Update on the application of Canadian Regulatory Framework to Advanced Reactor Technology Reviews

Oak Ridge National Laboratory – Molten Salt Reactor Workshop 2018

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Disclaimer

This presentation does not contain any specific discussions, activities or outcomes from engagement with vendors of molten salt or other new reactor technologies.

It is a sample of general observations noted in reviewing how new technology vendors are applying existing Canadian regulatory requirements in the CNSC's Vendor Design Review process.

CNSC Mandate : *Nuclear Safety and Control Act*

The CNSC regulates the development, production and use of nuclear energy, and the production, possession and use of nuclear substances, prescribed equipment and prescribed information in order to prevent unreasonable risk.

Regulatory requirements and processes support this mandate.

Potential Applicants vs Technology Developers (Vendors)

Role of an applicant

Licensing involves an **applicant** for a **licence** who is proposing to build and operate a vendor's design. This is usually an owner/ operator of a plant and they are ultimately responsible and accountable for the safe conduct of the activities being licensed.

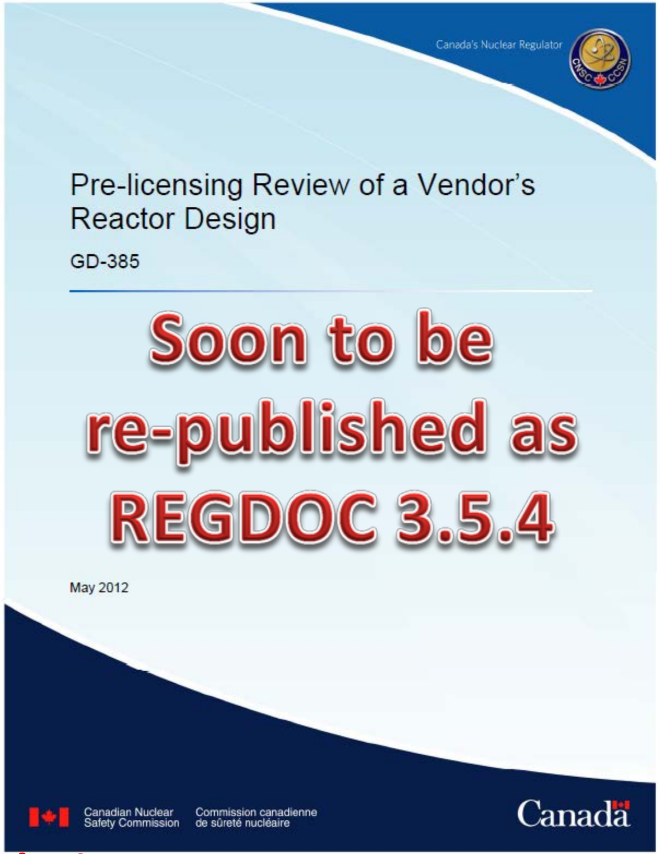
An applicant develops the safety case for their project

Role of a vendor

A **vendor** is part of the licensee's **procurement process**. They supply services and products including information which applicants can leverage to support a safety case.

What is a Vendor Design Review?

- An optional process for CNSC to provide early feedback to the technology developer on:
  - how the vendor is addressing Canadian requirements in their design and safety analysis activities taking into account new design features and approaches.
  - key issues emerging in a design that could impact a licensing process for a future project referencing the vendor's design.
  - progress by the vendor to address outstanding issues.



This process does not "approve" a generic design
Under Canadian regulations, a design can only be "accepted" within the licensing basis for a specific project

The Two Primary VDR Phases

- **Phase 1** – duration approx. 18 months
  - the vendor demonstrates, through their design program and associated design processes as well as conceptual level design information, intent to meet CNSC design requirements
- **Phase 2** –duration approx. 24 months
  - the vendor demonstrates, through design processes and system level design information that requirements are being met
  - The vendor shows how sufficient evidence is being generated to support safety claims
  - CNSC identifies where potential fundamental barriers to licensing may exist or are emerging in the design

