CANADIAN EXPERIENCE IN APPLICATION OF GRADED APPROACH FOR SAFETY ASSESSMENT OF RESEARCH REACTORS

J. E. Kowalski
Nuclear Safety Specialist,
Reactor Thermalhydraulics Division
Canadian Nuclear Safety Commission

Outline

- Introduction to CNSC
- Regulating the research reactors in Canada
- Safety assessment: regulatory views
- Graded approach
- Regulatory requirements for safety assessment and safety analysis
- CNSC expectations on the use of graded approach to deterministic safety analysis (DSA)
- Examples of the use of graded approach to safety assessment and DSA for SLOWPOKE-2 and NRU reactors
- Summary

Canadian Nuclear Safety Commission

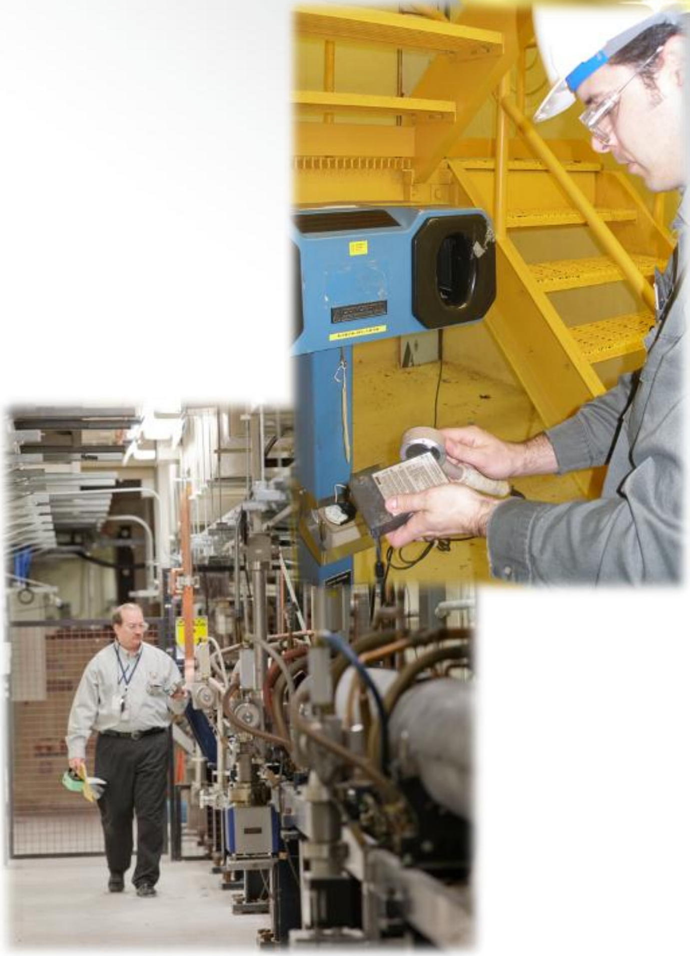
<u>Established May 2000,</u> under the *Nuclear Safety and Control Act*

Replaced the AECB, **<u>established in 1946,</u>** *Atomic Energy Control Act*

Canada's Independent Nuclear Regulator - 64 Years Of Experience

CNSC Regulates All Nuclear-Related Facilities and Activities

- Nuclear power plants
- Small/research reactors
- Uranium mines and mills
- Uranium fuel fabricators and processing
- Waste management facilities
- Industrial and medical applications
- Nuclear research
- Export/import control



…From Cradle To Grave

Regulating Research Reactors in Canada

- CNSC oversees safety of all nuclear facilities, including research reactors
- Safety assessment is a requirement for licensing research reactors in Canada
- CNSC expects licensees to demonstrate their safety case is commensurate with the risks posed by the facility

Regulating Research Reactors in Canada

- CNSC is developing regulatory framework for licensing small reactor facilities (<200 MW_{th}) including research reactors
  - Regulatory Documents for safety analysis (RD-308) and design requirements (RD-367) already exist

    see: http://www.nuclearsafety.gc.ca/eng/lawsregs/index.cfm
  - Guidance on meeting CNSC requirements with respect to the safety analysis and design to be covered in GD-308 and GD-367 (both in preparation)
- CNSC allows for the use of a graded approach for research reactors to meeting safety requirements
  - Below a certain power level, more flexibility in the use of the graded approach is possible

Safety Assessment of Research Reactors- Regulatory View

- Safety assessment should evaluate compliance with safety requirements for research reactors and activities
- Needs to be applied throughout the design, commissioning, operation and decommissioning phases to ensure that the design meets all relevant safety requirements
- Factors to be assessed: radiological consequences and protection, safety functions, site characteristics, engineering aspects and human factors

Safety Assessment for Research Reactors- Regulatory View

- The basis for the safety assessment:
  - data derived from the safety analysis
  - previous operational experience
  - results of supporting research
  - proven engineering practices.
- Must be performed by the licensee and independently verified and submitted to the regulatory authority as a part of the licensing process
- RD-308 allows to use graded approach to safety assessment of the research reactors

What is a Graded Approach?

