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Document Preparation Profile (DPP)
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1. IDENTIFICATION

Document Category or batch of publications to be revised in a concomitant manner

Specific Safety Guide

Working ID: **DS537**

Proposed Title: **Safety demonstration of innovative technology in power reactor designs**

Proposed Action: **New publication**

Review Committee(s) or Group: **NUSSC (lead), WASSC, NSGC, TRANSSC**

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2. BACKGROUND

There is a growing interest amongst States in advanced reactors such as small modular reactors (SMRs). Many of these reactor designs may include innovative technology and manufacturing techniques.

Reactor designs using innovative technology employ new approaches and concepts at the component level, system level and/or at the reactor level which are different from existing practices. Reactor designs using innovative technology may also incorporate known engineering practices and utilize existing structures, systems and components. Reactor designs using innovative technology have not yet reached the same level of maturity as current (proven) designs with respect to knowledge as well as regulatory and operating experience. Reactor designs using innovative technology include prototypes or commercial demonstration plants, and are at different stages of maturity in terms of knowledge and experience, for example:

- Advanced reactors that are at an early stage of maturity and introduce innovative safety approaches. Some of these designs for example rely on non-water-cooled technology.
- Reactor designs using existing technology from other sectors but new to nuclear technologies. Generally, these designs may be at a more intermediate stage of maturity if experience and knowledge accrued in other sectors are readily transferable to the nuclear industry.

- Proven and known nuclear technology implemented on a new application or which may be utilized in new context. Generally, these designs are more mature and could include evolutionary designs such as SMRs based on pressurized water reactor and boiling water reactor technologies.

The IAEA has completed a high level review of applicability of the IAEA safety standards to various technologies, including SMRs and non-water-cooled reactors. The outcome of this review identified areas for enhancement of IAEA safety standards in relation to reactor designs using innovative technology. When these designs are at early stages of maturity, some of the IAEA safety standards do not fully apply or are not sufficient. There is also a lack of guidance related to the application of safety standards to reactor designs with innovative technology that are at a more advanced stage of maturity, presenting a mixture of novel and proven approaches.

Among others, para. 4.29 of Requirement 10 in GSR Part 4 (Rev. 1) and paras 4.14 and 4.16 of Requirement 9 of SSR-2/1 (Rev. 1) are of specific relevance when a design incorporates innovative features or design aspects that have not been sufficiently proven as yet. For instance, para. 4.16 of SSR-2/1 (Rev. 1) states:

> “Where an unproven design or feature is introduced or where there is a departure from an established engineering practice, safety shall be demonstrated by means of appropriate supporting research programmes, performance tests with specific acceptance criteria or the examination of operating experience from other relevant applications. The new design or feature or new practice shall also be adequately tested to the extent practicable before being brought into service, and shall be monitored in service to verify that the behaviour of the plant is as expected.”

The current set of Safety Guides for nuclear power plants was primarily developed for water cooled reactors based on proven technology. However, there is now a need to consider designs with innovative technology which is expected to increase within the nuclear industry.

Amongst the challenges that can be faced when making safety demonstrations for innovative technologies the following are of particular importance:

- Limited information and research on phenomenology. This includes the potential lack of comprehensive knowledge about phenomena and their interactions that may impact a wide range of technical areas (e.g. physical, chemical, and structural material properties over the wide range of operating conditions in a reactor, degradation mechanisms and ageing behaviour, interactions between phenomena).
- No or limited experience, or no or limited operating experience.
- The lack of applicable codes and technical standards.
- Limited applicability of design safety approaches used in conventional reactors, including system design criteria and functional design criteria.
- Limitations in application of traditional approaches and methods for safety assessment.

These issues, if not adequately addressed, may challenge the abilities of developers, operators and other stakeholders to establish a safety demonstration of innovative technology and also may impact the evidence available for the regulatory body to take timely decisions on the safety of reactor designs involving innovative technology (e.g. granting a licence).

The topic is emerging in light of the dynamic developments and the expected timeline of deployment of advanced reactor designs using innovative technology.

