Examples of outputs include the following:<br><br>— Proposed safety improvements to the facility;<br>— New postulated initiating events;<br>— Proposed new or revised operational limits and conditions;<br>— Verification of the assumptions used in the deterministic analysis;<br>— Assessment of the capability of the design to provide for defence in depth;<br>— Proposals for reassessment of safety margins;<br>— Proposed modifications to the facility such as additional measures for design extension conditions;<br>— Proposed improvements to the deterministic analysis methodologies or modelling.<br><br>The results of this safety factor may provide inputs to other safety factors. |

TABLE I–7. SAFETY FACTOR 7: OPERATING EXPERIENCE

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international standards, requirements and good practices.<br><br>Operating experience:<br><br>— Best international practice in the use of safety performance indicators.<br><br>Facility specific documents:<br><br>— Records of operating experience relevant to safety, including the following:<br>• Frequency of unplanned trips and scrams;<br>• Frequency of unplanned operator actions in the interest of safety, and their success rate;<br>• Selected actuations of, or demands on, safety systems;<br>• Failures of safety systems;<br>• Unavailability of safety systems;<br>• Trends in causes of failures (e.g. human factors, equipment related);<br>• The backlog of outstanding maintenance activities;<br>• Configuration management;<br>• The extent of repeat maintenance;<br>• The extent of corrective (breakdown) maintenance;<br>• The integrity of physical barriers for the containment of radioactive material.<br>— Reports on the routine analysis of safety performance indicators.<br>— Procedures, documentation and outputs from the facility's routine processes for the review of operating experience.<br>— Inputs from safety factor 13.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of safety performance may lead to findings in some of the following areas:<br><br>— Training relating to safety performance, including collecting, storing and transmission of operational data to the regime;<br>— Facility processes and procedures, for example operating procedures, maintenance inspection and periodic testing;<br>— Culture for safety;<br>— The final safety analysis report;<br>— Operational experience demonstrated by trend analyses and performance indicators;<br>— Self-assessment and continuous improvement.<br><br>Examples of outputs are:<br><br>— New training courses promoting lessons learned and results from operating experience feedback;<br>— Changes to the approved operational limits and conditions in order to make revisions arising out of operational experience;<br>— Identified need for safety improvements as a result of root cause analysis for facility events;<br>— Changes in emergency preparedness and response procedures;<br>— Indentified need for update of the safety analysis report.<br><br>The results of this safety factor may provide inputs to other safety factors. |

TABLE I–8. SAFETY FACTOR 8: USE OF EXPERIENCE FROM OTHER FACILITIES AND RESEARCH FINDINGS

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international standards and safety requirements for both nuclear and non-nuclear facilities.<br><br>Operating experience:<br><br>— International databases collecting operating experience, such as the IAEA's Incident Reporting System for Research Reactors database;<br>— Operating experience from similar facilities in the State and in other States.<br><br>Facility specific documents:<br><br>— The review of the use of experience from other facilities and research findings includes inputs from:<br>• Reports from the operating organization's routine assessment of operating experience at other facilities;<br>• Procedures and documentation governing the operating organization's process for the review of operating experience at other facilities;<br>• Assessments from the operating organization's review of emerging research findings;<br>• Procedures and documentation governing the operating organization's routine process for the assessment of research findings;<br>• Independent internal or external audits and self-assessments regarding operating experience and research findings.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of experience from other facilities and research findings may lead to findings such as the following:<br><br>— Identification of best practices at similar and related facilities to be incorporated;<br>— Relevant training information for operating experience at other facilities that may be important to nuclear safety.<br><br>Outputs could include the following:<br><br>— Proposals for improving arrangements for receipt of operating experience feedback from other facilities;<br>— Proposals for improved dissemination of operating experience feedback within the operating organization;<br>— Arrangements for the receipt of findings from relevant research programmes (including international programmes);<br>— Proposals for practicable safety improvements within the operating organization.<br><br>The results of this safety factor may provide inputs to other safety factors.<br><br>Note: This safety factor needs to be reviewed early in the PSR programme. |

TABLE I–9. SAFETY FACTOR 9: ORGANIZATION, THE MANAGEMENT SYSTEM AND CULTURE FOR SAFETY

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national regulations, and national and international standards and good practices.<br><br>Facility specific documents:<br><br>— The operating organization's safety policy and related documentation;<br>— The operational limits and conditions;<br>— The management system procedures and documentation (e.g. on quality management, configuration management, ageing management, maintenance, training, chemical analysis, radiation protection, engineering support and peer review groups);<br>— Outputs from application of management system procedures, including quality plans;<br>— Records (e.g. on training, commissioning, maintenance, testing);<br>— The organizational structure documentation describing the safety related roles and responsibilities of individuals and groups including the reactor safety committee;<br>— The corrective action programme and processes for reporting;<br>— Surveys of culture for safety. | Safety factor review report<br><br>The review of the organization, the management system and culture for safety may lead to findings in some of the following areas:<br><br>— Clarity of policy statements;<br>— Adequacy of the documentation of the management system;<br>— The structure of the operating organization;<br>— Work processes (how work is specified, prepared, reviewed, performed, recorded, assessed and improved);<br>— Control of documents, products and records;<br>— The purchasing process;<br>— Communication;<br>— Organizational change management;<br>— Commitment to safety;<br>— Compliance with procedures;<br>— The existence of a questioning attitude among personnel;<br>— Determination of whether the operating organization has a 'learning culture';<br>— Prioritization of safety issues;<br>— Clarity of organizational roles and responsibilities;<br>— Training in culture for safety;<br>— Regular culture for safety assessments;<br>— Independence of reactor safety committee, health physics function and quality assurance functions. |

TABLE I–9. SAFETY FACTOR 9: ORGANIZATION, THE MANAGEMENT SYSTEM AND CULTURE FOR SAFETY (cont.)

| Inputs | Outputs |
|---|---|
| Operating experience:<br><br>— Operating experience with respect to organization;<br>— Internal audit and surveillance reports;<br>— External audits (e.g. reports from IAEA safety review missions, Integrated Safety Assessment of Research Reactors missions);<br>— Self-assessments;<br>— Safety performance assessments;<br>— Culture for safety assessments;<br>— Meeting records where safety issues are discussed;<br>— Interviews with operating personnel.<br><br>The review of this safety factor may require input from other safety factors. | Examples of outputs include the following:<br><br>— Revision of the organizational structure;<br>— Revision of some of the processes such as change control;<br>— Revision of the document control process;<br>— Additional training programmes.<br><br>The results of this safety factor may provide inputs to other safety factors |

TABLE I–10. SAFETY FACTOR 10: PROCEDURE MANAGEMENT

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international requirements for procedures;<br>— Current national and international good practices in procedures.<br><br>Facility specific documents:<br><br>— The facility operating procedures for normal operation, accident conditions and symptom based emergency operating procedures for restoring safety functions;<br>— Log books and similar records;<br>— The process for supporting facility operating procedures like the quality assurance manual (e.g. for their development, validation, review, approval, revision and withdrawal);<br>— Audits and self-assessments that question adherence to facility procedures.<br><br>Operating experience:<br><br>— Operating experience involving procedural issues at the facility;<br>— Safety significant events involving procedural issues.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of procedures may lead to findings in some of the following areas:<br><br>— The process for development, elaboration, validation, approval, revision and withdrawal of procedures;<br>— Format and content of procedures to bring clarity;<br>— Compliance with procedures;<br>— Effectiveness and adequacy of procedures;<br>— Culture for safety.<br><br>Examples of outputs include the following:<br><br>— Proposals for a development and implementation of new procedures;<br>— Proposals for updating of existing procedures;<br>— Proposals for retraining programmes.<br><br>The results of this safety factor may provide inputs to other safety factors. |

TABLE I–11. SAFETY FACTOR 11: HUMAN FACTORS

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international requirements;<br>— Current national and international good practices for ensuring that human factors do not affect the safe operation of the research reactor.<br><br>Facility specific documents:<br><br>— The safety policy statement and related implementing procedures;<br>— The training policy covering initial, refresher and upgrading training of the staff and related implementing procedures;<br>— Training records, also for training in culture for safety, particularly for staff in management positions;<br>— Staffing records;<br>— The requirements for physical and psychological fitness for different positions important for safety;<br>— Programmes for learning from operating experience in human performance that have contributed to safety significant events;<br>— Assessments of work loads of facility staff based on hours of work and time records.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of human factors may lead to findings in some of the following areas:<br><br>— Staffing levels;<br>— Training programmes;<br>— Operating, maintenance and engineering practices;<br>— Competency management;<br>— Staff selection and recruitment and succession management;<br>— Knowledge management;<br>— Use of external technical resources;<br>— The human–machine interface;<br>— Use of human performance tools;<br>— Communications.<br><br>The results of this safety factor may provide inputs to other safety factors. |