Status of Vendor Design Reviews

No.	Country of origin	Company (Design)	Reactor Type	Elec. Output per unit	Status
1	Canada - U.S.	Terrestrial Energy (IMSR-400)	Molten salt (graphite moderated)	200 MWe	PHASE 1 - Completed PHASE 2 – Start pending
2	U.S.- Korea - China	Ultra Safe Nuclear (MMR-5)	High-temperature gas cooled (graphite moderated)	5 MWe	PHASE 1 - Near completion PHASE 2 - Service Agreement signed
3	Sweden - Canada	LeadCold (SEALER)	Liquid metal cooled - Lead (no moderator - fast spectrum)	3 to 10 MWe	PHASE 1 - On hold at vendor's request
4	U.S.	Advanced Reactor Concepts (ARC-100)	Liquid metal cooled - Sodium (no moderator - fast spectrum)	100 MWe	PHASE 1 - In progress
5	U.K.	Urenco (U-Battery)	High temperature gas cooled (graphite moderated)	4 MWe	PHASE 1 - Service Agreement under development
6	U.K.	Moltex Energy (SSR-W300)	Molten salt (no moderator - fast spectrum)	300 MWe	PHASE 1 - In progress
7	Canada - U.S.	StarCore Nuclear	High-temperature gas cooled (graphite moderated)	20 MWe	PHASE 1 & 2 - Service Agreement under development
8	U.S.	SMR LLC - a Holtec International Company (SMR-160)	Pressurized water (light water moderated - PWR)	160 MWe	PHASE 1 - In progress
9	U.S.	NuScale Power (NuScale)	Pressurized water (light water moderated - PWR)	50 MWe	PHASE 2*- Service Agreement under development
10	U.S.	Westinghouse Electric (eVinci)	Heat pipe / Nuclear battery	< 25 MWe	PHASE 2*- Service Agreement under development

* Phase 1 objectives will be addressed within the Phase 2 scope of work

Lesson Learned #1: Vendor should emphasize "first plant" in VDR process with a vision to an "Nth of a kind"

- Safety provisions and related margins in the design must address uncertainties in view of limited or no operating experience.
- VDR process, particularly Phase 2 has an emphasis on providing feedback on potential fundamental barriers to licensing based on the state of evidence available for a first deployment of the design in a project.
- Vendor may identify strategies for future design changes as experience is gained. This strategy can be considered by applicants.

History has shown that significant design changes are made based on experience from constructing and operating the first plant.

Lesson Learned #2: Working with the Canadian regulatory framework (1)

There are many ways to acceptably meet safety objectives articulated in requirements:

- Existing requirements and guidance form the basis for the "conversation" around what is acceptable in a demonstration.
- They are informed by decades of global operating experience.
- In a VDR, how the vendor is arriving at their conclusions is as important as the final outcome.

Requirements and guidance will evolve over time as global science and operating experience grows.

Lesson Learned #2: Working with the Canadian regulatory framework (2)

CNSC will consider alternative approaches to requirements where:

- the alternative approach would result in an equivalent or superior level of safety.
- the application of the requirements conflicts with other rules or requirements.
- the application of the requirements would not serve the underlying purpose, or is not necessary to achieve the underlying purpose.

A demonstration is expected to be supported by an appropriate combination of research and development, relevant operating experience and other applicable information.

Lesson Learned #3: Management Systems

The vendor is expected to demonstrate an effective management system for design and safety analysis:

- Programs and processes expected to be logically and systematically implemented as well as risk-informed.
- Quality management is an integral part of each process.
- Bases for decisions need to be documented for traceability.

The "how" and the "why" is part of supporting that design claims and evidence are addressing requirements.

VDR Lesson Learned #4: Conduct of R&D Program

- Processes for identification and analysis of knowledge gaps are being used
- Effective governance of the program in place including arrangements between the vendor and service provider organizations
- R&D activities are conducted using appropriate good practices (e.g. standards for QA, record keeping)

The R&D Program is an integral part of the Management System for Design and Safety Analysis and will be used over the life of an operating fleet by licensees

