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1. IDENTIFICATION

Document Category: **Specific Safety Guide**

Working ID: **DS571**

Proposed Title: **Design of the Reactor Core for Nuclear Power Plants**

Proposed Action: **Revision of IAEA Specific Safety Guide No. SSG-52 "Design of the Reactor Core for Nuclear Power Plants" (2019)**

Review Committee: **NUSSC, NSGC**

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2. BACKGROUND

IAEA Safety Standards Series No. SSG-52, Design of the Reactor Core for Nuclear Power Plants, (hereinafter referred to as SSG-52) was published in 2019 to provide recommendations for meeting requirements established in IAEA Safety Standards Series No. SSR-2/1 (Rev.1), Safety of Nuclear Power Plants: Design, in relation to the fuel and core design for nuclear power plants.

Based on extensive operating experience with water-cooled reactor (WCR) technologies and to be consistent with the scope defined in SSR-2/1 (Rev. 1), the scope section of SSG-52 explicitly indicates that the applicability primarily refers to land based stationary NPPs with WCRs for electricity generation or for other heat production (such as district heating or desalination). In this context, all current recommendations are applicable to light water reactors (i.e. pressurized water reactors and boiling water reactors) and are generally applicable to pressurized heavy water reactors unless otherwise specified.

Advancements in nuclear reactor technologies have led to the deployment of, and growing interest in, non-water-cooled reactor (NCWR) designs, such as high temperature gas cooled reactors (HTGRs), liquid metal fast reactors (LMFRs) and molten salt reactors (MSRs). There are also recent technological advancements in WCRs, particularly within the framework of small modular reactors (SMRs) and micro reactors, regarding their fuel and core design. While these advancements are being considered for a wide range of civil applications, including electricity generation, process heat generation and desalination and claim offering potential safety and operational benefits, they also introduce new challenges related to the safety, performance, reliability, and functionality of the reactor fuel and core design. Such increasing relevance highlights the need to revise and expand the existing safety guidance, i.e. SSG-52, to ensure it remains applicable to evolving reactor technologies.

The feedback analysis is provided in Annex, including a summary of relevant publications.

3. JUSTIFICATION FOR THE PRODUCTION OF THE DOCUMENT

For several years, IAEA General Conference Resolutions on nuclear and radiation safety have requested the IAEA Secretariat to update the IAEA Safety Standards to incorporate specifics of advanced reactors technologies and designs, including both NPPs with NCWR technologies and NPPs with WCR designs, including those considered as SMRs[1]. In addition, recognizing the emergence of NCWR technologies,

[1] See Feedback Analysis Report (Annex) on General Conferences resolutions for advanced reactors and small modular reactors.

several Member States have undertaken or are considering new or updated guidance to address the specific characteristics and safety considerations associated with these designs.

In response to requests from IAEA Member States, the IAEA Secretariat has been collecting feedback for several years on the applicability of safety requirements and recommendations on design safety to identify possible gaps in the application of related IAEA Safety Standards to existing NPPs and to NPPs with advanced reactor technologies and designs[2]. This feedback has been gathered from various IAEA activities, such as technical meetings, workshops and technical safety reviews.

SSG-52 provides recommendations to meet the requirements established in SSR-2/1 (Rev. 1). In particular, there are specific requirements relevant to reactor fuel and core design. In connection with the ongoing revision of SSR-2/1 (Rev. 1), a preliminary gap analysis of the scope and content of SSG-52 has been conducted. It shows that updated technical content is needed to address changes in the revised version of SSR-2/1 (Rev. 1) under DS562, thereby justifying the revision of SSG-52.

Additionally, recent publications have been developed to compile the knowledge for the review. These include the IAEA Safety Report Series No. 123, Applicability of IAEA Safety Standards to Non Water Cooled Reactors and Small Modular Reactors, along with other publications (listed in Annex). SRS-123 categorizes the findings of the review into three distinct groups: i) areas where the standards are applicable to evolutionary and innovative designs (EID), ii) areas where the standards are non-applicable to EIDs, iii) identified gaps and areas for additional consideration. According to SRS-123, SSG-52 was identified as one of the safety standards with numerous applicability considerations, involving more than a third of its content.