TABLE I–12. SAFETY FACTOR 12: EMERGENCY PLANNING

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Current national and international standards on emergency planning.<br><br>Facility specific documents:<br><br>— The emergency response plan of the operating organization;<br>— The strategy and procedures for responding to emergencies;<br>— The structure of the emergency response organization;<br>— Studies of the mitigation of consequences of accidents;<br>— The accident management guidelines.<br><br>Operating experience:<br><br>— Records of past emergencies, accidents or other significant events at the research reactor and lessons learned;<br>— Records of emergency exercises held and lessons learned;<br>— Lessons learned from exercises held in the State and in other States and from international exercises.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of emergency planning may lead to findings in some of the following areas:<br><br>— Status of the emergency preparedness of the facility;<br>— Status of the emergency planning process is in place;<br>— Proposals for technical or administrative improvements for communication with external bodies;<br>— Proposals for emergency training with other organizations;<br>— Proposals for updates of the emergency plan and response procedures in accordance with the results of current safety analyses, accident mitigation studies and good practices.<br><br>The results of this safety factor may provide inputs to other safety factors. |

TABLE I–13. SAFETY FACTOR 13: OPERATIONAL RADIATION PROTECTION

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Relevant national and international standards.<br><br>Facility specific documents:<br><br>— Policy on operational radiation safety and protection;<br>— The description of the radiation protection and on-site monitoring programme;<br>— Records of potential sources of radiological exposure and other radiological impacts;<br>— The categorization of premises;<br>— The applicable limits and reference levels for exposures and emissions;<br>— The policy on radioactive waste generation and treatment;<br>— Records of radiation doses (to workers, users and contractors);<br>— Records of on-site and off-site contamination and radiation levels;<br>— Records of discharges of radioactive effluents;<br>— Records of generation of radioactive waste.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of this safety factor may lead to findings such as the following:<br><br>— The status of the on-site radiation monitoring programme of the facility;<br>— Confirmation that exposure to the staff of the research reactor is as low as reasonably achievable;<br>— Proposals for reducing the radiation levels and contamination levels in the facility;<br>— Proposals for improvements to operating procedures;<br>— Confirmation that generations of radioactive waste and effluent releases are as low as reasonably achievable and treatment of them is adequate;<br>— Proposals for improvements to waste handling and storage facilities.<br><br>The results of this safety factor may provide inputs to other safety factors. |

TABLE I–14. SAFETY FACTOR 14: RADIOLOGICAL IMPACT ON THE ENVIRONMENT

| Inputs | Outputs |
|---|---|
| Standards and requirements:<br><br>— Relevant national and international standards;<br>— The release limits for effluents.<br><br>Facility specific documents:<br><br>— Records of potential sources of radiological impact;<br>— Off-site monitoring programme for contamination levels and radiation levels, including alarm systems to respond to unplanned releases of effluents from on-site facilities;<br>— An overview of recent, and a forecast of future, changes in the use of areas around the site;<br>— Records of effluent releases, comprehensive evaluation of the records;<br>— Records from off-site environmental monitoring, comprehensive evaluation of the records;<br>— Published environmental data.<br><br>The review of this safety factor may require input from other safety factors. | Safety factor review report<br><br>The review of this factor may lead to findings such as the following:<br><br>— Status of the environmental monitoring programme of the facility;<br>— Proposals for improvements to the environmental monitoring programme in the vicinity of the facility;<br>— Confirmation that the environmental impact caused by the research reactor is as low as reasonably achievable;<br>— A prognosis on future use of areas around the site that has to be taken into consideration in planning for a strategy on optimizing environmental impact.<br><br>The results of this safety factor may provide inputs to all the other safety factors. |

## Annex II

## PERIODIC SAFETY REVIEW FOR THE OPAL REACTOR: OVERVIEW AND LESSONS LEARNED

### II–1. INTRODUCTION

This annex is intended to provide practical information on performing a periodic safety review (PSR) for a research reactor. It is based on the lessons learned from the PSR for the Australian Nuclear Science and Technology Organisation (ANSTO) Open Pool Australian Lightwater (OPAL) reactor, as performed in 2011.

### II–2. BACKGROUND

As part of the facility licence and operating authorization for the OPAL reactor, in July 2006 the Australian Radiation Protection and Nuclear Safety Agency imposed a number of licence conditions. One of these conditions (licence condition 1) is related to the need for ANSTO to perform a PSR.

### II–3. GUIDANCE ON PERFORMING A PSR

At the time the PSR was to be performed for the OPAL reactor, there was no formal international guidance on conducting a PSR for a research reactor, although some national guides existed that reflected the specific legal and regulatory regime of those countries. The Australian Radiation Protection and Nuclear Safety Agency had been developing a regulatory guide for PSR for nuclear installations, but that document had not been formally issued.

ANSTO selected IAEA Safety Standards Series No. NS-G-2.10, Periodic Safety Review of Nuclear Power Plants[1], as guidance for PSR for the OPAL reactor. This was on the basis that NS-G-2.10 was considered to provide a structured and comprehensive framework for such a review for a high powered and highly utilized reactor like OPAL. It was supported by para. 1.5 of NS-G-2.10, which states that "The review process described in this Safety Guide is valid for

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Periodic Safety Review of Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.10, IAEA, Vienna (2003). NS-G-2.10 has been superseded by Ref. [II–1].

nuclear power plants of any age, but may have a wider applicability, for example, to research reactors and radioactive waste management facilities."

However, ANSTO considered that it was appropriate to modify the requirements of NS-G-2.10 to address the fact that the OPAL reactor had been operating for less than five years. During one of these years, OPAL was effectively shut down while a problem with the fuel was resolved.

Since that time, SSG-25 [II–1] has been issued by the IAEA to replace NS-G-2.10. While the structure of SSG-25 is significantly different from that of NS-G-2.10 and there are also many changes at the detailed level, the overall approach recommended in para. 2.13 of SSG-25 [II–1] is effectively the same, in that the review is to be undertaken in accordance with 14 safety factors under five subject areas as follows:

*"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."[2]

For each safety factor, SSG-25 provides an objective for the review, a description of the background to the safety factor, expectations for the assessment process and a list of generic review elements that are recommended for inclusion in the assessment.

## II–4. IMPLEMENTING A PSR

Overall, a major lesson learned was that performing a PSR has to be treated like any other major project and appropriate project management tools and expertise need to be used.

### II–4.1. Project management

Setting up an appropriate project management structure and organization is fundamental to the success of a PSR.

In the case of the OPAL PSR, the standard ANSTO project management processes were applied, with a project plan, project quality assurance plan and task briefings for each reviewer prepared by the project manager in conjunction with appropriate subject matter experts. This documentation ensured that there was a clear definition of the scope and terms of reference of the PSR and that the roles and responsibilities of the organizations and the individual staff involved in the PSR were identified. The task briefings prepared for the review of each safety factor were particularly beneficial to the reviewers, as they addressed the following targets specific to that reviewer:

(a) An objective as defined in NS-G-2.10.
(b) A background based on NS-G-2.10, but adapted to the OPAL context, referencing OPAL source documentation as appropriate.
(c) Requirements based on NS-G-2.10, but adapted to the OPAL context, again referencing OPAL source documentation as appropriate.
(d) Generic elements to review as defined in NS-G-2.10.
(e) A suggested approach the expert can adopt in relation to the specific safety factor.

[2] See footnote 1 on p. 82.

(f) The specific deliverables required and the timescale for delivery. Deliverables were staggered so as to facilitate the technical writer's job of putting the full report together and the internal review of the individual deliverables.

SSG-25 [II–1] recommends that this type of information be documented in a PSR basis document, but the approach used for the OPAL PSR was considered by ANSTO to be equally appropriate.

The interface with the regulatory body also needs to be clearly defined so as to ensure that both the operating organization and the regulatory body have a clear understanding of what is expected from both parties. One shortcoming of OPAL PSR process was the absence of any such agreement with the regulatory body, which resulted in the need for subsequent additional effort to be expended to address comments received from the regulatory body and to prepare a PSR supplement.