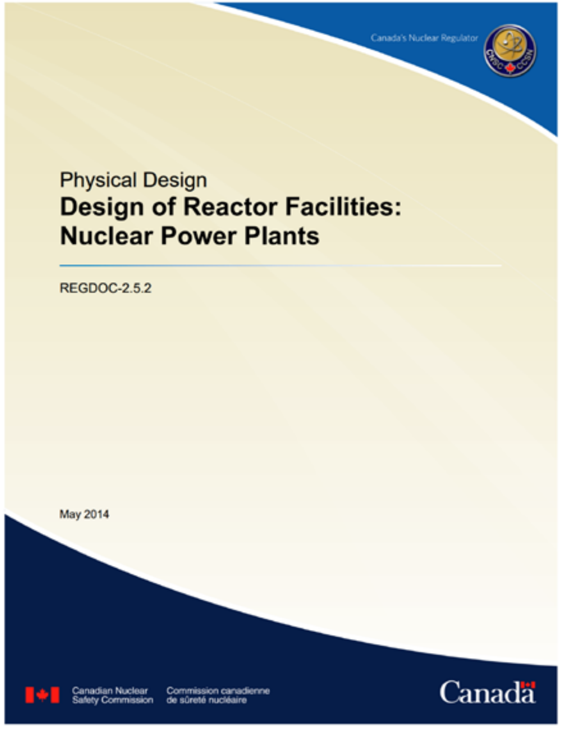
SPECIFIC LESSON LEARNED: DEMONSTRATING TECHNICAL SAFETY OBJECTIVES ARE MET

Technical safety objectives

"The technical safety objectives are to provide all reasonably practicable measures to prevent accidents in the NPP, and to mitigate the consequences of accidents if they do occur. This ***takes into account all possible accidents considered in the design, including those of very low probability"***

Technical safety objectives provide the basis for requirements that support the achievement of:

- **Dose Acceptance Criteria** – Anticipated Operational Occurrences (AOO) and Design Basis Accidents (DBA)
- **Safety Goals** – Beyond Design Basis Accidents (BDBA)


Canada's Nuclear Regulator

Physical Design

Design of Reactor Facilities: Nuclear Power Plants

REGDOC-2.5.2

May 2014

Canadian Nuclear Safety Commission — Commission canadienne de sûreté nucléaire

Canada

Application of the technical safety objectives – Design Basis

The design shall meet the Dose Acceptance Criteria:

- 0.5 mSv for any AOO or
- 20 mSV for any DBA

Application of the technical safety objectives: Beyond Design Basis

1. The sum of frequencies of all event sequences that can lead to significant core degradation shall be less than 10^{-5} per reactor year. Level 1 Probabilistic Safety Analysis (PSA)
2. The sum of frequencies of all event sequences, whose release to the environment requires temporary evacuation of the local population, shall be less than 10^{-5} per reactor year. Level 2 PSA
3. The sum of frequencies of all event sequences, whose release to the environment requires long-term relocation of the local population, shall be less than 10^{-6} per reactor year. Level 2 PSA

These criteria are measures of the plant's accident prevention and mitigation capabilities.

Core degradation is not limited to fuel damage

- Vendors seeking to develop and use more resilient fuels/coolants.
- Other reactor core structures may continue to play a role in prevention and mitigation of consequences from accidents.
- **External and internal** initiating events may result in degradation of reactor core structures despite the resiliency of the fuel and coolant.

The impacts of core degradation need to be understood and documented by the vendor as part of demonstrating technical safety objectives have been met.

Examples of core degradation in a Molten Salt Reactor

- Structural failure of primary tank or vessel (e.g. leak into a secondary confinement area or plant structures).
- Failure of static fuel assemblies within a core vessel.
- Failure of other internal structures leading to a core configuration change.

The vendor is expected to characterize and document the nature and severity of the degradation states to demonstrate an understanding of the impacts on other defence-in-depth provisions.

How are design provisions being balanced to ensure effective Defence in Depth? Is the design over-relying on the containment function?

Key areas to be demonstrated by the vendor in a VDR

The vendor has established and is applying systematic and quality assured processes and methodologies for conducting design, safety analysis and, in particular, safety classification.

The vendor is expected to demonstrate effective identification and analysis of Postulated Initiating Events (PIEs). This is a key input to design and safety analysis.

The vendor is expect to demonstrate <u>how</u> the PIE list is being established, taking into account internal and external events.

Conclusions

- The CNSC’s regulatory framework is robust, flexible and informed by decades of operating experience.
- Vendor Design Reviews are working effectively to:
  - Understand key issues associated with new technologies.
  - Enable CNSC and vendors to anticipate interpretation of regulatory requirements in specific cases.
  - Gather information for consideration in refining requirements and guidance as experience is gained with new technologies.

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