Based on the above context, it is proposed to revise SSG-52 to ensure consistency with the revised version of SSR-2/1 (Rev. 1) under DS562, to enhance its applicability to a broader range of reactor technologies and to offer more practical recommendations.

4. OBJECTIVE

The objective of the revision of SSG-52, hereinafter referred to as SSG-52 (Rev. 1) or this Safety Guide, is to provide recommendations for the design of the reactor core for NPPs, as defined in the scope section of this DPP, to meet the relevant requirements established in the revised version of SSR-2/1 (Rev. 1) under DS562.

The recommendations in SSG-52 (Rev. 1) will primarily be aimed at regulatory bodies, designers and operating organizations of NPPs. The recommendations will also be useful for technical support organizations and other organizations involved in manufacture, construction, modification, maintenance, commissioning, and decommissioning of NPPs.

The recommendations in this Safety Guide will be targeted mainly at new NPPs. For existing stationary land-based NPPs in operation or under construction, it may not be practicable to apply all the revised or new recommendations of SSG-52 (Rev. 1). Furthermore, it may not be feasible to modify designs that have already been approved by regulatory bodies. In such cases, it is expected that comparisons will be made with the current IAEA Safety Standards[3] (e.g. during periodic safety reviews) to assess whether reasonably practicable safety improvements could be implemented to further enhance the safety of the plant.

5. SCOPE

SSG-52 (Rev. 1) will expand its current scope to consider all power producing nuclear reactors used for civil purposes (e.g. electrical generation, process heat supply, and desalination), and to integrate updated considerations for WCR (including advanced) and NWCR technologies (e.g. HTGRs, LMFRs, and

[2] Advanced reactor technologies and designs refer to the terminology established in IAEA Nuclear Energy Series NT-T-1.19.

[3] The current IAEA Safety Standards refer to the latest published versions of the documents.

MSRs)[4]. In addition, modularization[5] and specifics of NPPs with small and micro reactor designs, and corresponding deployment options (e.g. modularity[6], remote locations, underground installation) will be considered.

SSG-52 (Rev. 1) will primarily apply to land based stationary nuclear power plants. This Safety Guide will not address the design specific aspects of transportable nuclear power plants (TNPPs). It is also recognized that, for reactor types other than those mentioned above, including innovative developments in future systems, certain parts of this Safety Guide may not be applicable or may require engineering judgment in their interpretation.

The core design considerations for load following flexible operation for co-generation will also be included in the scope of this Safety Guide.

Nuclear reactors for aviation or outer space applications, accelerator-driven systems and fusion facilities will be out of scope for SSG-52 (Rev.1).

The interfaces between safety and security and between safety and safeguards related to the design of the reactor core will be considered in this Safety Guide.

General recommendations on design limits and engineering criteria will be provided. Specific design limits and engineering criteria for individual NPP designs, together with the system parameters that could be used to verify them, will be outside the scope of SSG-52 (Rev.1). Some.

The reactor core consists of basic systems and components, such as the fuel, the coolant, the moderator (if applicable), and the reactivity control devices, as well as additional structures, such as the neutron reflector and shielding structures, the flow guides and supporting structures, and other reactor vessel internals. These systems and components will be covered in the scope of this Safety Guide.

As stated in a requirement of the revision of SSR-2/1 (Rev. 1) under DS562, plant states are required to be identified and grouped into categories. The plant states typically considered for the design of the reactor core are normal operation, anticipated operational occurrences, design basis accidents and design extension conditions without significant fuel degradation. These four states will be referred to as 'all applicable plant states' and covered in the scope of this Safety Guide. Accidents with significant core or fuel degradation, which are addressed in the IAEA Safety Standards Series No. SSG-88, Design Extension Conditions and the Concept of Practical Elimination in the Design of Nuclear Power Plants, will be out of the scope of SSG-52 (Rev.1).

In addition to the core design, recommendations will be provided on the qualification and testing that are necessary to ensure that the core structures, systems, and components (SSCs), especially the fuel, can accomplish their intended functions throughout their respective lifetimes under environmental conditions at all applicable plant states that will be included in the scope of SSG-52 (Rev. 1).