The OPAL PSR also made use of a dedicated and very experienced project manager, who was the former engineering manager and assistant project manager during the construction of OPAL. As such, the project manager was very familiar with the design of OPAL, the reactor operations, the operating organization and ANSTO as a whole. The project manager's responsibilities were defined in the project plan and involved the following:

(a) Coordinating the overall PSR project;
(b) Arranging for the collation and production of the overall PSR report based on inputs from the individual expert reviewers;
(c) Coordinating the review of the PSR report;
(d) Drafting an action plan based on the recommendations identified by the individual safety factor reviewers;
(e) Providing support and advice to individual safety factor reviewers.

The project manager was supported by a professional technical writer who collated the inputs from the various safety factor reviewers and prepared the complete PSR report, including a single collated list of recommendations identified by the expert reviewers. As part of this function, the technical writer aimed to ensure a consistent approach to language and terminology throughout the PSR report, thus ensuring that the end result formed a single report rather than a mismatch of independent reports. It was felt that this approach would help the expert reviewers to concentrate their efforts on the actual review activity and not on report writing. The technical writer, while not an expert in PSR or nuclear reactor design and operation, was also able to provide early feedback to

the expert reviewers with respect to obvious errors or inconsistencies within their reviews or between their reviews and the reviews of other safety factors.

The project manager also facilitated and encouraged the appropriate use and involvement of other resources, particularly non-professional staff (technicians, fitters) and support staff within reactor operations. For example, the use of maintenance technicians when reviewing against safety factor 2 (actual condition of SSCs) is very useful, as they normally have very good knowledge of the actual state of the as-built plant through their experience maintaining the plant.

### II–4.2. Project implementation

The project manager arranged regular project review meetings at which the overall status of the project was assessed and areas where additional effort was required were identified. These meetings also enabled the project plan to be revised in the light of feedback from the individual reviewers. Since these meetings involved all the reviewers, they also gave an opportunity for issues and topics that affected more than one safety factor to be identified and discussed. There was also an opportunity for 'cross-fertilization' between the different reviewers and the different safety factors to try to ensure that the overall approach to the PSR was as consistent as possible across all safety factors.

In general, the project manager did not actually perform any of the reviews against the individual safety factors but did review the deliverables provided by the individual reviewers. Where appropriate, the project manager also coordinated the review of the deliverables by a second reviewer. Having reviewed all the individual reviews of safety factors, the project manager was also able to contribute to the global assessment in conjunction with the general manager of nuclear operations.

Once all the individual deliverables had been collated into a single report by the technical writer, the report was subject to review by all the reviewers in relation to their contributions in order to verify that their input had been correctly incorporated into the overall report. The reactor operations senior management team also reviewed the entire PSR report as part of the standard line management review and approval process. This review considered the overall adequacy of the PSR as well as consistency across the safety factors.

## II–5. REVIEW OF SAFETY FACTORS

### II–5.1. Safety factor 1: Plant design

The main part of this safety factor relates to the review of applicable codes and standards in order to assess the level of compliance of the facility with the current codes and standards, which may have changed significantly since the facility was originally constructed. The main difficulties with this are the large number of codes that may need to be reviewed and the fact that very few standards organizations actually identify the changes to the individual clauses as a standard is revised. This means that (as stated in SSG-25 [II–1]), a clause by clause review of the applicable standards is normally required. Determining which codes and standards, and particularly what revisions of those codes and standards, were used during the original construction may require significant resources. For this reason, when building a facility or undertaking modifications to it, it is important to keep a copy of the version of each code or standard used which was current at the time of design. Without access to these, it is very difficult to establish a baseline against which to do the assessment.

The process of shortlisting the standards and codes in the original safety analysis report for closer study and comparison with current standards consisted of the following steps:

(a) Tabulate all the standards, including acts of parliament, regulations, standards, guidelines and codes of practice cited in the safety analysis report. (All such documents will be referred to generically as ‘standards’ in the following descriptions.)
(b) Consider if each standard is specifically related to plant design.
(c) Consider if each standard is specifically related to nuclear (which includes thermohydraulic and nucleonic aspects) or radiological safety in the plant design.
(d) Review the safety analysis report to identify the context in which the shortlisted standards (in step (b) and step (c)) have been cited in the safety analysis report and determine if the standard is central to the safety argument presented in the safety analysis report.
(e) In addition, examine plant codes, design documents and manuals for safety category 1 and safety category 2 SSCs to determine which standards were referenced. Add relevant standards that were used in the design and manufacture of these SSCs to the list produced through step (a) to step (d).
(f) For the shortlisted standards, check if there are updates to the standard since the last issue of the safety analysis report. Also check if there are any current standards related to the subject.

(g) Compare the contents of the current standards with the superseded standards used in the OPAL reactor plant design and safety analysis report.
(h) Compare the contents of the relevant sections of the revised or current standards with the arguments presented in the safety analysis report.
(i) Review relevant aspects of the OPAL reactor against the new requirements or guidance in the shortlisted current standards.
(j) Identify any significant safety issues or actions that need to be addressed in the future by ANSTO to meet current standards.

In the case of OPAL, the size and difficulty of this task was recognized early on and it was decided that the best option to perform the actual review would be to recall as a contractor the retired ANSTO staff member who was responsible for the codes and standards used during the construction of OPAL. This enabled the project to take advantage of not only the former staff member's expertise on codes and standards but also that person's intimate knowledge of OPAL and how those codes and standards were applied during construction. Even so, it was found that this review was one of the single biggest tasks of the PSR, and an operating organization intending to perform a PSR on its own facility needs to take this into consideration.

By comparison, the other part of this safety factor, that is, the review of the change control process and the configuration management of documentation, was relatively straightforward. This was owing to a robust change control process and a dedicated configuration management group in place within the OPAL operating organization prior to initial startup of the reactor.

### II–5.2. Safety factor 2: Evaluating the actual condition of structures, systems and components

This safety factor covers the evaluation of the actual condition of the SSCs important to safety so as to determine whether they are able to adequately fulfil their required safety function. This section of SSG-25 [II–1] goes on to outline the scope, tasks and methodology. The following two points may be useful in performing the actual review:

(a) The SSCs that are to be considered need to be clearly identified, as do their design safety requirements. For older plants, it is not always clear what the SSCs important to safety are, and what the safety function they are required to fulfil is. Even for newer plants, differentiating between an SSC's safety function and operational design requirements is not always clear.
(b) As indicated previously, use of the expertise and knowledge of non-professional staff, such as maintenance technicians and fitters, is likely

to make a significant contribution to the review of this safety factor. A particular issue to be aware of is maintenance technician 'work-arounds' that are not formally identified in the plant procedures or instructions in order to keep the plant operational.

In the case of the OPAL PSR, the assessment of the condition of each SSC was performed in four steps as follows (this information was reported in a tabulated form to ensure consistency):

(1) Identify the maintenance, surveillance, inspection and testing activities performed to date that provide information on the condition of the SSC, including routine and corrective maintenance tasks.
(2) Identify significant issues or problems encountered, or modifications done to the SSC to date that provide additional information on the condition of the SSC.
(3) Based on available information, assess and provide a summary description of the present condition or status of the SSC and whether it is adequate to meet its design requirements.
(4) Identify recommended actions to be completed or considered to ensure or improve the condition of SSCs into the future.

The review of this safety factor often has significant interfaces with the reviews of other safety factors, the most obvious of these being safety factor 4 in relation to ageing management. However, from the OPAL PSR experience, significant interfaces also arise with safety factor 8 relating to safety performance, safety factor 10 relating to organization and management systems, and safety factor 11 relating to procedures.

### II–5.3. Safety factor 3: Equipment qualification

The objective of this safety factor was to determine whether equipment important to safety was qualified to perform its designated safety function throughout its installed service life.

For the OPAL PSR, this safety factor was relatively straightforward because, like most research reactors, equipment qualification is generally limited to the seismic qualification of SSCs and some specific qualification requirements applied to electrical equipment and instrumentation and control equipment. This is on the basis that the environmental conditions experienced by research reactors are generally similar to normal ambient conditions. In addition, the original equipment qualification information was readily available and, owing to the young age of the plant, first hand knowledge of the quality systems under

which the plant was constructed was also available. Furthermore, as identified in safety factor 1, a robust change control process and a dedicated configuration management group was in place within the OPAL operating organization prior to initial startup of the reactor. On this basis, a full plant walkdown to verify that installed equipment matched the qualified equipment was not considered necessary.