- A risk-informed approach that — without compromising safety — allows safety requirements to be implemented in a way that the level of design, analysis and documentation are commensurate with potential risks posed by the reactor

Graded Approach – Key Elements

Factors to be considered in applying graded approach include:

- reactor power
- reactor safety characteristics
- amount and enrichment of fissile material
- fuel design
- type and mass of moderator, reflector and coolant
- intended utilization of the reactor
- presence of high-energy sources and other radioactive and hazardous sources
- safety design features
- source term
- siting
- proximity to populated areas

CNSC Requirements for Assessment of Radiation Risk and Radiation Protection

- The potential radiological consequences from the facility or activity must be identified and assessed including:
  - radiation exposure to workers and the public
  - release of radioactive material to the environment following the accident.
- The assessment needs to determine if adequate measures are in place to control the occupational radiation exposure within any relevant dose limit
- Application of graded approach may vary according to stage of the safety assessment
  - the assessment for the decommissioning stage may contain significantly less details than that for the operational stage

CNSC Requirements on Assessment of Safety Functions

- The fundamental safety functions shall be indentified and assessed including those associated with SSC and human actions required to ensure the safety of the research reactor
- Basic safety functions for reactor shutdown, core cooling and confining of radioactive material must be demonstrated. However, the graded approach may be applied to the design of safety systems that fulfill the safety functions.
- The extent and rigor for demonstrating that such safety functions are achieved may vary depending on the reactor design

CNSC Requirements for Assessment of Site Characteristics

- An assessment of the site characteristics related to the safety of the facility or activity shall be carried out and include:
  - The physical and chemical characteristics that will affect the dispersion or migration of radioactive materials released in normal operation or due to an incident or accident
  - The identification of the external and internal hazards that have the potential to affect the safety of any facility or activity
- Graded approach may be applied.

  The scope and level of detail of the site assessment depend on:
  - the potential radiological consequences from the facility or activity,
  - the type of facility or activity to be carried out and
  - the purpose of the assessment (i.e. safety evaluation for new site or existing site)

CNSC Requirements for Assessment of Engineering Aspects

- The safety assessment should determine whether a facility or activity uses, structures, systems and components (SSCs) of robust and proven design
- Grading may be applied to:
  - the core design (challenges that the core must meet during intended reactor life should be considered)
  - emergency core cooling systems (ECCS)
  - means of confinement

CNSC Requirements for Safety Analysis

- Safety analysis should confirm that the design of the research reactor is capable of meeting the safety requirements, dose acceptance criteria and safety goals
- Safety analysis should contribute to demonstrating that the reactor facility provides defence in depth
- Safety analysis should incorporate deterministic, probabilistic and hazard analyses

CNSC Requirements for Deterministic Safety Analysis (DSA)

- DSA shall evaluate the consequences of over range of event sequences and confirm that appropriate acceptance criteria are met
- Regulatory requirements for DSA are given in RD-308
  - the scope of deterministic safety analysis may be limited
- GD-308 provides information on how the requirements set out in RD-308 to be met
- detailed guidance covers the following areas of DSA
  - identification of PIE,
  - acceptance criteria,
  - safety analysis methods and assumption
  - documentation (review and updates)

Application of Graded Approach to DSA: CNSC Expectations

Identifying Postulating Initiating Event (PIE)

- A systematic process should be used to identify PIE that can challenge any of the safety functions of the research reactor
- A list of PIE is longer for a high-power, complex reactor with many irradiation sites than for a small reactor with inherent safety characteristics

Application of Graded Approach to DSA: CNSC Expectations

Safety Analysis Methods

- Extent and detail of safety analysis for low-power research reactors may be significantly smaller than for high-power research reactors because certain accident scenarios may not apply
- For a higher-power reactor, extensive analysis using complex codes is required
  - conservatism should be incorporated in the analysis
- Applicability of the analysis methods need to be justified but the extent of such justification may be gradable