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

During the revision process, appropriate consistency with the contents of all relevant safety standards will be maintained, in particular with those currently under revision and proposed to be revised, SSR-2/1 (Rev. 1) under DS562, SSR-2/2 (Rev.1) under DS532, SSG-30 (proposed to be revised), SSG-48 under DS561, SSG-53 (proposed to be revised), SSG-56 (proposed to be revised), SSG-67 under DS563,

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[4] The main design-specific characteristics of HTGRs, LMFRs and MSRs are described respectively in the IAEA TECDOCs on Considerations on the Safety of High Temperature Gas Cooled Reactors, Considerations on the Safety of Liquid Metal Fast Reactors, Considerations on the Safety of Molten Salt Reactors, currently under development. These characteristics will be explicitly discussed in the revised safety guide.

[5] Modularization is understood as the possibility to assemble several structures, systems and components (SSCs) of the NPP in the manufacturing factory, thereby facilitating subsequent transport / relocation of such assembled modules to the construction site (IAEA-TECDOC-2010).

[6] Modularity is understood as the possibility for the subsequent placing of SMR modules (i.e. reactor modules) close to each other in one NPP (IAEA-TECDOC-2010).

and SSG-68 under DS564. Representatives involved in the development and maintenance of these safety guides will be consulted as appropriate, and cross-references, scope boundaries and common technical topics will be reviewed during drafting meetings and technical reviews to ensure consistent recommendations and a coherent treatment of areas where the guidance overlaps or interacts.

SSG-52 (Rev. 1) will interface with at least the following IAEA Safety Standards Series and other publications (the list is not intended to be final or exhaustive):

1. SF-1 – Fundamental Safety Principles (2006);
2. GSR Part 2 – Leadership and Management for Safety (2016) under revision as DS565;
3. GSR Part 4 (Rev. 1) - Safety Assessment for Facilities and Activities, proposed to be revised
4. SSR-2/1 (Rev. 1) – Safety of Nuclear Power Plants: Design (2016) under revision as DS562;
5. SSR-2/2 (Rev. 1) – Safety of Nuclear Power Plants: Commissioning and Operation (2016) under revision as DS532;
6. SSG-13 (Rev. 1) – Chemistry Programme for Water Cooled Nuclear Power Plants (2024);
7. SSG-30 – Safety Classification of Structures, Systems and Components in Nuclear Power Plants (2014), proposed to be revised;
8. SSG-34 – Design of Electrical Power Systems for Nuclear Power Plants (2016);
9. SSG-39 – Design of Instrumentation and Control Systems for Nuclear Power Plants (2016);
10. SSG-48 - Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants (2018) under revision as DS561;
11. SSG-53 – Design of the Reactor Containment and Associated Systems for Nuclear Power Plants (2019), proposed to be revised;
12. SSG-56 – Design of the Reactor Coolant System and Associated Systems for Nuclear Power Plants (2020), proposed to be revised;
13. SSG-61– Format and Content of the Safety Analysis Report for Nuclear Power Plants (2024);
14. SSG-62 – Design of Auxiliary and Supporting Systems for Nuclear Power Plants (2020);
15. SSG-63 – Design of Fuel Handling and Storage Systems for Nuclear Power Plants (2020);
16. SSG-64 – Protection against Internal Hazards in the Design of Nuclear Power Plants (2021);
17. SSG-67 – Seismic Design for Nuclear Installations (2021) under revision as DS563;
18. SSG-69 – Equipment Qualification for Nuclear Installations (2021);
19. SSG-70 – Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants (2022);
20. SSG-73 – Core Management and Fuel Handling for Nuclear Power Plants (2022)
21. SSG-74 – Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants (2022);
22. SSG-88 – Design Extension Conditions and the Concept of Practical Elimination in the Design of Nuclear Power Plants (2024);
23. SSG-90 – Radiation Protection in the Design of Nuclear Power Plants (2024);
24. Safety Demonstration of Innovative Technology in Nuclear Power Plants (DS537);
25. IAEA Nuclear Safety and Security Glossary (2022 Interim Edition);
26. NSS 13 – Nuclear Security recommendations on physical protection of nuclear material and nuclear facilities (2011);
27. NSS 48-T – Identification and Categorization of Sabotage Targets and identification of Vital Areas at Nuclear Facilities (2024);

28. NSS 33-T – Computer Security of Instrumentation and Control Systems at Nuclear Facilities (2018);
29. Legal Framework for IAEA Safeguards (2013).

