Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

Canada

Reviewing Innovative Reactor Designs – A CNSC Perspective

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Canadian Nuclear Safety Commission

OUR MANDATE

REGULATE
the use of nuclear energy and materials to protect health, safety, and security and the environment

IMPLEMENT
Canada's international commitments on the peaceful use of nuclear energy

DISSEMINATE
objective scientific, technical and regulatory information to the public

OVER 70 YEARS OF REGULATORY EXPERIENCE

Legal Basis for Risk-Informed Regulation

The purpose of this Act is to provide for

Section 3(a) the limitation, to a reasonable level and in a manner that is consistent with Canada's international obligations, of the risks to national security, the health and safety of persons and the environment that are associated with the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information;

Basis for a Licensing Decision

Section 24 (4) *No licence may be issued, renewed, amended or replaced unless, in the opinion of the Commission, the applicant:*

(a) is qualified to carry on the activity that the licence will authorize the licensee to carry on; and

(b) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed

Safety Case and the Licence Application

Safety and Control Areas (SCAs)
Management System
Human Performance Management
Operating Performance
Safety Analysis
Physical Design
Fitness for Service
Radiation Protection
Conventional Health and Safety
Environmental Protection
Emergency Management and Fire Protection
Waste Management
Security
Safeguards and Non-Proliferation
Packaging and Transport
Other regulatory areas
Public information and disclosure
Engagement with indigenous peoples

- Technical topics the CNSC uses to assess, review, verify and report on regulatory requirements and performance across all regulated facilities and activities
- Regulatory framework documents exist for each **Safety and Control Area** (SCA)
- Application comprises the safety case, and is part of the licensing basis for the regulated activity

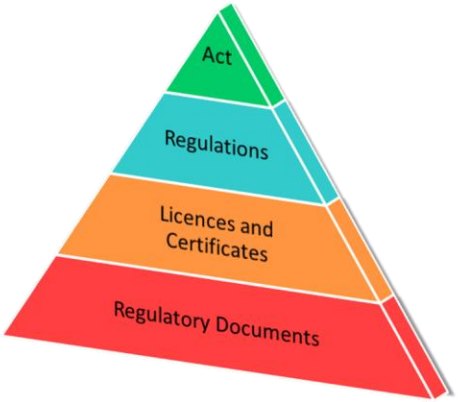
Technical Topic – Physical Design

REGDOC-2.5.2 Design of Reactor Facilities

- Sets out design requirements and guidance
- Aligned with international practice (IAEA SSR-2/1)
- Outlines safety objectives and concepts to be applied
- Includes requirements for safety management of the design

Important sections for new materials and components:

- Proven engineering practices
- Design rules and limits
- Alternative approaches



Industry Codes and Standards

REGDOC-2.5.2, Section 5.4 Proven Engineering Practices (Codes and Standards):

- Design authority shall identify the modern codes and standards that will be used for the plant design
- Codes and standards need to be evaluated for applicability, adequacy, and sufficiency with respect to the design
- Where needed, codes and standards shall be supplemented to ensure that the final quality of the design is commensurate with safety function
- Structures, Systems and Components (SSCs) important to safety shall be of "proven" design, and shall be designed according to the standards and codes identified for the Nuclear Power Plant (NPP)

Novel Designs or Features

REGDOC-2.5.2, Section 5.4 Proven Engineering Practices (New design or feature):

- Adequate safety shall be demonstrated by a combination of supporting research and development programs and by examination of relevant experience from similar applications
- An adequate qualification program shall be established to verify that the new design meets all applicable safety requirements
- New designs shall be tested before being brought into service and shall be monitored while in service so as to verify that the expected behaviour is achieved
- Where the design has to accommodate an SSC failure, preference shall be given to equipment that exhibits known and predictable modes of failure, and that facilitates repair or replacement

Engineering Design Rules and Limits

REGDOC-2.5.2, Section 7.5 Design Rules and Limits:

- The design authority shall specify the engineering design rules for all SSCs. These rules shall comply with appropriate accepted engineering practices
- The design shall also identify SSCs to which design limits are applicable
- The engineering design rules for all SSCs should be determined based on their importance to safety (safety classification) and include:
  - Material specifications
  - Conservative safety margins
  - Reliability and availability
  - Equipment qualification
  - Operational considerations

Appropriate Margins

- Understanding margins to failure is tantamount to maintaining safety
- Design Margin, analysis margin, safety margin, operating margin, etc.
- Materials properties knowledge is fundamental
- Margins should cover uncertainties, aging and wear, and unknown unknowns, etc.
- Failure limits need to be established for the physical barriers
  - based on experimental data obtained under sufficiently representative conditions
  - set close to the values indicating non-failed state (rather than close to data for failed states) especially where the experimental data are limited,
  - account for measurement uncertainties and data scatter
- Margins need to consider the entire lifecycle of the material or component

It is recognized that, at the same time, efficiency of operation requires optimization of safety margins