3. JUSTIFICATION FOR THE PRODUCTION OF THE PUBLICATION

During 2021, the results of the applicability review have been intensively discussed with Member States' representatives through different platforms. Feedback has been received from discussion with Member States at various topical working groups such as NUSSC, the CSS and the SMR Regulators Forum. Relevant representatives of the Member States with programmes to developed SMRs and non-water cooled reactors such as the US, the UK and Canada have indicated that there is a very timely need to consider the available tools to complement the safety standards in relation to the safety demonstration of reactor designs using innovative technology.

There is also a pressing need to encourage information sharing and dialogue among different Member States' regulatory bodies, design development organizations and operating organizations to seek common solutions or common responses to the technological challenges the new designs pose. This will contribute to ensuring the safe deployment of these technologies.

The existing IAEA safety standards do not explicitly consider how to address innovative technologies (unproven), in particular, how to demonstrate that designs using these technologies can be safely built and operated. For example, there is limited guidance on how to produce a robust safety demonstration when there is a lack of operating experience and limited information on relevant phenomena. There is also a limited guidance on approaches that regulatory bodies and responsible organizations can implement to address the knowledge gaps and uncertainties of reactor designs with innovative technologies and manufacturing techniques. Such approaches may include special design features, specific quality assurance and qualification requirements, programmes of inspections and acceptance testing in the factory or facility and approaches for maintaining oversight of the first of a kind supply chain, as well as the use of expert elicitation and data from other industries.

There is sufficient experience available accumulated through years of demonstrations of the previous and current generation of reactors as well as early interactions between regulatory bodies and developers, for example during pre-application engagements. Even if experience with assessing the safety of innovative technology already exists, it has not been systematically gathered and analysed, and therefore is not specifically reflected in the IAEA safety standards or in other international and national guidance documents.

Additionally, the development of this Safety Guide complements the medium-term plan in design and construction as there is not sufficient information and experience currently to develop requirements and recommendations that cover the design of specific innovative technologies. There is an urgent need to develop this Safety Guide as reactor designs using innovative technology are being developed and deployed, some are already at early stages of regulatory review. In the absence of fully applicable safety standards, the development of this proposed publication will provide timely help for Member States in the context of the challenges described above in Section 2.

4. OBJECTIVE

The Safety Guide will provide recommendations on approaches to address, mitigate, and/or resolve unknowns associated with innovative technology, including systems, components, materials and advanced manufacturing techniques. The objective of these approaches is to support safety demonstrations by developers, operators and other stakeholders that would meet requirements in each

State. These are intended to be used by regulatory bodies in making the necessary and timely decisions to ensure that reactor designs using innovative technology can be safely built and operated.

The Safety Guide will provide recommendations on the elements that are necessary to ensure the safety of innovative technology as well as on the use of specific approaches that can be used at different stages of design, licensing, manufacturing and construction. For example, the use of expert opinion and expert elicitation, the use of data from experiments and operating experience from non-nuclear industries, specific design solutions, safety analysis, codes, quality assurance and approaches to equipment qualification, development and prioritisation of R&D and prototypes. Other available techniques are inspections and tests to identify, eliminate or greatly reduce the impact of these unknowns on the safety of reactors based on innovative technology.

The impact of issues associated with innovative technology during the design (including features to facilitate radioactive waste management and decommissioning), manufacturing and construction and the interface between safety, security and safeguards will also be considered.

The target audience for this Safety Guide includes regulatory bodies assessing the safety demonstration for reactor designs using innovative technology. It will also provide guidance to developers, to facilitate the finalization of their designs in a timely manner prior to submittal to a regulatory body. This Safety Guide may also provide guidance to those organizations working on codes and standards and research laboratories working on design, testing and manufacturing for innovative reactors.

5. SCOPE

This Safety Guide will provide guidance on how the necessary technical aspects of safety demonstration of reactor designs can be achieved for innovative technologies. It will consider design safety and safety assessment, including aspects related to various lifetime phases and potential interfaces between safety, security and safeguards in design. It also covers the specific aspects of construction and manufacturing that are related to the safety demonstration, including specific issues related to the first of a kind supply chain.