Given the interfaces with other IAEA Safety Standards listed above, SSG-52 (Rev. 1) will be coordinated, as relevant with NSNI/EESS, NSNI/OSS, NSNS and the safeguards team dealing with 'safeguards by design' (SGCP POC). In addition, staff from NE will be invited to be members of the development team, and/or consulted for the revision of this Safety Guide.

7. OVERVIEW

The recommendations in SSG-52 (Rev.1) will retain the overall structure and table of contents of the current version of SSG-52, while potentially incorporating new sections, appendices as appropriate, to provide specific recommendations to cover various reactor technologies and their applications. Additional annexes may be included to support the interpretation and application of these recommendations through practical examples.

Section 2 will provide recommendations on general safety considerations in the design of the reactor core that are related to management system, design objectives, design basis for core SSCs, design for safe operation, and reactor core safety analysis. Following revision, this section is expected to be fully inclusive for all reactor technologies.

Section 3 is intended to provide recommendations on specific safety considerations in the design of the reactor core, covering key aspects of neutronic design, thermal-hydraulic design, thermo-mechanical design of fuel, mechanical design of core structures and components, design of reactor core control and shutdown systems, design of core monitoring system, core management schemes, and coolant chemistry control in the core. Following revision, the majority of the safety recommendations in this section are expected to be inclusive for all reactor technologies; whereas some safety recommendations will be applicable only to one or few reactor technologies and their applicability will be clearly specified. In addition, new technology-inclusive or technology-specific recommendations within the above aspects will be developed as needed.

Section 4 is intended to provide new recommendations on technology-specific considerations in the design of the core with liquid fuel, covering, but not limited to, the key aspects of special considerations of heat removal from the fuel[7] and fuel salt compositions and properties. Following the development, the new safety recommendations will complement the guidance provided in Sections 2 and 3.

Section 5 will provide recommendations on the qualification programme for reactor core design as well as on testing and inspection of core SSCs, primarily for fuel. Following revision, this section is expected to be generally inclusive for all reactor technologies.

Annex I will provide explanatory and background information on terminology used in this Safety Guide, consistent with the terminology adopted in the revised version of SSR-2/1 (Rev. 1) under DS562, as well as additional background information or examples supporting certain safety recommendations.

Annex II will describe the safety aspects to be addressed in the design of the common fuel types (such as fuel rod, fuel pebble, prismatic fuel block, and liquid fuel) and in-core assemblies (such as fuel assembly, reactivity control assembly, and neutron source assembly) being used in different reactor technologies covered in this Safety Guide.

1. INTRODUCTION

   Background
   Objective
   Scope

[7] A notable amount of fuel in such designs is expected to be circulated outside the core. As a result, heat removal from the fuel (in and out of the core) needs to be addressed with special considerations in this Safety Guide.

Structure

2. GENERAL SAFETY CONSIDERATIONS IN THE DESIGN OF THE REACTOR CORE

Management system
Design objectives
Design basis for structures, systems and components of the reactor core
Design for safe operation
Reactor core safety analysis

3. SPECIFIC SAFETY CONSIDERATIONS IN THE DESIGN OF THE REACTOR CORE

General
Neutronic design
Thermal-hydraulic design
Thermo-mechanical design of fuel
Mechanical design of core structures and components
Design of reactor core control and shutdown systems
Design of core monitoring system
Core management scheme
Coolant chemistry control in the core

4. TECHNOLOGY SPECIFIC CONSIDERATIONS IN THE DESIGN OF THE CORE WITH LIQUID FUEL

Special considerations of heat removal from the fuel
Fuel salt compositions and properties

5. QUALIFICATION AND TESTING OF REACTOR CORE DESIGN

General
Qualification programme for reactor core design
Testing and inspection for structures, systems and components of the reactor core