### II–5.4. Safety factor 4: Ageing

The objective of this safety factor was to determine whether ageing in the OPAL reactor was being effectively managed so that required safety functions were being maintained, and whether an effective ageing management programme was in place for future plant operation.

The review of this safety factor was also fairly straightforward, principally owing to the relatively young age of the OPAL reactor at the time of the first PSR. As such, the review was not structured using the elements identified in SSG-25 [II–1], but rather as an outline of the proposed approach to ageing management at the OPAL reactor as part of a broader asset management programme. The asset management programme covers all the OPAL reactor SSCs to a level commensurate with the criticality of the SSC in relation to plant safety, availability or capability, with safety significance determined based on the SSC safety category as defined in the safety analysis report.

### II-5.5. Safety factor 5: Deterministic safety analysis

The objective of this safety factor was to determine the adequacy of the current deterministic safety case as presented in the safety analysis report, taking into account operating experience since startup and events that have occurred both within the OPAL reactor and at other facilities. However, rather than trying to address each one of the elements identified in SSG-25 [II–1] separately, the methodology adopted was the development of a comprehensive fault schedule for the OPAL reactor.

The paper ‘Application of a Fault Schedule to the PSR of the OPAL Deterministic Safety Case’ presented at the Joint Research Reactor Fuel Management/International Group on Research Reactors Conference in Prague in March 2012 [II–2] outlined the use of a fault schedule as a means of independently reviewing a research reactor’s deterministic safety case. A fault schedule is a comprehensive schedule of initiating events which have the potential to give rise to a radiological release, together with the corresponding lines of protection. It is not simply a list of postulated initiating events and, as such, it is a tool that

enables the verification of the adequacy of the deterministic safety case and also facilitates understanding by non-safety specialists.

It was determined that the deterministic safety case adequately takes into consideration the range of design basis initiating events that could impact safety. In the case of a number of initiating events, it was found that the deterministic safety case could be improved or clarified through the explicit (rather than implicit) consideration of initiating events.

### II–5.6. Safety factor 6: Probabilistic safety assessment

Similar to safety factor 5, the objective of this safety factor was to determine the adequacy of the current probabilistic safety assessment (PSA) as presented in the safety analysis report. This safety factor was only applicable to the OPAL reactor because there was a PSA prepared for it. Since most research reactors worldwide do not have PSAs, this safety factor would not be applicable in those cases.

Since the issue of the original PSA for the OPAL reactor in November 2004, there have been changes that nominally would have affected the results of this PSA. However, these effects are either bounded by the uncertainty margins already contained in the PSA or do not impact the core damage frequency itself. Areas where such changes have been identified include changes to the source data used, implementation of plant modifications and feedback from operational experience. One modification that was assessed in more detail in relation to its potential impact on the PSA was the change from an 8 hour shift roster to a 12 hour shift roster, but this was done as part of the change control process, not specifically as part of the PSR.

### II–5.7. Safety factor 7: Hazard analysis

The objective of this safety factor was to determine the adequacy of the protection of the OPAL reactor against internal and external hazards, with account taken of the actual plant design, site characteristics, condition of SSCs and their predicted state at the end of the period covered by the PSR, as well as current analytical methods, safety standards and operating experience.

The comprehensive fault schedule for the OPAL reactor developed in the safety factor 5 review was also used in the review of this safety factor, specifically in relation to internal hazards, but it was supplemented by a review of the OPAL reactor events. One area where a need for additional work was identified was

the treatment of combinations of external hazards. This was because the safety analysis report as written did not explicitly consider the following combinations:

(a) Two or more external hazards that may be reasonably assumed to occur in conjunction with each other;
(b) One external hazard that may be a consequence of another;
(c) More than one external hazard that may occur coincidentally.

However, such combinations had been considered in a preliminary assessment of the impact of the Fukushima Daiichi nuclear power plant accident on the OPAL reactor, performed at the same time as the PSR, and this assessment was incorporated into the PSR. This resulted in the recommendation that an additional section or subsection be incorporated into the safety analysis report that would address combinations of hazards. In addition, the review determined that the safety case could be improved or clarified through explicitly addressing certain hazards.

### II–5.8. Safety factor 8: Safety performance

The objective of this safety factor was to determine the safety performance of the OPAL reactor and performance trends from records of operating experience. The following were the main areas assessed:

(a) The event reporting and investigation system, including the adequacy of determining root causes and the implementation of any actions arising from the analysis of events;
(b) The selection and recording of safety related operational data, including trend analysis and (again) the implementation of any actions arising from the analysis of that data;
(c) The analysis of safety performance indicators.

The maintenance of records, particularly those associated with performance testing of the containment and doses to operating personnel, was also reviewed and reported on. Performance of this review was facilitated by the dedicated online event reporting system that enables any OPAL staff member to record events. Events are categorized as safety, operational, quality or relationship events, and the event owner is automatically allocated based on the categorization of the event. The event owner can then determine what needs to be done with the event, up to and including allocating an investigator to perform a formal investigation so as to determine root causes and identify actions. The information contained in the event reporting system database was reviewed in relation to the areas of

assessment identified above and a number of recommendations were identified, including improving the training of staff in performing root cause investigations and improving the ability to analyse trends in event data.

Similarly, the original operating licence included a licence condition requiring that a set of safety performance indicators be put in place and reported on to the regulatory body on a quarterly basis. The review consisted principally of reviewing the historical safety performance indicator data and identifying areas for improvement. A number of opportunities for improvement were identified, including giving more emphasis to safety performance indicators that were leading (i.e. predicting future problems) rather than lagging.

### II–5.9. Safety factor 9: Use of experience from other plants and research findings

The objective of this safety factor review was to assess whether there was adequate feedback of safety experience from other research reactors that could reveal unknown safety weaknesses, assist with improvement in design and practices or help solve existing problems at the OPAL reactor. The main elements of the review for this safety factor are the following:

(a) Arrangements for the feedback of experience relevant to safety from other research reactors, other nuclear plants and selected 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 and assessments of and actions on information generated from the research programmes;
(d) Major plant modifications resulting from the above.

This safety factor indicated that the arrangements adopted at ANSTO and for the OPAL reactor use a variety of methods that effectively utilize international links to gather feedback, which assists with identification of issues relevant to the safe operation of the facility. The main recommendation was related to developing a formalized approach to identifying, reviewing and assessing international events that may be relevant to the OPAL reactor's safety and operation.

### II–5.10. Safety factor 10: Organization and administration

The objective of this safety factor review was to determine whether the organization and administration were adequate for the safe operation of the OPAL reactor. The elements considered in this review were the following:

(a) The safety policy stating that safety takes precedence over production and implementation of the policy;
(b) The mechanism for setting operating targets and safety targets;
(c) The documented roles and responsibilities of individuals and groups;
(d) The procedures for the feedback of experience to the staff, including experience relating to organizational and management failures;
(e) The mechanisms for maintaining and documenting the configuration of the OPAL reactor;
(f) Formal arrangements for employing external technical, maintenance or other specialist staff;
(g) Staff training facilities and programmes;
(h) The quality assurance programme and regular quality assurance audits involving independent assessors;
(i) Compliance with regulatory requirements;
(j) Comprehensive, readily retrievable and auditable records of baseline information and operational and maintenance history;
(k) The programme for continuous improvement 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.

This safety factor review was given special attention because, in comparison with a nuclear power plant, a research reactor tends to have a more flexible and dynamic operating organization owing to the greater variation in users and stakeholders. For example, the management of the potential for conflicting demands between the needs of neutron beam research and commercial radioisotope production, while ensuring compliance with the relevant safety requirements, can be complex.

Overall, it was determined that the OPAL operating organization and administrative arrangements were consistent with the then applicable IAEA NS-R-4 requirements (superseded by IAEA Safety Standards Series No. SSR-3 [II–3]) and ensured both nuclear and conventional safety in the broadest sense of the word ‘safety’. A key aspect identified was that both management and staff were working closely together to continuously improve safety and safety culture. A number of recommendations were made, all of

which were opportunities for improvement, including two relating to suggested improvements in the control of subcontractors.

