IAEA Study on Design Safety Requirements to SMR Technologies

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Fundamental Safety Objective

The fundamental safety objective aims at protecting people, society and the environment from the harmful effects of ionizing radiation.
Who We Are
NSNI Mission

• To support Member States
  – in establishing the appropriate safety infrastructure
  – to continuously improve the safety of nuclear installations
    • site evaluation
    • design
    • construction
    • operation
  – through the development of up-to-date safety standards and providing for their effective application
Under Article III.A.6 of its Statute, the IAEA is authorized:

“To establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards to its own operation as well as to the operations making use of materials, services, equipment, facilities, and information made available by the Agency…”
Safety Standards Hierarchy

Global Reference Point for a High Level of Nuclear Safety
Fundamental Safety Principles

Safety Objective
To protect people and the environment from harmful effects of ionizing radiation

10 Safety Principles

Responsibility for Safety
Role of Government
Leadership and Management for Safety
Justification of Facilities and Activities
Optimization of Protection
Limitation of Risks to Individuals
Protection of Present and Future Generations
Emergency Preparedness and Response
Protective Actions to Reduce Existing Or Unregulated Radiation Risks

Safety Objective
To protect people and the environment from harmful effects of ionizing radiation
Safety Assessment

Revised after the Fukushima Daiichi accident

Main changes

- Margins to withstand external events and to avoid cliff-edge effects
- Multiple facilities / activities at one site
- Cases where resources are shared
- Human factors in accident conditions
Relevant Safety Guides

Safety Fundamentals

Safety objectives and safety principles

Functional conditions required for safety

Safety Requirements

Guidance on how to fulfill the requirements

Safety Guides

IAEA Safety Standards for protecting people and the environment

Deterministic Safety Analysis for Nuclear Power Plants

Specific Safety Guide No. SSG-2

IAEA Safety Standards for protecting people and the environment

Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants

Specific Safety Guide No. SSG-3

IAEA Safety Standards for protecting people and the environment

Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants

Specific Safety Guide No. SSG-4
Outline and work plan
Prepared by the Secretariat

Review by the committees and Commission on Safety Standards

Drafting or revising of safety standard
by the Secretariat and consultants

Review by the safety standards committee(s)

Endorsement by Commission on Safety Standards

Establishment by the IAEA’s Director General or BoG

Member States

Publication

- SF and SRs approved by BoG
- SGs approved by DG
Commission and Committees

Commission on Safety Standards (CSS)

- Nuclear Safety Standards Committee (NUSSC)
- Radiation Safety Standards Committee (RASSC)
- Waste Safety Standards Committee (WASSC)
- Transport Safety Standards Committee (TRANSSC)
- Emergency Preparedness Safety Standards Committee (EPRNeSC)
Involvement of Stakeholders

Participation by the different stakeholders (for example, regulators, users and co-sponsors) during the **drafting and review phase** is a long established practice.
Applicability

• Primarily: land based stationary NPPs with water cooled reactors
• With judgement: for application to other reactor types, to determine the requirements that have to be considered in developing the design
• It might not be practicable to apply all the requirements to NPPs that are already in operation
• It is expected that a comparison will be made against the current standards, for example as part of the periodic safety review for the plant
Safety Standards are

- Non binding on Member States (MSs) but may be adopted by them
- Binding for IAEA’s own activities
- Binding on MSs in relation to operations assisted by the IAEA or MSs wishing to enter into project agreements with IAEA
IAEA Study on Design Safety Requirements to SMR Technologies
Objective

• Perform a review of the current practices of the application of SSR-2/1 design safety requirements to SMR technologies

• Will be used as an input in future IAEA safety standard review processes in order to reflect practises in this area and foster the practical applicability to SMRs
Principle

- Conducted study on the application of IAEA Safety Standard SSR-2/1 design safety requirements to the following near-term deployment SMR technologies:
  - Light Water Reactor
  - Floating Light Water Reactor
  - High Temperature Gas Reactor
- Study results collected in December 2016
- Feb 2017 held consultancy meeting to develop common understanding amongst comments and develop project report
Participation

- Participation from IAEA SMR Regulators Forum and fourteen organizations from Argentina, China, France, Japan, South Africa, Republic of Korea, United Kingdom and United States of America

- BWXT
- CGNPC
- CNEA
- CNNC
- Holtec
- IRSN
- INET
- JAEA
- KAERI
- NuScale
- Steenkampshraal
- Thorium Limited
- Rolls-Royce
- Westinghouse
- X-Energy
Evaluation

SSR-2/1, Rev 1 Requirement

Requirement 1: Responsibilities in the management of safety in plant design

An applicant for a licence to construct and/or operate a nuclear power plant shall be responsible for ensuring that the design submitted to the regulatory body meets all applicable safety requirements.