REFERENCES

ANNEX I: BACKGROUND INFORMATION AND EXAMPLES FOR KEY TECHNICAL TERMS

ANNEX II: SAFETY ASPECTS TO BE ADDRESSED IN THE DESIGN OF THE COMMON FUEL TYPES AND IN-CORE ASSEMBLIES

CONTRIBUTORS TO DRAFTING AND REVIEW

8. PRODUCTION SCHEDULE

The provisional schedule for preparation of the document, outlining realistically expected dates for each step, is as follows:

STEP 1: Preparing a DPP	Q2 2026
STEP 2: Approval of DPP by the Coordination Committee	Q3 2026
STEP 3: Approval of DPP by the relevant review Committees	Q4 2026
STEP 4: Approval of DPP by the CSS	Q2 2027
STEP 5: Preparing the draft	Q3 2027 – Q1 2029
STEP 6: Approval of draft by the Coordination Committee	Q2 2029

STEP 7: Approval by the relevant review Committees for submission to Member States for comments	Q4 2029
STEP 8: Soliciting comments by Member States	Q2 2030
STEP 9: Addressing comments by Member States	Q3 2030
STEP 10: Approval of the revised draft by the Coordination Committee Review in NSOC-SGDS (Technical Editorial review)	Q3 2030
STEP 11: Approval by the relevant review Committees	Q4 2030
STEP 12: - Submission to the CSS - Submission in parallel and approval by the Publications Committee - MTCD Editing - Endorsement of the edited version by the CSS	Q2 2031
STEP 13: Establishment by the Publications Committee and/or Board of Governors (for SF and SR only))	NA
STEP 14: Target publication date	Q3 2031

9. RESOURCES

It is estimated that full revision of the Safety Guide will involve approximately 400 weeks of effort by experts. This is based upon assuming 10 one-week consultation meetings involving no more than 20 experts and an average of one week of work per expert between meetings.

Agency resources involved are estimated at 60 weeks of effort by the Technical Officers and 40 additional weeks of other IAEA staff.

ANNEX – FEEDBACK ANALYSIS REPORT

In recent years, the IAEA Secretariat and Member States have launched several initiatives to support the safe deployment of nuclear reactors for power generation, including both water-cooled and non-water-cooled technologies. Key initiatives include the SMR Regulators' Forum (SMR RF) and the Nuclear Harmonization and Standardization Initiative (NHSI).

The SMR RF[8] has conducted its work in phases, focusing on the safety and regulatory issues most affected by innovative SMR technologies. The SMR RF has developed common regulatory positions on topics such as the use of passive and inherent safety features, defence-in-depth, multi-units/modules, and shared systems, design extension conditions, safety, security and safeguards in the design and mechanistic source term, thereby contributing to revision of SSG-52.

Similarly, NHSI provides a platform for cooperation among regulatory bodies, technology developers, and industry stakeholders to facilitate the safe and efficient global deployment of advanced reactors. In particular, the NHSI Regulatory Track[9], aims to create a harmonized and technology-inclusive approach for the review of advanced reactor designs building on the IAEA Safety Standards. The NHSI Regulatory Track emphasizes the need for harmonized regulatory approaches to ensure consistent application of key safety design principles. It is developing a technology neutral Global Framework for Advanced Reactors Reviews[10] that will outline essential scope of reviews for international cooperation, key requirements and how these are interpreted by regulatory bodies. It is important that this framework be developed in a manner that is consistent with, and informed by, the revision of SSG-52.

In summary, both the SMR RF and NHSI recommend that the IAEA consider revising SSG-52 to better reflect the unique characteristics of advanced reactor and SMR designs, particularly NWCR technologies, and have developed work that can provide input to this revision.

Recent IAEA General Conference resolutions have highlighted several important gaps and priorities related to the design safety of advanced reactors. The IAEA General Conference has acknowledged that, while current Safety Standards provide a strong foundation, however, given the differences in reactor technologies, there are gaps and additional considerations are needed to address the novel design features of advanced reactors and SMRs (Nuclear Safety Review 2023, GC(67)/INF/2[11]).

The 67th and 68th IAEA General Conferences have reaffirmed the importance of updating safety standards to reflect these emerging technologies.