### II–5.11.Safety factor 11: Procedures

This safety factor review evaluated the reactor operations business management system documentation to ensure that there were sufficient procedures in place to operate the OPAL reactor in normal and abnormal situations. Elements assessed included the formal review and approval of new and revised documentation, the understanding and acceptance of procedures by staff, and evidence that procedures were being followed. The adequacy of the procedures in comparison with good practice, including how human factors have been taken into consideration in their preparation and use, was also assessed.

The OPAL reactor had implemented an integrated, hierarchical business management system compliant with Australia and New Zealand standards (which follow ISO 9001 and ISO 14001) as part of the original organizational set-up. This included identifying the administrative controls by which the OPAL reactor was to be safely and effectively managed, which greatly facilitated this review. Owing to the internal and external audit process in place and an ANSTO policy that requires all business management systems to be subject to review and verification of continued and ongoing applicability at least once every five years, a systematic review of individual procedures was not considered necessary or appropriate.

Separate from safety factor 10, this review also determined that the OPAL operating organization and administrative arrangements were consistent with the then applicable IAEA NS-R-4 requirements (now SSR-3 [II–3]). In particular, the reactor operations business management system provides a systematic and integrated approach to ensure effective control of all activities conducted within reactor operations. One area for improvement was the treatment of ageing documents, and a recommendation was for a review process to be established to assist with maintaining the accuracy and relevance of all controlled documentation.

### II–5.12. Safety factor 12: Human factors

The objective of this safety factor review was to determine the status of various human factors that could affect the safe operation of the OPAL reactor. In particular, it was intended to determine whether operator actions that were claimed to be in support of safety were feasible and properly supported. In addition, human factors in maintenance were assessed. The review was wide

ranging and included staffing levels, selection and training; personnel related issues; the style of procedures; and the human–machine interface.

Overall, it was determined that appropriate programmes were in place to ensure that the impact of human factors on safety was controlled and monitored. Continuous improvement of processes relating to human factors had been ongoing and was continuing, and a number of opportunities for improvement were identified as recommendations, including improvements to training records and training curricula.

### II–5.13. Safety factor 13: Emergency planning

The objective of this safety factor review was to determine whether the plans, staff, facilities and equipment for dealing with emergencies were adequate; whether the OPAL reactor's arrangements had been adequately coordinated with other on-site, local and national systems; and whether the emergency plans were regularly exercised.

This review concluded that the emergency planning arrangements at the OPAL reactor and on the ANSTO site were adequate, but a number of recommendations were identified to improve the integration between the OPAL reactor and ANSTO emergency response personnel. Subsequently, a review of emergency planning and testing arrangements was performed as part of the safety reassessment of OPAL in the light of the accident at the Fukushima Daiichi nuclear power plant, and this resulted in further opportunities for improvement.

### II–5.14. Safety factor 14: Radiological impact on the environment

The objective of this safety factor was to review the radiological impact of the OPAL reactor on the environment and to determine whether the operating organization had an adequate programme for surveillance of its radiological impact. This review was facilitated by the following two features:

(a) The extensive environmental monitoring programme that was in place prior to the construction of OPAL and was subject to upgrade (particularly in relation to groundwater monitoring) as a result of the siting licence;
(b) The comprehensive airborne baseline radiological survey of the Lucas Heights site and the surrounding area within the buffer zone that had been performed in response to a licence condition imposed under the siting licence.

In addition, even though emissions from the High Flux Australian Reactor (HIFAR) were low, a comparison with HIFAR was also included to demonstrate

how the design and operation of the OPAL reactor had reduced the radiological impact on the environment compared with HIFAR operation. Overall, the review confirmed that ANSTO had an appropriate and sufficiently comprehensive programme for the surveillance of the radiological impact of the OPAL reactor on the environment and that this impact was negligible.

## II–6. THE GLOBAL ASSESSMENT

Paragraph 6.5 of SSG-25 [II–1] states:

> "The global assessment should be performed by an interdisciplinary team, with appropriate expertise in operation, design and safety at the plant, including an appropriate number of participants from the safety factor reviews. The team should also include members who are independent from the safety factor review teams."

Paragraph 6.6 of SSG-25 [II–1] states:

> "The global assessment should also consider overlaps and omissions between the separate safety factors and so determine whether additional or grouped safety improvements arising from more than one safety factor review are also reasonable and practicable."

For many research reactor operating organizations, compliance with this guidance is often difficult if not impossible due to resource limitations, both financial and human. Limited staffing numbers also tend to mean that there is a reliance on a relatively small number of highly knowledgeable and experienced staff to perform the reviews of individual safety factors, leaving nobody 'independent' within the operating organization to prepare the global assessment. The fact that most research reactors are effectively unique designs compounds this difficulty, since it is often difficult to bring in an appropriate expert from another research reactor who is knowledgeable on the reactor being assessed.

In the case of the OPAL reactor PSR, the global assessment was mainly written by the project manager, who oversaw the review process against the individual safety factors but did not have direct responsibility for any specific review. The general manager of nuclear operations, who had ultimate responsibility for the PSR, also contributed to the global assessment even though he was also responsible for the review of one of the safety factors. This approach was considered the best compromise between the guidance of SSG-25 [II–1] and

the fact that there were no suitably expert ANSTO staff available who were not already involved in the PSR and the review of the individual safety factors.

Although not specifically identified in SSG-25 [II–1], the identification of common themes and root causes across multiple safety factors is an aspect of a PSR that may be requested by a regulatory body. It may be covered in the global assessment through the consideration of interface issues, overlapping issues and omissions, but in the case of the OPAL PSR, the regulator commented that the global assessment was insufficient in this respect. As such, it was necessary to prepare a supplement to the PSR that addressed this comment (among others). This was done by two separate staff members (one of whom was not involved in the original PSR), who reviewed the list of recommendations and allocated one or more keywords or themes for each recommendation. The resultant set of keywords and themes was then reviewed and rationalized, and the common themes and root causes were thus identified. The benefit of identifying them using this approach, as opposed to simply reviewing the individual safety factor reports, was that it was systematic, repeatable and demonstrable in a documented form.

### II–6.1. Findings and recommendations

Paragraph 6.7 of SSG-25 [II–1] states:

> "A method for assessing, categorizing, ranking and prioritizing safety improvements to address negative findings should be established prior to performing the global assessment. The method should be based on the safety significance of each proposed improvement and then applied to all the improvements proposed within the global assessment."

While this sounds simple and straightforward, there are some lessons to be learned, as follows:

(a) Findings can be positive as well as negative and need to include any good practices identified during the course of the PSR. An overly negative PSR can have an adverse impact on the safety culture of the operating organization unless very carefully managed.
(b) The categorization of findings and recommendations needs to be done in accordance with an agreed and documented set of criteria that may be set out in the PSR basis document referred to previously. These criteria may be based on deterministic analysis, PSA, engineering judgement, cost–benefit analysis, risk analysis or a combination of these methods.
(c) Recommendations need to be clearly written as recommendations and not as actions, since actions are defined by the operating organization's line

management to address the recommendations. As an associated point, not every recommendation will have a corresponding action, as recommendations may be rejected by the operating organization's line management if there is appropriate justification (e.g. the potential increase in safety is not sufficient to justify the cost involved).

As indicated above, while the categorization of recommendations in relation to their significance to safety is done as part of the PSR, the subsequent identification and prioritization of actions to implement the recommendations is done by line management. This is necessary, as performing actions generally requires resources (staff, materials, funding), the source of which is normally limited and subject to multiple and often conflicting demands. As such, a recommendation allocating a high safety category does not necessarily result in high priority or high urgency actions.

In the case of the original OPAL PSR, 124 recommendations were identified, although a number of recommendations also had subsidiary recommendations, meaning that a total of 226 individual recommendations were identified. However, 28 of the top level recommendations were effectively related to the same topic: the need to develop appropriate long term maintenance strategies and associated integrated logistic support provisions for 28 different SSCs. Furthermore, this issue was something that had been previously identified, and plans were in place to address this issue as part of the overall ANSTO reactor operations strategic plan to implement a formal maintenance strategy for OPAL that was intended to generally be compliant with the guidance contained in ISO 55001.

All the recommendations arising from the OPAL PSR were allocated to three categories as follows:

(1) Areas where improvements are essential;
(2) Areas where improvements need to be considered;
(3) Observations, where improvements could be beneficial.