Application of Graded Approach to DSA: CNSC Expectations

Safety Analysis Methods

- In the case of a low-power reactor, the disposition may be as simple as providing adequate design information or simple calculations to confirm design and safety requirements
- Graded approach cannot compromise technical soundness of the chosen method of analysis. This method should be qualified in terms of its applicability and adequacy to the analyzed accident scenarios
- Codes used for safety analysis should be validated using data relevant to the reactor configuration and operating conditions - graded approach is not applicable

Application of Graded Approach to DSA: CNSC Expectations

Review and Updates of Documentation

- Safety analysis reports should be periodically updated to account for:
  - changes to reactor configuration
  - new operating parameters and procedures
  - advances in knowledge (new research)
- Frequency of safety analysis updates depends on complexity of design (graded approach can be applied)

Examples of graded approach applied in safety assessment and DSA for Canadian SLOWPOKE-2 and NRU reactors

COMPARISON OF TWO CANADIAN RESEARCH REACTORS: SLOWPOKE-2 AND NRU

	SLOWPOKE-2	NRU
Thermal power	20 kW_{th}	135 MW_{th}
Reactivity coefficients	• Negative reactivity coefficients for coolant void, fuel temperature, and coolant and moderator temperature	• Negative reactivity coefficients (except for small positive void coefficient for the experimental loops)
Control System	•One cadmium control rod	•Seven control rods
Cooling System	•Light water •Natural convection cooling	•Forced convection cooling •Two high pressure loops supply coolant to the test sections

COMPARISON OF TWO CANADIAN RESEARCH REACTORS, SLOWPOKE-2 AND NRU

	SLOWPOKE-2	NRU
Shutdown means	•**No** automatic reactor trip •Control system is the first shutdown means (**manual**) •Second shutdown means is a **manual** insertion of cadmium capsules into the irradiation sites	•**Automatic** reactor trip •Two fast acting, automatic, independent shutdown means are provided
Emergency core cooling system	•**Not** available	•The Emergency Core Cooling System
Containment	•**Not** available	•Confinement system with Emergency Filtration system
Exclusion boundary	•**Not** available	•6 km plant boundary

Graded Approach Applied to Safety Assessment of SLOWPOKE-2 and NRU Reactors

	SLOWPOKE-2	NRU
Scope of safety assessment	•Breadth and depth of assessment limited due to low hazards of the reactor	•Extensive due to complexity, size and utilization of the reactor (isotope production)
Assessment of radiation risk and provisions for radiation protection	•Magnitude of radiation risk arising from the facility is small due to a smaller amount of fission product inventory - simple assessment sufficient	•Detailed assessment needed due high potential radiological consequences
Assessment of safety functions	•Mandatory Basic safety functions are not gradable.	•Mandatory
Assessment of engineering aspects	• Few details needed due to: - small number of SSCs - inherently safe design	•The assessment should confirm robustness of the reactor design

Graded Approach Applied to DSA for SLOWPOKE-2 and NRU Reactors

	SLOWPOKE-2	NRU
Identification of Postulated Initiating Events (PIE)	•Limited number of AOO and DBA events considered due to inherent safety characteristics and small number of SSCs	•Significant number of PIE selected due to complexity of the core and the effects of interfacing the system and loops
Analysis assumptions	•Realistic with some conservatism	•Deliberately biased in conservative directions
Analysis methods	•Realistic computer models used •Some DBA and BDBA events not analyzed due to inherently design	•LOE methodology used with conservative assumptions of operational parameters and an actuation of the mitigating system

Graded Approach Applied to DSA for SLOWPOKE-2 and NRU Reactors

	SLOWPOKE-2	NRU
Complexity of safety analysis	•Simplified analysis is acceptable	•Significant number of accident scenarios must be analyzed in detail
Analysis documentation	•Level of detail provided in the safety analysis report is limited Documentation does not exceed 50 pages	•Documentation contains sufficiently detailed information to meet regulatory requirements • Substantially larger volume of the safety analysis report (~1000 pages)
Safety Analysis Review and Updates	•Infrequent update (every 10-15 y)	• Updates every 5 years or earlier if any change in the reactor configuration or operating conditions occurred

Summary/Conclusions

- A regulatory view on use of graded approach to safety assessment of radiation risk, safety functions, engineering aspects, defence-in-depth site characteristics and safety analysis is presented
- Safety assessment has to be consistent with the magnitude of the possible radiation risk arising from the reactor facility.
- Before starting the safety assessment, a judgment has to be made as to the scope and level of detail of the safety assessment for the facility or activity and it has to be agreed with the regulatory body
- Examples of graded approach to safety assessment of two Canadian research reactors SLOWPOKE-2 and NRU are discussed in detail

Thank You!

CNSC

Canadian Nuclear Safety Commission

Canada

nuclearsafety.gc.ca