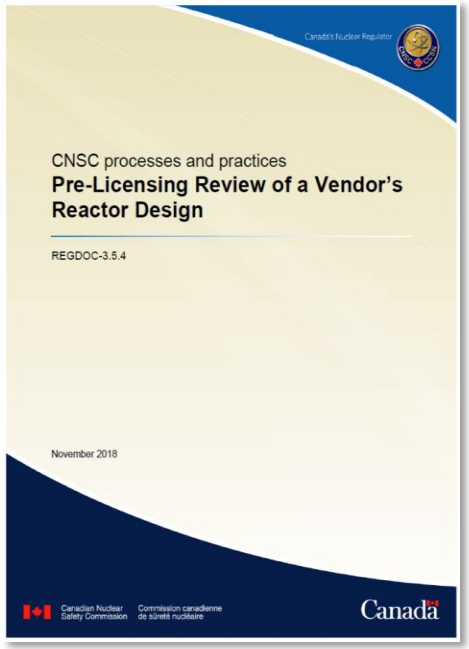
Vendor Design Review

AN OPTIONAL PRE-LICENSING PROCESS THAT ASSESSES:

1. How the vendor is addressing Canadian requirements in their design and safety analysis activities
2. Key issues emerging in a design that could impact a licensing process for a potential future project referencing the vendor's design

This process does not "approve" a generic design and is not site specific.

The conclusions of any design review ***do not bind or otherwise influence decisions made by the Commission*****.**



CNSC Pre-Licensing Vendor Design Reviews

Company	Reactor type / output per unit	VDR Status
Terrestrial Energy	Molten salt integral / 200 MWe	PHASE 1 completed 2018, **PHASE 2 in progress**
Advanced Reactor Concepts	Sodium pool fast spectrum /100 MWe	PHASE 1 completed 2019, PHASE 2 service agreement under development
Moltex Energy	Molten salt fast spectrum / ~300 MWe	**PHASE 1 in progress,** phase 2 pending
SMR, LLC. (A Holtec International Company)	Pressurized water / 160 MWe	**PHASE1 in progress** PHASE 2 service agreement under development
UltraSafe Nuclear/Global First Power	High-temperature gas prismatic block / 5 MWe	Phase 1 completed 2018 PHASE 2 project start pending mid-2020
NuScale Power	Integral Pressurized Water / 50 MWe	PHASE 2 project start pending
U-Battery	High temperature gas prismatic block / 4 MWe	PHASE 1 project start pending
GE-Hitachi	Boiling Water / 300 MWe	PHASE 2 service agreement under development
X Energy	High temperature gas pebble bed / 75 MWe	PHASE 2 service agreement under development
Westinghouse Electric Co.	eVinci Micro Reactor / < 25 MWe	PHASE 2 service agreement under development
LeadCold	Molten lead pool fast spectrum / 3 – 10 MWe	PHASE 1 on hold at vendor request
StarCore Nuclear	High-temperature gas prismatic block / 10 MWe	PHASE 1 and 2 service agreement on hold

Determination of "Proven"

- What level of evidence is necessary for a regulator to make the determination that an aspect of the design is "proven" enough?
- Are uncertainties understood and adequate safety margins applied?
- Are additional safety and control measures needed?

Prototypical experiments	Collect specific scientific/ engineering information on (proof of concept)	Low state of proven-ness – risks and uncertainties are higher – additional safety and control measures needed
Demonstration reactor / First-of-a Kind	Demonstration of integrated components / systems and collection of OPEX to refine design for nth of a kind	Varying amounts of OPEX – proving in progress- varying risks and uncertainties to be addressed – some additional safety and control measures needed where uncertainties are high
Nth-of-a-Kind	Commercial operation – information used to improve operational performance	High state of proven-ness – uncertainties generally well understood and ongoing R&D supports management of uncertainties

Supporting Safety Claims

- Effective Management Systems
- Quality-assured scientific and engineering processes
- Adequate and relevant R&D experimental or field-derived data
- Relevant operating experience
- Application of codes and standards or alternatives
- Verified and validated computer models
- Identification and characterization of uncertainties
- Lifecycle considerations taken into account (margin deterioration)

Regulatory Research Program

Generates knowledge and information to:

- Support timely, science-based regulatory judgments and decisions
- Allow the regulator to perform a challenge function when discussing safety claims (what questions to ask)
- Aid in the development of safety standards
- Contribute to the independence of the regulator
- May include supplemental training, technical papers and Workshops
- Supported by the Federal Nuclear Science and Technology program

Conclusions

- CNSC continues to take steps to improve its readiness to regulate SMRs
- A diversity of technologies with innovations are under review
- Supporting research is underway to fill regulatory knowledge gaps
- International collaboration is an important contributor to regulatory efficiency

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- SMR design and safety analysis must be supported by R&D activities
- Effective management systems and quality assurance must be used
- The development and application of codes and standards will be crucial in supporting innovation

Questions

Thank You!

As Scientists and Engineers, we must hold the balance between irresponsible optimism and crippling caution. Gwen Martin 2011

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