The safety guide will focus exclusively on how to consider the specific issues related to innovative technology which is first of a kind and not as mature as current (proven) designs with respect to knowledge, regulatory and operating experience. The Safety Guide will focus on areas where existing safety standards do not apply or may need to be graded, or areas where existing safety requirements are not sufficient to address specific aspects related to the innovative technologies in reactor designs. Any overlap that causes conflicts with existing Safety Guides will be avoided. This Safety Guide will further support and provide clarity on the application of the relevant safety standards for treatment of innovative technology in safety demonstration.

Key topics covered in the safety guide may include the consideration of how innovative technology issues (such as limited information and research on phenomenology, limited experience, lack of applicable codes and technical standards, limited applicability of design safety and safety assessment approaches used in conventional reactors) can be addressed in the safety demonstration including:

- General safety aspects (design safety requirements and general design approaches);
- Development of design, construction and manufacturing requirements (including tests and experiments);
- Safety assessment (including safety analysis, assessment of engineering aspects, equipment qualification, human factors and long-term safety);

- Consideration of interfaces between safety, security and safeguards;

Guidance will also be given on the regulatory oversight of the aforementioned topics.

The Safety Guide recommendations will be applicable to the wide range of innovative reactors and applications at the different stages of design development.

The following topics are out of the scope of the Safety Guide: the consideration of innovative deployment models[1], operational safety and alternative operating approaches, and the lifetime management aspects.

Moreover, it is out of scope to replace or replicate parts of existing safety standards. Amendments and annexes to existing Safety Guides, if considered necessary, will be covered by separate DPPs. The Safety Guide will not aim to provide guidance on evolutionary new systems for the currently operating reactor designs. General issues that are applicable to proven technology are out of scope of the safety guide.

6. PLACE IN THE OVERALL STRUCTURE OF THE RELEVANT SERIES AND INTERFACES WITH EXISTING AND/OR PLANNED PUBLICATIONS

This is a cross-cutting publication that will elaborate on systematic consideration of innovative technology in the design and safety assessment of reactor designs with consideration of aspects related to various lifetime phases .

This Safety Guide will interface at least with the following IAEA safety standards (the list is not exhaustive):

- SSR-2/1 (Rev. 1): Safety of Nuclear Power Plant: Design (2016)
- GSR Part 4 (Rev. 1): Safety Assessment for Facilities and Activities (2016)
- SSR-1: Site Evaluation for Nuclear Installations (2019)
- SSG-69: Equipment Qualification for Nuclear Installations (2021)
- DS508: Assessment of the Safety Approach for Design Extension Conditions and Application of the Concept of Practical Elimination in the Design of Nuclear Power Plants
- SSG-30: Safety Classification of Structures, Systems and Components in Nuclear Power Plants (2014)
- SSG-38: Construction for Nuclear Installations (2015)
- SSG-28: Commissioning for Nuclear Power Plants (2014)
- SSG-2 (Rev. 1): Deterministic Safety Analysis for Nuclear Power Plants (2019)
- SSG-3: Level 1 Probabilistic Safety Analysis for Nuclear Power Plants (2010) and its ongoing revision (DS523)

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[1] Deployment model is understood as the approach taken for the deployment of a NPP that will impact the general ownership of the of the NPP, the responsibility for the lifetime of the NPP including operation, decommissioning and managing of the spent fuel and radioactive waste and the responsibility for liability in case of a nuclear accident.