The 28 top level recommendations relating to the development and implementation of a formal maintenance strategy for OPAL were identified as category 1. This categorization was also consistent with the operational importance of developing and implementing such a strategy for OPAL. Another set of 28 top level recommendations were also identified as category 1, and many of these recommendations had similarly significant operational benefits. Of the remaining top level recommendations, 60 were identified as category 2, and only 8 were identified as category 3. However, the highest category did not automatically mean that the resultant actions had the highest priority or highest urgency. Using the example of the 28 top level recommendations relating to the

development and implementation of a formal maintenance strategy for OPAL, this resulted in a total of 149 separate actions and was a long term activity.

## II–7. INTERNATIONAL PEER REVIEW

The original licence condition required that ANSTO arrange for the PSR to be subject to international peer review. Initially, consideration was given to requesting the IAEA to arrange for such an international peer review, but owing to resource and time issues, it was decided that ANSTO would arrange this review directly. As such, informal contacts were made with a number of experts from various research reactor facilities worldwide. The peer review team consisted of members from the Nuclear Research and Consultancy Group, the Netherlands; the French Alternative Energies and Atomic Energy Commission, Centre de Cadarache, France; and the High Flux Isotope Reactor, Oak Ridge National Laboratories, United States of America. The report of the peer review team was incorporated into the PSR report unchanged as a separate section.

## II–8. LESSONS LEARNED

The following is a list of lessons learned from the experience of performing the OPAL PSR, which other organizations may wish to take into consideration if and when they also need to perform a PSR:

— Treat the PSR as a project and use normal project management tools to manage its planning and implementation. This includes the preparation of a formal project plan, project quality assurance plan and task briefs for individual technical experts that clearly identify the scope and deliverables of the work.
— Appoint a good project manager to manage the project, preferably one with experience with the facility being subject to the PSR.
— Provide appropriate supporting resources, such as a technical writer or specialist administrative officer, to collate the inputs from the technical experts actually performing the PSR. This ensures that the technical experts concentrate on the PSR itself and not on producing an end report.
— Encourage communication between the technical experts through regular team meetings and one-on-one discussions to maximize cross-fertilization across safety factors.
— An international peer review is highly beneficial not only as an independent review of the PSR but also as a focus for the review team to aim at completing

their work. Arranging and coordinating an international peer review may be done through the IAEA, although the operating organization can arrange such a review itself if it has the appropriate contacts and experience to do so.

— NS-G-2.10 was considered to be an extremely useful starting point for developing the PSR process for a research reactor. However, care needs to be taken to ensure that an appropriate graded approach is adopted relevant to the specific facility.
— The PSR process and its outcomes were considered very useful by the OPAL line management as a way of identifying safety and operational issues and priorities for the reactor independent of the views of the international peer review team, the ANSTO internal safety committees and the Australian nuclear regulator. As such, the operational and organizational benefits of performing a PSR are not to be underestimated.
— The systematic identification of themes and root causes common to a number of safety factors through the review of recommendations can be beneficial in the strategic planning and prioritization of follow-on actions arising from the PSR.

## II–9. CONCLUSIONS

ANSTO undertook a PSR for the OPAL reactor in response to a licence condition imposed by the CEO of the Australian Radiation Protection and Nuclear Safety Agency when granting an operating licence on 14 July 2006. This review was generally in accordance with the guidance provided in NS-G-2.10.

The review addressed the safety factors within the subject areas of plant, safety analysis, performance and feedback of experience, and the environment. The global assessment of the facility concluded that, provided the identified necessary improvements were carried out, suitable arrangements were in place to maintain the safety of the facility for the next ten years, until the next PSR. Recommendations were identified and categorized into areas where improvements were essential (rated as category 1), areas where improvements needed to be considered (rated as category 2) and observations where improvements could be beneficial (rated as category 3). The report was subjected to an international peer review which concluded that the OPAL reactor had accomplished the objectives of a PSR.

## REFERENCES TO ANNEX II


[II–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Periodic Safety Review for Nuclear Power Plants, IAEA Safety Standards Series No. SSG-25, IAEA, Vienna (2013).

[II–2] SUMMERFIELD, M., Application of a Fault Schedule to the Periodic Safety Review of the OPAL Deterministic Safety Case (2012), http://www.igorr.com/Documents/2012-PRAGUE/rrfm2012-transactions.pdf

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

## Annex III

## REGULATORY ASSESSMENT OF THE BUDAPEST RESEARCH REACTOR PERIODIC SAFETY REVIEW

### III–1. INTRODUCTION

According to the Hungarian Atomic Energy Act, the licensee and the nuclear safety regulator need to carry out, at regular intervals, a full scope review and assessment of the safety of nuclear installations by periodic safety review (PSR). The PSR needs to cover the status of fulfilment of nuclear safety requirements and the level of risk, and take into account operational experience and new knowledge relating to nuclear safety. The first ever PSR in Hungary was conducted on a research reactor, serving as a pilot for nuclear power plants. This annex describes the second PSR of the Budapest Research Reactor (BRR).

The Centre for Energy Research of the Hungarian Academy of Sciences — the operating organization of BRR — carried out the second PSR of BRR in 2012–2013. The results are documented in the PSR report according to requirements of the governmental decree on the nuclear safety requirements of nuclear installations and the relevant regulations. The operating organization submitted the periodic safety assessment report (PSAR) to the regulatory authority, as a part of the application for a ten year operational licence renewal. This annex describes the regulatory body's review process of the PSAR.

### III–2. THE BUDAPEST RESEARCH REACTOR

BRR is one of the leading research infrastructures in Hungary and in Central Europe. The basic scientific activity at BRR is the use of neutron beam lines for neutron scattering investigations. BRR is a water cooled, water moderated reactor. BRR went critical on 25 March 1959. Originally, the reactor power was 2 MW, and it was upgraded to 5 MW in 1967. A second full scale reactor refurbishment was started in 1986, fully designed and performed by Hungarian companies. The project was supported by the IAEA and the European Union. The refurbishment was completed by the end of 1990, but owing to political changes in the country, the licence for reactor start-up was issued only in 1992. In 1992, a consortium named Budapest Neutron Centre was formed as an association of the neutron research based laboratories on the Central Research Institute for Physics (Hungary) campus site.

BRR is a tank type reactor, moderated and cooled by light water. The reactor was initially fuelled with Russian type WWR–SM fuel with 36% uranium enrichment. Following the commitment to join the Russian Research Reactor Fuel Return programme, BRR was prepared to change from high enriched uranium (HEU) fuel to low enriched uranium (LEU) fuel. The core conversion took place in a gradual manner during 2007–2012. The selected type of LEU was the Russian type WWR–M2 fuel with 20% enrichment. The core conversion was completed by gradually decreasing HEU fuel assembly numbers. During the core conversion, BRR was operated for four cycles (over eight months each) with mixed HEU–LEU fuel, but since 2012 only 20% enriched fuel has been used.

The core is surrounded by a solid beryllium reflector. The main technical data of the reactor are as follows: thermal power 10 MW; mean power density 39.7 kW/L; approximate maximal thermal neutron flux $2.1 \times 10^{14}$ n · cm$^{-2}$ · s$^{-1}$; maximum cooling water outlet temperature 60°C.

## III–3. LEGAL BACKGROUND OF THE PERIODIC SAFETY REVIEW

The highest level legal instrument of Hungarian nuclear legalization is the Atomic Act [III–1]. It has established a modern, multistage legal and regulatory framework, while the detailed regulations are included in government and ministerial decrees issued based on the empowerment ensured by the Atomic Act. In order to support compliance with the requirements and decrees corresponding to nuclear safety, security and the peaceful use of atomic energy, the Hungarian Atomic Energy Authority (HAEA) provides recommendations on good practices, issued in the form of guidelines. The respective requirements of PSR appear in various levels of legal instruments.