3.1. All organizations, including the design organization, engaged in activities important to the safety of the design of a nuclear power plant shall be responsible for ensuring that safety matters are given the highest priority.

Requirement 2: Management system for plant design

The design organization shall establish and implement a...
Criteria

• Applicable as is
• Applicable with interpretation
  – No modification is required, but the rationale for the application of the requirement to the design is different than that of the standard light water reactor
• Application with modification
  – Modification is required to be applicable to the design
• New criteria
• Not applicable
Water-Cooled SMR Outputs (1/7)

- Modification: 6
- Interpretation: 4
- Modification and Interpretation: 1
- New: 1
– Requirement 11, Provision for Construction
  • Change wording “construction and operation” to “manufacture and construction”

– Requirement 12, Features to Facilitate Radioactive Waste Management and Decommissioning
  • Allow for a fleet solution for waste management and the decommissioning process

– Requirements 17, Internal and External Hazards
  • Change the word ‘located’ to ‘located and/or segregated’ in paragraph 5.15A
– Requirement 33, Safety Systems, and Safety Features for Design Extension Conditions, of Units of a Multiple Unit Nuclear Power Plant
  • Each unit, which may be comprised of one or more reactor cores, of a multiple nuclear power plant shall have its own safety systems and shall have its own safety features for design extension conditions

– Requirements 53, Heat Transfer to an Ultimate Heat Sink
  • P. 6.19B deleted, as DEC is already described in Requirement 17, P. 5.21A
– Requirement 57, Access to Containment
  • Many SMR containments are not designed for any human habitation during power operations and are not equipped with large doors or equipment access hatches

– Requirement 68, Design for withstanding the Loss of Off Site Power
  • Add a new paragraph that the design of a power plant may incorporate safety features that are not dependent on electrical power. Consideration should be given for alternate power sources to further strengthen the adopted defence in depth against design extension conditions
– Requirement 73, Air Conditioning and Ventilation Systems
  • Utilize other mechanisms for achieving negative pressure differential for the minimization of contamination spread
  • Consideration should be given to including margin in the design capability of HVAC to allow for the potential addition of new equipment at a later date

– Requirement 76, Overhead Lifting Equipment
  • Broaden the lifting equipment to include non-overhead equipment as some SMRs designs do not allow for the use of overhead lifting equipment because of a lack of overall volume to handle the items and increased risk if load is dropped
– Requirement 78, Systems for Treatment and Control of Waste
  • Allow for a fleet solution for waste management and the decommissioning process
  • Alternate power source may not be required against DEC

– New Requirement 41A, Interactions between the Heat Delivery System and the Plant
  • SMRs provide greater opportunity for nuclear power plants to support industrial facilities that utilize heat or both heat and electricity. This proposed requirement addresses potential disturbances from the process heat user
– **General Enhancements**

• **Modify title of Requirement 45 from “Control of the Reactor Core” to “Control of the Reactivity of the Reactor Core” to enhance understanding**

• **Harmonize terminology specifically related to the terms reactor core, unit and plant**

• **Review all SSR-2/1 requirements for references to DEC and clarify where the requirement is applicable to 1) multiple failure events (without core damage) or 2) postulated severe accidents (with core damage)**
Gas-Cooled SMR Outputs (1/2)
Gas-Cooled SMR Outputs (2/2)

Recommendations based on:

– General design differences
  • LWR specific examples
  • Fuel – fuel assemblies vs pellets / block fuel design
  • Reactivity Control
  • Reactor Coolant System
  • Containment
    • Inherent and passive safety systems

– Redefine DEC (with core melt)

– Emphasis on power generation and process heat applications
Gas-Cooled SMR Outputs (2/10)

– General design differences
  • LWR specific examples: 7, 30, 81
  • Fuel – fuel assemblies vs pellets / block fuel design: 43, 44, 80
  • Reactivity Control: 45, 46,
  • Reactor Coolant System: 47, 48, 50
  • Emergency Operations: 52, 68, 77
  • Containment: 54, 55, 56, 57, 58
  • Use of inherent and passive safety systems: 33, 42
  • Other: 66,

