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Response to Commission Request for Information

Réponse à une demande d’information de la Commission

Royal Military College of Canada

Collège militaire royal du Canada

SLOWPOKE-2 Reactor

Réacteur SLOWPOKE-2

Public Hearing in Writing

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Background

In this CMD, CNSC staff will provide responses in writing to questions from the Commission documented in CMDQ 23-H3Q with respect to the hearing in writing 23-H3 concerning the request from the Royal Military College of Canada (RMC) to renew its operating licence for the RMC SLOWPOKE-2 reactor.

Questions from the Commission directed to CNSC staff, as well as staff responses, can be found in the next section.

Referenced documents in this CMD are available to the public upon request, subject to confidentiality considerations.

Staff Response

The Commission's questions, including any quoted text from the original CMD, have been reproduced below in the shaded boxes to provide suitable context for CNSC staff's responses.

#1	CNSC staff's assessment noted that the safety of the reactor had been demonstrated for a reactivity addition of up to 6.5 mk and, therefore, an increase of the maximum allowable excess reactivity of 4.3 mk would not affect the safety of the reactor, "with a significant margin". Describe the adequacy of the safety margin around 6.5 mk.

The reactivity insertion experiments are documented [1] and demonstrate that SLOWPOKE-2 reactors remain safe for positive reactivity insertions as high as 6.48 mk. This work demonstrated that the SLOWPOKE-2 reactor power is self-limited by the negative thermal power coefficient and negative void coefficient, which means that after a reactivity insertion, the power increases, plateaus and then decreases, effectively self-shutting down until the cycle starts again as the reactor core cools down. The highest coolant outlet temperature is reported as 91.6 °C for a corresponding peak power of 124 kW. The integrity of the reactor is not compromised by this reactivity insertion and corresponding transient.

The requested increase from 4.0 to 4.3 mk is a small change in comparison to the current allowable excess reactivity and the margin of safety demonstrated up to 6.48 mk. The safety margin is adequate as there is no credible scenario where reactivity could be inserted to exceed 6.48 mk given the controls in place and physical limitations. During commissioning of the RMC SLOWPOKE-2 reactor in 1985, 500 mg of U-235 were irradiated in the inner sites to measure the reactivity worth of the sample, which was found to be 0.17 mk [2]. Further, the RMC safety analysis [3], which is part of the licensing basis, limits the amount of fissile material to be irradiated to 100 mg U-235 based on the sample reactivity worth.

Finally, from an operational perspective, an installed reactivity of 4.3 mk decreases below 4.0 mk and further down within a few months of operation due to normal fuel burnup. On September 10^{th}, 2021, during commissioning of the new fuel core, the installed excess reactivity was measured at 3.66 mk. RMC has indicated that the reactivity of the fuel core is now running at 2.67 mk (March 27, 2023).

#2	CNSC staff propose extracting the Operating Limits and Conditions (OLCs) from the licence and incorporating them in the Licence Conditions Handbook under 'Operating Performance' instead. What is the reason for this move? Ease of reference?

CNSC's licensing regime has evolved over time. When the *Nuclear Safety and Control Act* first came into force in 2000, licences directly contained a lot of relevant information related to the licensing basis. Since 2009 the CNSC licensing approach has evolved to introduce the use of a licence conditions handbook (LCH), which is a companion piece to the licence that is used to clarify regulatory requirements, and highlight relevant parts of the licensing basis for each licence condition. Before the LCH was available, referencing specific information directly in the licences was common practice, since the licence was the only option to highlight the important elements of the licensing basis. This resulted in long, detailed licences that provided administrative and logistic challenges to maintain or update while not achieving the same level of clarity of requirements provided by the LCH.

At the time of the 2013 issuance of the current RMC SLOWPOKE-2 licence, it was still not uncommon for relevant limits (e.g., OLCs) to be referenced directly in a licence. During the past 10 years, CNSC continued to modernize its licensing practices by adopting an approach that uses a set of standardized licence conditions and providing further detail in the LCH, including relevant limits. In alignment with current practices, CNSC proposes incorporating the OLCs in the RMC LCH. Listing the OLCs in the LCH would ensure that they are easily accessible with all other important licensing basis information. It does not downgrade their importance nor change the status of the OLCs as important regulatory limits. As it is done with other licensees, proposed changes to OLCs are thoroughly assessed by CNSC staff and only permitted if they are determined to be within the licensing basis approved by the Commission. If a change were determined to be outside the licensing basis and to have potential negative impacts on safety, CNSC staff would direct the licensee to seek approval from the Commission.

It is CNSC staff's conclusion that including the OLCs in the LCH rather than in the licence is appropriate and reasonable for the SLOWPOKE-2 reactor licensees, and consistent with current practices.