Additional requirements in the next level legal instrument in Governmental Decree 118/2011 Chapter V state the following:

"• The licensee shall prepare a periodic safety assessment every 10 years for all nuclear facilities and the results shall be presented to the nuclear safety authority in a Periodic Safety Assessment Report;
- PSAR prepared one year before the authorities' own deadline; corrective action plan shall be prepared;
- Comparing operational risk of the facility with the Final Safety Assessment Report, national requirements and best practices;
- Authority review finished by decision; modifications of operational licence possible;
- Scope: defined and justified, as wide as possible." [III–2]

The most detailed requirements regarding the periodic safety review are included in annex 1 to the Nuclear Safety Code [III–2]. In addition to the above mentioned requirements, the Nuclear Safety Code states:

> "The scope of the review shall be defined and justified, but at the same time as wide as possible, taking into account the safety aspects of the facility. The minimal contents of PSAR shall be as follows:
>
> — The design of the nuclear facility documented in the Final Safety Analysis;
> — Site characteristics, resistance to external hazard factors;
> — Decommissioning;
> — The current condition of systems and system components;
> — Equipment qualification;
> — Ageing;
> — Safety analyses;
> — Analysis of hazard factors;
> — Safety indicators of the nuclear facility;
> — Evaluation and feedback of relevant technical and scientific results, and
>
> • Operational experience;
> • Utilization of research results and the experience of other similar nuclear facilities;
> • Organization, human factors, management system and safety culture;
> • Procedures;
> • Accident management;
> • Nuclear emergency preparedness;
> • Radiation protection of employees and the population and radiation exposure of the environment; and
> • Experimental equipment in the case of research reactors." [III–2]

## III–4. REGULATORY GUIDANCE ON PSR

To support the review and assessment procedure, the HAEA released Guideline 1.51, Guideline to the Implementation of Periodic Safety Assessment of the Budapest Research Reactor [III–3]. The licensee was actively involved in the process of the development of the guideline via consultancy meetings. The guideline summarizes the purpose of the PSR and specifies the timelines,

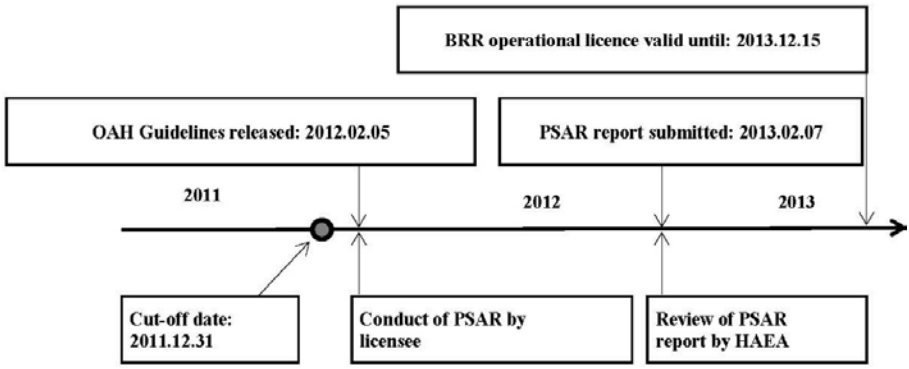


*FIG. III–1. Timeline for periodic safety review of BRR.*

the legal requirements, the standards, the volumes of the report and the quality assurance requirements.

The date of commencement of the PSR is not determined in the legislation, but following the appropriate preparation, the review is expected to be completed within one year. The regulatory review is determined by the regulation, which stipulates that the deadline is six months, and can be extended by 90 days (Fig. III–1).

The periodic safety review is carried out by the licensee on the basis of a designated reference date, and the licensee performs the intended examinations according to the characteristics of the nuclear facility at that time. The reference date needs to precede the commencement of PSR.

In addition to the collective legal requirements and standards taken into account during licensing, the guideline provides a matrix of co-authorities.

In accordance with quality assurance requirements, the HAEA formulated very detailed recommendations. These included recommendations on the enumeration of chapters, the version marking, and the place and form of the signatures of the authors, supervisors and approvals. The licensing documentation needed to be submitted in both paper copy and electronic versions. Taking into account the number of co-authorities, the documentation had to be submitted to the HAEA as one paper copy and six electronic copies on non-writable data carriers.

The guideline recommends that the documents be split into three levels. The first level is the main volume. This is a comprehensive evaluation of the safety of BRR, highlighting the most important findings and statements in particular fields as well as the related corrective actions and their schedule. The second level includes all the volumes on reporting. This involves the review of one or more fields assigned to the volume and its evaluation documentation. The third

level includes all the source documents, the common appendices of the volumes, and records of tests and measurements.

The guideline defines the volumes in the following manner:

(0) Main volume.
(1) Review area volumes:
    (a) Actual technical condition of the facility;
    (b) Equipment qualification;
    (c) Safety analyses;
    (d) Ageing management;
    (e) Indicators of safe operation;
    (f) Use of results of operational experience and research and development;
    (g) Procedures;
    (h) Organizational and administrative factors;
    (i) Human factors;
    (j) Environmental impact;
    (k) Comparison with valid nuclear safety codes;
    (l) Emergency preparedness;
    (m) Research equipment and use of the facility.
(2) Collection volume.

## III–5. HAEA ASSESSMENT PROCESS

To help the process of assessment, the HAEA created internal procedures, which were applicable for the review of the PSAR and the performance of the quarterly and annual assessments. The HAEA staff involved in assessment activities were qualified for the assigned tasks. The regulatory PSAR review began with making a document called the 'work plan', before the PSAR documents were received. The approved work plan's preliminary chapter provided a short description of the goal of the assessment activity and previous inspection activities. The second chapter covered the description of the assessment process including the classifications of a PSAR volume (acceptable, acceptable with correction and not acceptable). The second chapter also provided the ranking process of an identified deficiency: important, less important and not important. The third chapter defined the assessor group members and leaders of each of the volumes. The fourth chapter contained the list of assessment form templates and auxiliary materials, which included the final safety assessment report, nuclear safety codes and other regulations, and inspection records. The fifth and last chapter described the assessment schedule including the deadlines for the assessment group.

The coordinator is in charge of the whole process, including the construction of the team to determine who assesses what. The coordinator prepares the final decision of the regulator and is in contact with the licensee or its representative.

The assessment team is made up of assessment groups, which can consist of one or more people. In the case of the BRR PSAR, one or two people were normally in each group. In the case of nuclear power plants, each group can be made up of five people. The head of the group is responsible for making an assessment summary of the group.

Three different types of assessment forms are used: individual remarks (Fig. III–2), corrective actions (Fig. III–3) and volume assessment (Fig. III–4). Individual remarks are the observations of an individual assessor. Each of the PSAR volumes includes a 'corrective actions' chapter. The measures written there need to be classified by the licensee's organization and reviewed by the regulator. If there is a difference between the opinions of the licensee and the regulator on the classification of a corrective action, it needs to be recorded and justified. The volume assessment is the envelope that covers the results of assessment. This is a summary of all the findings in a more generalized way. It is important during the assessment process, and especially for the volume assessment form, that all the findings and opinions be written in such a way that

**Assessment form_1_Individual remarks**

**BRR PSR – 2013** **Name of assessor:**……

*Volume…*

**INDIVIDUAL REMARK**

| Item No. | Location (page, paragraph) | Remark description | Rank 1[a] | Rank 2[b] | Rank 3[c] | Justification of ranking |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

[a] Important/essential remark: Without its resolution, the PSR volume is not acceptable.
[b] Less important remark: The PSR volume is acceptable, but remark's resolution has to be performed by the next PSR.
[c] Non-important remark: PSR volume is acceptable. Remark's resolution is not obligatory, but it is beneficial to call the attention of Licensee to it.

*FIG. III–2. Assessment form — individual remarks.*

**Assessment form_2_Corrective actions**

**REGULATORY REVIEW OF BUDAPEST RESEARCH REACTOR PERIODIC SAFETY ASSESSMENT REVIEW REPORT**

**Corrective actions**

**Volume number** | **Volume title**

**Assessment group**

**Head of group** | **Members**

| 1. Corrective actions of Budapest Research Reactor | | | | |
|---|---|---|---|---|
| **Identification of the corrective action** | **Nature of deficiency** | **Nature of corrective action** | **Deadline (date, continuous)** | **Classification (preventive, corrective)** |
| | | | | |
| | | | | |

| 2. Further corrective actions suggested by assessment group member | | | |
|---|---|---|---|
| **Identification of the corrective action** | **Nature of deficiency** | **Nature of corrective action<br>A: Administrative<br>T: Technical** | **Deadline (date, continuous)** |
| | | | |
| | | | |

*FIG. III–3. Assessment form — corrective actions.*

sentences can be inserted into higher regulatory documents (letters, decisions) with as little modification as possible.

The assessor prepares a volume assessment and submits it to the head of the group on volume assessment. The head of the group prepares the volume assessment summary, including all the findings of the subordinate assessors. The head of the group can decide to cross out some minor remarks and may reclassify some corrective actions, but this needs to be documented.