– Redefine DEC (with core melt)
  • Requirements 13, 20

– Power generation and process heat applications
  • Requirements 17, 35
– Requirement 7, Application of Defence in Depth
  • *Examples are specific to water-cooled reactors and thereby, not applicable*

– Requirement 13, Categories of Plant Status
  • *DEC with core melt is not definable for mHTGR ceramic fuel*

– Requirements 17, Internal and External Hazards
  • *Account for power generation and process heat application by demonstrating that transients and events at the power conversion or industrial facility can be decoupled from the nuclear power plant*
– Requirement 20, Design Extension Conditions
  • *DEC is applicable to all reactor types, but generalization required in reference to core melt and reactivity releases exterior to the fuel / containment*

– Requirement 30, Qualification of Items Important to Safety
  • *Examples are specific to water-cooled waters and thereby, not applicable; e.g., containment leak rate*

– Requirements 33, Safety Systems, and Safety Features for Design Extension Conditions, of Units of a Multiple Unit Nuclear Power Plant
  • *Reword to allow for safety systems to be shared if they do not lead to greater risk*
– Requirement 35, Nuclear Power Plants used for Cogeneration of Heat and Power, Heat Generation or Desalination
  • *In title, replace “heat” with “process heat”*
  • *Add provisions to focus on decoupling from NPP, external and internal hazards and transport of radionuclides*

– Requirement 42, Safety Analysis of the Plant Design
  • *More emphasis on inherent safety features and passive safety systems rather than operator action*

– Requirements 43, Performance of Fuel Elements and Assemblies
  • Augment definition for “fuel elements and assemblies” to include mHTGR pebble and block fuel designs
– Requirement 44, Structural Capability of the Reactor Core
  • Requirements for mHTGR reactor core and supporting structures fundamentally different – design focus primarily on reactor core and supporting structures is placed on preventing unacceptable loads to the coated fuel particles

– Requirement 45, Control of the Reactor Core
  • Include reference to on-line refuelling

– Requirements 46, Reactor Shutdown
  • Replace “independent systems” with “independent means” to ensure means other than rapid control rod insertion can be used to shutdown the reactor
Gas-Cooled SMR Outputs (6/10)

– Requirement 47, Design of Reactor Coolant Systems
  • *Place emphasis on air ingress*

– Requirement 48, Overpressure Protection of the Reactor Coolant Pressure Boundary
  • *Revision required to address design changes – no means to remove radioactive materials from reactor coolant released from the pressure relief device*

– Requirement 50, Cleanup of Reactor Coolant
  • Additional text required to address impurities introduced via helium coolant
Gas-Cooled SMR Outputs (7/10)

– Requirement 52, Emergency Cooling of the Reactor Core
  • Cooling of reactor core typically not required during accident conditions but rather for reactor pressure vessel

– Requirements 54, Containment System for the Reactor; 55, Control of Radioactive Releases from Containment; 56, Isolation of the Containment; 57, Access to Containment; and 58, Control of Containment Conditions
  • Some designs do not have a containment structure but may have a containment system or confinement system
Gas-Cooled SMR Outputs (8/10)

– Requirement 66, Supplemental Control Room
  • Not as important as for water-cooled technologies

– Requirement 68, Design for withstanding the Loss of Off-Site Power
  • Modify requirement as mHTGRs rely on passive residual heat removal systems not active safety systems. Post-accident power requirements are adequately addressed by batteries only.

– Requirement 77, Steam Supply System, Feedwater System and Turbine Generators
  • Additional text required to address water ingress from secondary to primary and over-pressure protection
Gas-Cooled SMR Outputs (9/10)

– Requirement 80, Fuel Handling and Storage Systems
  • Remove reference to term “fuel assembly”
  • Provide means for management of individual fuel elements (pebbles)
  • Address HTGR’s air cooling fuel storage system

– Requirement 81, Design for Radiation Protection
  • Examples are specific to water-cooled waters and thereby, not applicable
– *New Requirement 83*, Nuclear Power Plants with Multi-Reactor Modules
  
  • Address plant layout and construction, interconnections between modules, control and protection systems and safety analysis
Considerations for Future Work

• Revision of SSR-2/1 to incorporate considerations
• Review of U.S. NRC 10CFR50 Appendix A requirements for advanced non-light water reactors;
• Development of an IAEA technical report to document the outcomes of this project
Future Activities

• 2Q 2018, HTGR specific consultancy meeting
Thank you for your kind attention!
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