Therefore, the IAEA has been working to compile technical information necessary for the future revision of IAEA Safety Standards. For the revision of SSG-52, the feedback analysis has primarily considered inputs from:

1) Feedback from publications related to the latest developments of nuclear reactors for power generation, including water-cooled and non-water-cooled reactor technologies;
2) Feedback from the ongoing efforts to address the identified areas of non-applicability and gaps in safety considerations that are relevant to SSG-52 for selected NWCR technologies.

1. Feedback from publications

Over the years, the IAEA has published several documents that highlight the unique characteristics and key design features of advanced reactors. While these publications do not directly address gaps in the guide or its limitations, they offer valuable insights. Many of them describe design aspects that may have a direct or indirect impact on the recommendations provided in the guide. A brief overview of relevant publications is provided in the following.

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[8] https://gnssn.iaea.org/regnet/SMR-Forum/Pages/default.aspx

[9] https://nucleus.iaea.org/sites/smr/SitePages/NHSI-Regulatory-Track.aspx?web=1

[10] https://nucleus.iaea.org/sites/smr/SitePages/Blueprint-for-Development-of-the-Global-Framework-for-Advanced-Reactor-Reviews-(GFARR).aspx

[11] https://www.iaea.org/sites/default/files/gc/gc67-inf2.pdf

IAEA Safety Report Series No. 123 (SRS-123), "Applicability of IAEA Safety Standards to Non-Water-Cooled Reactors and Small Modular Reactors" (2023)

The report identifies areas of novelty of SMRs and NWCRs compared to conventional designs and assesses their impact on the applicability and completeness of current IAEA safety standards. It highlights gaps and areas requiring further consideration across the entire lifecycle of these technologies, from siting and design to decommissioning.

SRS-123 presents the results of the high-level review of SSG-52, where some areas of non-applicability of SSG-52 related to NWCR core design, such as certain WCR terminology used, recommendations specific to WCR design features and characteristics, guidance on moderators, and certain types of accidents specific to WCRs, were identified.

SRS-123 also confirmed gaps in SSG-52 where the current design safety recommendations do not fully reflect the design features of NWCR cores, such as the implementation of design solutions within the safety approach, some technology-specific reactivity feedback, thermo-physical properties of some new materials and the corresponding thermal-hydraulic design limits, core (support) structure, core management schemes, and testing plans and protocols.

As a conclusion, the report emphasizes the need to incorporate reactor technology-specific and design-specific characteristics into the Safety Guide for reactor fuel and core design.

Other relevant publications

Other relevant publications are listed hereafter. They represent a comprehensive and up-to- date body of knowledge that directly supports the revision of SSG-52.

Cross-cutting topics:

- IAEA-TECDOC-2010 (2022), Approach and Methodology for the Development of Regulatory Safety Requirements for the Advanced Nuclear Power Reactors, provides in Appendix A.2. an example for examining existing requirements and the need for new requirements on control of reactivity. The technical document supports the revision of SSG-52 by facilitating the assessment of the existing recommendations and identifying areas where additional guidance may be needed for alternative fuel systems and NCWR core designs.
- IAEA-TECDOC-2110 (2025), Approaches to and Preparation for the Operation of Small Modular Reactors, provides technical information on summarizing the operation modes, such as power operation, hot shutdown, and cold shutdown, for various SMR designs indicate the needs of safety guidance to be covered by the SSG-52 revision.
- IAEA-TECDOC-2134 (2026), Technical Basis for the Emergency Planning Zone for Small Modular Reactors discusses the use of a graded approach to determine emergency planning zone (EPZ) due to smaller core inventory and lower probability of severe accident need to be taken into consideration in the update of relevant recommendations in the SSG-52.
- SMR RF Working Group on Design and Safety Analysis Phase 2 Summary Report (2021) has identified challenges related to certain distinct NWCR core design features, such as increased core surface to volume ratios for integral WCRs and LMFRs, and reduced core power density for HTGRs which support updating the relevant recommendations in the SSG-52.