During the evaluation, the assessment team has meetings to share information. At the first meeting, the moderator of the meeting, generally

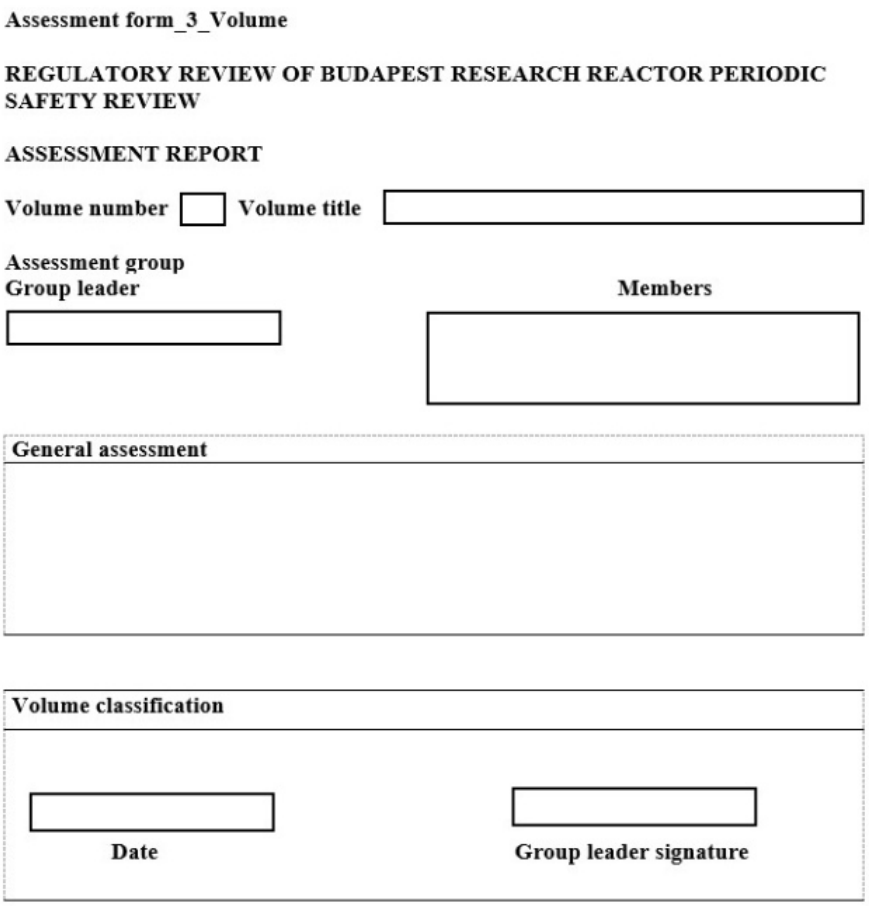


*FIG. III–4. Assessment form — volume assessment.*

the coordinator who is in charge of the whole process, clarifies the situation for the assessment team members and removes any ambiguity regarding the responsibilities of group members. Progress assessment meetings are held every two weeks. The assessment team members have the opportunity to perform inspections at BRR to clarify open issues. A final meeting is held before handing in the documents and discussing problems needing coordinator intervention. The assessments finalized by the assessment group are submitted by the head of the group to the assessment coordinator. The coordinator prepares a preliminary assessment of the whole periodic safety assessment and discusses it with the licensee. At this stage, it is possible to make some minor adjustments. In the case of BRR, some minor technical modifications were removed and some new

analyses were inserted into the decision. The final decision was released with a condition that in ten years the next PSAR needs to be conducted.

## III–6. PSAR CLOSURE AND OPERATIONAL LICENCE

The final decisions of the PSAR included regulatory decision HA5728, which stated the acceptance of the PSAR and closed the review process at BRR; and regulatory decision HA5729, which provided an operational licence for the next ten years for BRR.

The assessments of the following special authorities were converted into conditions and obligations, supported by documentation, that were inserted into the HAEA's final decision:

— National Public Health and Medical Officer Service, Office of the Chief Medical Officer;
— National Directorate General for Disaster Management, Ministry of the Interior;
— Local fire directorate;
— South Transdanubian Inspectorate for Environmental Protection, Natural Protection and Water Management.

The regulatory decision on the closure of the BRR PSAR contained 37 conditions and obligations (see Table III–1). The deadlines for compliance were between 31 December 2013 and 31 December 2016.

Some of the more important reviews and plans for fulfilling conditions and obligations are listed in the following:

(a) Earthquake stability analysis review;
(b) Review of ageing of radiation protection monitoring system;
(c) Reconstruction plan;
(d) Procedure review of the whole management system;
(e) Manufacturing technology, spare part kit maintenance discipline, spare part kit;
(f) Assessment of reactor physics algorithms on the basis of HEU–LEU conversion experience;
(g) Evaluation of role of aluminium in $H_2$ generation during incidents, accidents;
(h) Capacity review of 220 V battery bank and replacement schedule

TABLE III–1. SUMMARY OF CONDITIONS AND OBLIGATIONS OF CLOSURE OF BRR PSAR BY CATEGORY AND RESPONSIBLE PARTY

| Responsible party | Number of conditions by category | | | | Total |
|---|---|---|---|---|---|
| | Technical | Analysis | Management | Administrative | |
| Hungarian Atomic Energy Authority | 7 | 4 | 8 | 1 | 20 |
| Environmental protection authorities | 2 | 0 | 1 | 9 | 12 |
| Health authorities | 0 | 0 | 2 | 3 | 5 |
| Total | 9 (24%) | 4 (11%) | 11 (30%) | 13 (35%) | |

The new licence replaces the former operational licence of BRR, and is valid until 15 December 2023. The new licence contains seven major obligations and conditions, given in the following:

(1) To comply with the BRR PSAR closure points (HA5728);
(2) To operate according to the licensing basis and operational limits and conditions;
(3) To obtain and follow the licences of authorities; to inform the HAEA on licences of other authorities within eight days;
(4) To comply with Ministry of Local Government and Regional Development (Hungary) Decree 19/2007, Chapter II — special fire protection requirements relating to nuclear energy;
(5) To comply with current legislation for references and markings in the PSAR;
(6) To inform the Ministry of the Interior contact point in case of a nuclear emergency or an evolving emergency;
(7) To regularly send data on environmental monitoring to the Ministry of the Interior contact point.

The operational licence contains a list of reportable events, divided into two kinds of events: those reported immediately and those not reported immediately (reported on the next working day).

## III–7. FOLLOW-UP

The fulfilment of a condition needs to be properly documented and this document is to be submitted to the HAEA by the deadline given in the condition. In addition to this, semi-annual reports on the progress of the individual conditions due in the future are required to be submitted.

The fulfilment of a condition is assessed by the PSAR coordinator and the relevant expert as well as the special authorities involved in fulfilment evaluation. The result of the assessment is sent to the licensee and is also documented in the information database of the PSAR, which is the information source for HAEA management on fulfilment progress. In this specific case, some corrective actions reported in the semi-annual report of 2014 were not accepted by the HAEA and additional work needed to be performed.

The PSAR coordinator held an inspection on PSR progress at the end of 2014. PSR progress is also included as an additional item in the regular comprehensive inspection that is held every three years.

## REFERENCES TO ANNEX III


[III–1] Nuclear Safety Regulation of Hungary, Act CXVI of 1996 on Atomic Energy (1996).

[III–2] Nuclear Safety Regulation of Hungary, Governmental Decree 118/2011 (2011).

[III–3] HUNGARIAN ATOMIC ENERGY AUTHORITY, Guideline 1.51, Guideline to the Implementation of Periodic Safety Assessment of the Budapest Research Reactor (2012).

# ABBREVIATIONS

| | |
|---|---|
| ANSTO | Australian Nuclear Science and Technology Organisation |
| BRR | Budapest Research Reactor |
| HAEA | Hungarian Atomic Energy Authority |
| HEU | high enriched uranium |
| HIFAR | High Flux Australian Reactor |
| ISO | International Organization for Standardization |
| LEU | low enriched uranium |
| OPAL | Open Pool Australian Lightwater reactor |
| PSA | probabilistic safety assessment |
| PSAR | periodic safety assessment report |
| PSR | periodic safety review |
| SSCs | structures, systems and components |
| WWR | water cooled, water moderated |

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