- SSG-4: Level 2 Probabilistic Safety Analysis for Nuclear Power Plants (2010) and its ongoing revision (DS528)
- NS-G-2.13: Evaluation of Seismic Safety for Existing Nuclear Installations (2009) and its ongoing revision (DS522)
- DS536: Safety Guide on Safety Assessment and Verification for Nuclear Power Plants (proposed to be developed)
- Safety Guide on the Development and Application of Level 3 Probabilistic Safety Assessment for Nuclear Power Plants (proposed to be developed)
- DS533-NST067: Safety Guide on Management of the Interfaces between Nuclear and Radiation Safety and Nuclear Security (proposed to be developed)

7. OVERVIEW

The envisaged Safety Guide would include the following contents:

1. INTRODUCTION
2. DEFINITION OF INNOVATIVE TECHNOLOGY AND RELATED ISSUES

   This section will provide the definition of innovative technology and identify related issues that generate unknowns and uncertainties.

3. GENERAL APPROACHES TO ENSURING SAFETY FOR INNOVATIVE TECHNOLOGY

   This section will outline general recommendations on the elements that are necessary to ensure the demonstration of safety of innovative technology and specific challenges for the regulatory assessment.

   This may include the consideration of general design safety aspects and regulatory assessment in terms of the following aspects:

   - *Comprehensive identification of issues and knowledge gaps*
   - *Study of uncertainties to understand their impacts and potential mitigation*
   - *Use of general approaches to address the knowledge gaps and uncertainties and to gather knowledge to reduce the uncertainties.*
   - *Application of a graded approach based on risk considerations to innovative technology*

   The objective of these general approaches is to address, mitigate, and/or resolve unknowns associated with innovative technology.

4. SPECIFIC STRATEGIES TO ENSURE SAFETY FOR INNOVATIVE TECHNOLOGY

   This section will provide recommendations on specific strategies designers and operators should follow when addressing the safety of innovative technology and what assurance regulatory bodies should seek in safety submissions associated with the aspects listed below:

- *Developing general design expectations for which innovative technology should comply with*
- *Means of gathering the data for design and safety analysis (including consideration of tests and experiments)*
- *Various aspects of safety assessment (including safety analysis, assessment of engineering aspects, human factors and long-term safety, verification and validation of codes and testing) during design and licensing phase*
- *Implementation, manufacturing, construction, pre-operational testing and qualification;*
- *Design lifetime issues such as ageing and degradation, waste management and decommissioning (from 'by design' perspectives);*
- *Consideration of interfaces between safety, security and safeguards.*

5. REFERENCES
6. ANNEXES

To provide specific examples and case studies for solving specific innovative issues

8. PRODUCTION SCHEDULE: Provisional schedule for preparation of the publication, outlining realistic expected dates for each step

STEP 1: Preparing a DPP	DONE
STEP 2: Internal review of the DPP (Approval by the Coordination Committee)	March 2022 (done)
STEP 3: Review of the DPP by the review Committee(s) (Approval by review Committee(s))	13-16 June 2022 (done)
STEP 4: Review of the DPP by the CSS (approval by CSS) or information of the CSS on the DPP	17-21 Oct 2022
STEP 5: Preparing the draft publication	Q4 2023
STEP 6: First internal review of the draft publication (Approval by the Coordination Committee)	April 2024
STEP 7: First review of the draft publication by the review Committee(s) (Approval for submission to Member States for comments)	June 2024
STEP 8: Soliciting comments by Member States	Q3-Q4 2024
STEP 9: Addressing comments by Member States	Q2-Q3 2025
STEP 10: Second internal review of the draft publication (Approval by the Coordination Committee)	September 2025
STEP 11: Second review of the draft publication by the review Committee(s) (Approval of the draft)	November 2025
STEP 12: (For Safety Standards) Editing of the draft publication in MTCD and endorsement of the draft publication by the CSS (For nuclear security guidance) DDG's decision on whether additional consultation is needed, establishment by the Publications Committee and editing	December 2025
STEP 13: Approval by the Board of Governors (for SF and SR only)	
STEP 14: Target publication date	Q2 2026

9. RESOURCES

It is estimated that the proposed new guide would involve approximately 30 weeks of effort by experts. This is based upon assuming 3 one-week consultant meetings involving around 5 experts, and an average of one week of work per expert before each meeting.

Agency resources involved are estimated at 10 weeks of effort for each Technical Officers.