LWRs

- IAEA-TECDOC-2032 (2023), Status of Knowledge for the Qualification and Licensing of Advanced Nuclear Fuels for Water Cooled Reactors evaluates the applicability of existing IAEA Safety Requirements and Safety Guides in ensuring the safety of advanced fuels during design and operation, and identifies specific aspects that could inform future recommendations, including potential revisions to SSG-52.
- IAEA-TECDOC-2053 (2024), Safety and Performance Aspects in the Development and Qualification of High Burnup Nuclear Fuels for Water Cooled Reactors, presents valuable insights for revising SSG-52 to expand its coverage for high burnup nuclear fuels.

HTGRs

- IAEA-TECDOC-1936 (2020), Applicability of Design Safety Requirements to Small Modular Reactor Technologies Intended for Near-Term Deployment, highlights the specific design features of modular water-cooled reactors and HTGRs. It also proposes amendments to the SSR-2/1 design requirements (including requirements relevant to SSG-52), to address those specifics.
- TECDOC on Considerations on the Safety of High Temperature Gas Cooled Reactors (in preparation). This TECDOC provides technical insights to determine the applicable HTGR plant states within the scope of the upcoming revision of SSG-52.

LMFRs

- IAEA-TECDOC-1569 (2007), Liquid Metal Cooled Reactors: Experience in Design and Operation, provides an overview of the global experience in design, operation and decommissioning of LMFRs. It highlights the unique characteristics of LMFRs, including process parameters, neutron spectrum and coolant chemistry that are directly relevant to core design. It also provides technical insights into LMFR fuel degradation mechanisms to support the development of technology-specific recommendations for the thermomechanical design of fuel.
- IAEA-TECDOC-1912 (2020), Challenges for Coolants in Fast Neutron Spectrum Systems, discusses alternative coolant options for reactor technologies operating in the fast neutron spectrum provides technical insights on specific phenomena that could affect heat removal from the reactor core, e.g. slagging with lead oxides in LFRs and Joint Oxyde Gaine (JOG) in SFRs supporting the development of technology-specific recommendations in SSG-52.
- TECDOC on Considerations on the Safety of Liquid Metal Fast Reactors (in preparation) describes specific safety design features implemented in LMFR concepts to address these conditions. It provides technical insights into neutronics and reactivity control of LMFRs that support the establishment of new technology-specific recommendations addressing the neutronic design of the core for LFMRs in SSG-52.

MSRs

- Technical Report Series No. 489 (2023), Status of Molten Salt Reactor Technology highlights distinct features of MSR core design with liquid fuel (e.g. radioisotope solubility, chemical inertness, no irradiation damage or mechanical failure, and online refuelling). This technical document supports the establishment of new technology-specific recommendations addressing the core design with liquid fuel, covering, but not limited to, the key aspects of special considerations of heat removal from the fuel outside the core as well as fuel salt compositions and properties, i.e. the new Section 4 of the upcoming revision of SSG-52.
- TECDOC on Considerations on the Safety of Molten Salt Reactors (in preparation) provides technical insights into liquid fuel salt properties and the control of reactivity that support the establishment of new technology-specific recommendations addressing the neutronic design of MSR cores with liquid fuel in SSG-52.

2. Feedback from consultancy meetings

In preparation of the SSG-52 revision, three consultancy meetings have been conducted since 2024 to collect Member States' experience in the safety considerations of reactor core and fuel design for NWCRs, including HTGRs, LMFRs, and MSRs. Results of these efforts will be documented in an IAEA TECDOC which is expected to be published in 2027. Methodological approaches to addressing the revision needs of SSG-52 will be summarized by specific technical areas. In addition, detailed proposals for revising the safety guide paragraphs will be suggested, taking into account the technology-specific core design features of the NWCRs.

A categorization methodology has been established to review and assess the revision needs, addressing the safety recommendations in one of the following three categories:

Category 1 (C1): The recommendation in this paragraph is technology neutral or technology inclusive and fully applicable to all reactor technologies and applications. No changes are necessary.

Category 2 (C2): The recommendation in this paragraph is not fully technology-inclusive, but only wording adjustments are needed to ensure broad applicability.

Category 3 (C3): The recommendation in this paragraph is technology specific to land base, water-cooled reactor technologies, or at least not sufficiently applicable (inclusive) to most reactor technologies. It could be retained as is, with clear indication of the applicability. Equivalent or additional recommendations should be developed for specific characteristics of NWCRs.

