

1 **SPESS F**
2 **Document Preparation Profile (DPP)**
3 **Version 3 dated 31 May 2022**
4

5 **1. IDENTIFICATION**

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

7 **Specific Safety Guide**

8 **Working ID: DS537**

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

11 **Proposed Action: New publication**

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

13 **Technical Officer(s): Paula CALLE VIVES, Shahen POGHOSYAN (NSNI/SAS)**
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15 **2. BACKGROUND**

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

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

- 26 • Advanced reactors that are at an early stage of maturity and introduce innovative safety
27 approaches. Some of these designs for example rely on non-water-cooled technology.
- 28 • Reactor designs using existing technology from other sectors but new to nuclear technologies.
29 Generally, these designs may be at a more intermediate stage of maturity if experience and
30 knowledge accrued in other sectors are readily transferable to the nuclear industry.
- 31 • Proven and known nuclear technology implemented on a new application or which may be
32 utilized in new context. Generally, these designs are more mature and could include
33 evolutionary designs such as SMRs based on pressurized water reactor and boiling water reactor
34 technologies.

35 The IAEA has completed a high level review of applicability of the IAEA safety standards to various
36 technologies, including SMRs and non-water-cooled reactors. The outcome of this review identified
37 areas for enhancement of IAEA safety standards in relation to reactor designs using innovative

38 technology. When these designs are at early stages of maturity, some of the IAEA safety standards do
39 not fully apply or are not sufficient. There is also a lack of guidance related to the application of safety
40 standards to reactor designs with innovative technology that are at a more advanced stage of maturity,
41 presenting a mixture of novel and proven approaches.

42 Among others, para. 4.29 of Requirement 10 in GSR Part 4 (Rev. 1) and paras 4.14 and 4.16 of
43 Requirement 9 of SSR-2/1 (Rev. 1) are of specific relevance when a design incorporates innovative
44 features or design aspects that have not been sufficiently proven as yet. For instance, para. 4.16 of SSR-
45 2/1 (Rev. 1) states:

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

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

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

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

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

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

74

75 **3. JUSTIFICATION FOR THE PRODUCTION OF THE PUBLICATION**

76 During 2021, the results of the applicability review have been intensively discussed with Member States’
77 representatives through different platforms. Feedback has been received from discussion with Member
78 States at various topical working groups such as NUSSC, the CSS and the SMR Regulators Forum.
79 Relevant representatives of the Member States with programmes to developed SMRs and non-water

80 cooled reactors such as the US, the UK and Canada have indicated that there is a very timely need to
81 consider the available tools to complement the safety standards in relation to the safety demonstration
82 of reactor designs using innovative technology.

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

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

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

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

110

111 **4. OBJECTIVE**

112 The Safety Guide will provide recommendations on approaches to address, mitigate, and/or resolve
113 unknowns associated with innovative technology, including systems, components, materials and
114 advanced manufacturing techniques. The objective of these approaches is to support safety
115 demonstrations by developers, operators and other stakeholders that would meet requirements in each
116 State. These are intended to be used by regulatory bodies in making the necessary and timely decisions
117 to ensure that reactor designs using innovative technology can be safely built and operated.

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

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

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

134

135 **5. SCOPE**

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

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

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

- 154 • General safety aspects (design safety requirements and general design approaches);
- 155 • Development of design, construction and manufacturing requirements (including tests and
156 experiments);
- 157 • Safety assessment (including safety analysis, assessment of engineering aspects, equipment
158 qualification, human factors and long-term safety);
- 159 • Consideration of interfaces between safety, security and safeguards;

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

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

163 The following topics are out of the scope of the Safety Guide: the consideration of innovative
 164 deployment models¹, operational safety and alternative operating approaches, and the lifetime
 165 management aspects.

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

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171 **6. PLACE IN THE OVERALL STRUCTURE OF THE RELEVANT SERIES AND** 172 **INTERFACES WITH EXISTING AND/OR PLANNED PUBLICATIONS**

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

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

- 178 - SSR-2/1 (Rev. 1): Safety of Nuclear Power Plant: Design (2016)
- 179 - GSR Part 4 (Rev. 1): Safety Assessment for Facilities and Activities (2016)
- 180 - SSR-1: Site Evaluation for Nuclear Installations (2019)
- 181 - SSG-69: Equipment Qualification for Nuclear Installations (2021)
- 182 - DS508: Assessment of the Safety Approach for Design Extension Conditions and Application
 183 of the Concept of Practical Elimination in the Design of Nuclear Power Plants
- 184 - SSG-30: Safety Classification of Structures, Systems and Components in Nuclear Power Plants
 185 (2014)
- 186 - SSG-38: Construction for Nuclear Installations (2015)
- 187 - SSG-28: Commissioning for Nuclear Power Plants (2014)
- 188 - SSG-2 (Rev. 1): Deterministic Safety Analysis for Nuclear Power Plants (2019)
- 189 - SSG-3: Level 1 Probabilistic Safety Analysis for Nuclear Power Plants (2010) and its ongoing
 190 revision (DS523)
- 191 - SSG-4: Level 2 Probabilistic Safety Analysis for Nuclear Power Plants (2010) and its ongoing
 192 revision (DS528)
- 193 - NS-G-2.13: Evaluation of Seismic Safety for Existing Nuclear Installations (2009) and its
 194 ongoing revision (DS522)
- 195 - DS536: Safety Guide on Safety Assessment and Verification for Nuclear Power Plants
 196 (proposed to be developed)

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.

197 - Safety Guide on the Development and Application of Level 3 Probabilistic Safety Assessment
198 for Nuclear Power Plants (proposed to be developed)

199 - DS533-NST067: Safety Guide on Management of the Interfaces between Nuclear and Radiation
200 Safety and Nuclear Security (proposed to be developed)

201

202 **7. OVERVIEW**

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204 The envisaged Safety Guide would include the following contents:

205 1. INTRODUCTION

206 2. DEFINITION OF INNOVATIVE TECHNOLOGY AND RELATED ISSUES

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

209 3. GENERAL APPROACHES TO ENSURING SAFETY FOR INNOVATIVE
210 TECHNOLOGY

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

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

216 • *Comprehensive identification of issues and knowledge gaps*

217 • *Study of uncertainties to understand their impacts and potential mitigation*

218 • *Use of general approaches to address the knowledge gaps and uncertainties and to*
219 *gather knowledge to reduce the uncertainties.*

220 • *Application of a graded approach based on risk considerations to innovative*
221 *technology*

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

224 4. SPECIFIC STRATEGIES TO ENSURE SAFETY FOR INNOVATIVE TECHNOLOGY

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

228

229 • *Developing general design expectations for which innovative technology should comply*
230 *with*

231 • *Means of gathering the data for design and safety analysis (including consideration of*
232 *tests and experiments)*

- 233 • *Various aspects of safety assessment (including safety analysis, assessment of*
 234 *engineering aspects, human factors and long-term safety, verification and validation of*
 235 *codes and testing) during design and licensing phase*
- 236 • *Implementation, manufacturing, construction, pre-operational testing and qualification;*
- 237 • *Design lifetime issues such as ageing and degradation, waste management and*
 238 *decommissioning (from 'by design' perspectives);*
- 239 • *Consideration of interfaces between safety, security and safeguards.*

240 5. REFERENCES

241 6. ANNEXES

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

243

244 **8. PRODUCTION SCHEDULE:** Provisional schedule for preparation of the publication, outlining
 245 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
STEP 3: Review of the DPP by the review Committee(s) (Approval by review Committee(s))	13-16 June 2022
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

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248 **9. RESOURCES**

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

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

254