The gap analysis results indicate that the paragraphs in SSG-52 are categorized as follows:

- In Section 2: There are approximately 11 paragraphs falling under C1, 4 paragraphs under C2, and no paragraphs under C3. There are also 12 paragraphs in the section associated with no recommendations;
- In Section 3: There are approximately 65 paragraphs falling under C1, 32 paragraphs under C2, and 57 paragraphs under C3. There are also 12 paragraphs in the section associated with no recommendations;
- In Section 4: There are approximately 5 paragraphs falling under C1, 3 paragraphs under C2, and 1 paragraph under C3. There is also 1 paragraph in the section associated with no recommendations.

In summary, approximately 40% of paragraphs in SSG-52 fall under C1, where no revision is needed, 19% of paragraphs under C2, where minor revision efforts are expected, and 29% of paragraphs under C3, where major revision efforts are needed. There are also 12% of paragraphs in the safety guide associated with no recommendations.

It is noted that the ongoing efforts to revise SSR-2/1 (Rev. 1) under DS562 could introduce new safety requirements or a new formulation of safety requirements that need to be addressed in the revision of SSG-52. For example, in the revised requirement on structural capability of the reactor core, the technical functions of “insertion of control rods” are expected to be reformulated “to avoid reactivity changes beyond established design limits” and “to render the core subcritical”. Relevant safety recommendations to address this revised requirement need to be added in the revision of this Safety Guide.

As agreed in the consultancy meetings, the revision will focus on the specific safety considerations in the design of the reactor fuel and core for NPPs. It will consider relevant operating experience and the current status of technology development, in order to provide recommendations on how to meet the revised or newly introduced requirements in the revision of SSR-2/1 (Rev. 1) under DS562, including:

1. WCRs (including advanced) with integral and/or compact designs[12] and advanced technology fuels;
2. NWCRs, including HTGRs, LMFRs, and MSRs;
3. Different power outputs, ranging from large to small (e.g. SMRs) or micro reactors;
4. Modularization and modularity of reactor designs;
5. Different neutron spectrum reactors, including thermal, intermediate, and fast;
6. Fuel materials, including UO_2 fuel and plutonium-blended UO_2 fuel (i.e. mixed oxide fuel), metallic fuel, uranium carbide fuel, and uranium nitride fuel;
7. Fuel forms, including pellet (or slug) in fuel rods, kernel in TRISO fuel[13] for HTGRs, and liquid fuel for MSRs;

[12] Integral design refers to the integration of several components of the reactor coolant system inside the reactor vessel which allows simplification of the design because of fewer components. The compact design means a reduced size of the reactor core. (IAEA-TECDOC-2010).

[13] TRISO fuel stands for TRi-structural ISOtropic particle fuel. The kernel of each TRISO particle is typically encapsulated by three layers of carbon- and ceramic-based materials that prevent the release of radioactive fission products.

8. A first leak-tight physical barrier to contain fuel material, including fuel cladding, coated layers in TRISO fuel, and structural boundaries in contact with the liquid fuel;
9. A system allowing fuel to be loaded into and subsequently removed from the core as a single unit, including fuel assemblies and prismatic blocks or spherical pebbles in HTGRs;
10. Reactivity control devices, including control rods, absorber plates, control drums, and moveable reflectors, changing fuel compositions at power, as well as burnable poisons;
11. Core management considerations, including periodic (batch-wise) refuelling scheme and on-power refuelling scheme (e.g. refuelling for pebble fuel and liquid fuel);
12. Chemical properties and toxicity, parameters, and design considerations due to different fuel materials, fuel forms, and coolants.

It is important to note that SSG-52 (Rev.1) will not be limited to the changes listed above. The current version of SSG-52 already provides recommendations for meeting all relevant requirements related to the design of the reactor core, as established in the current version of SSR-2/1 (Rev. 1). The upcoming revision will build upon this foundation, ensuring continued alignment with the full set of applicable safety requirements in the revision of SSR-2/1 (Rev. 1) under DS562. In addition, recognizing that the implementation of a single safety requirement may be supported by recommendations in multiple Safety Guides, SSG-52 (Rev. 1) will consider relevant interfaces to ensure alignment and coherence across the IAEA Safety Standards.