#3	With respect to the OLCs: It appears that if both the Uninterruptible Power Supply and the backup generator fail to supply power to the reactor, there would be a guaranteed shutdown of the reactor. How? Does it mean that the SLOWPOKE-2 has an automatic trip system? Automatic shutdown or a manual shutdown system? Incidentally, is the main shutdown system decoupled from the control system (cadmium control rod)? Should the control rod fail and/or the reactor room cannot be entered, cadmium shut down capsules can be inserted in the irradiation sites. Is this considered as the backup (2nd) shutdown system? Is the action of inserting cadmium capsules in the irradiation sites fast enough to prevent a reactor excursion? Or is the reactor dynamics bounded by its safety design characteristics (negative thermal power coefficient, decrease in density of moderator)? Has this shut down procedure been tested on the RMC SLOWPOKE?

The SLOWPOKE-2 reactor has a primary automatic shutdown system and a backup or auxiliary shutdown system. The primary shutdown system uses the main cadmium control rod and is part of the control system. During operation of the reactor, the cadmium control rod is partially withdrawn from the fuel core by the stepper motor. In a situation when the stepper motor loses electrical power (i.e., failure of both the uninterruptible power supply and the backup generator), the control rod drops down by the force of gravity and shuts the reactor down.

The backup or auxiliary shutdown system uses cadmium capsules that are manually inserted into the irradiation sites to shut down the reactor. Each reactor operator is required to execute the auxiliary shutdown procedure at least once a year. This activity is verified by CNSC staff during inspections and through the personnel certification process, and it is also reported in the RMC annual compliance report (ACR).

The reactor dynamics are effectively bounded by the safety design characteristics of the SLOWPOKE-2 reactor, which include negative thermal power coefficient and negative void coefficient to prevent a reactor excursion.

#4	During the refueling of the SLOWPOKE in August/September 2021, cameras were used to provide detailed visual examination of the reactor container and its components (radiation sites, shims, etc.). Does a visual examination suffice to conclude that there are no aging issues related to the structures, the systems, and the components of the reactor facility?

RMC is required by its licence to implement an aging management program, including a maintenance program, to ensure that all components remain fit for service. Licence condition 6.1 requires that “The licensee shall implement and maintain a fitness for service program”, and the LCH lists several requirements for inspection and maintenance.

CNSC staff verify RMC's implementation of these programs during compliance verification activities. RMC performs preventive maintenance to detect early warning signs of aging infrastructure and assets. Maintenance requirements, refurbishment or replacement due to obsolescence or deterioration are identified on a maintenance schedule. Equipment tests are also done on an established schedule. During the current licensing period, CNSC staff performed 5 inspections that included compliance verification items related to this Safety and Control Area (SCA) to ensure that tests, maintenance and inspections were conducted as required. There were no non-compliances identified in this area.

The visual inspection done by Canadian Nuclear Laboratories (CNL) staff during the refueling provided additional assurance that components, otherwise difficult to inspect (i.e., reactor container, irradiation sites, beryllium reflectors and shims), are fit for service and as such, there was no visible degradation that could be observed. This was also confirmed for the components of the Saskatchewan Research Council and University of Alberta SLOWPOKE-2 reactors when they were decommissioned by CNL. This lack of degradation is due in part to the very low gamma and neutron flux in comparison with other reactors.

CNSC staff remain confident that aging issues at the SLOWPOKE-2 reactors are well understood and effectively managed through the licensee's maintenance and aging management programs, which are mandated by the licence and verified by CNSC staff.

#5	The SLOWPOKE reactor is said to be 'inherently safe'. Is there a formal (e.g., International Atomic Energy Agency) definition for this expression?

According to IAEA TECDOC-626, "Inherent safety refers to the achievement of safety through the elimination or exclusion of inherent hazards through the fundamental conceptual design choices made for the nuclear plant. Potential inherent hazards in a nuclear power plant include radioactive fission products and their associated decay heat, excess reactivity and its associated potential for power excursions, and energy releases due to high temperatures, high pressures and energetic chemical reactions. Elimination of all these hazards is required to make a nuclear power plant inherently safe. For practical power reactor sizes, this appears to be impossible. Therefore, the unqualified use of inherently safe should be avoided for an entire nuclear power plant or its reactor."

"On the other hand, a reactor design in which one of the inherent hazards is eliminated is inherently safe with respect to the eliminated hazard. An inherent safety characteristic is a fundamental property of a design concept that results from the basic choices made in the design, which assures that a particular potential hazard cannot become a safety concern in any way."

As such, the SLOWPOKE-2 reactor has passive inherent safety characteristics or features. The terminology of inherently safe has been used for the SLOWPOKE-2 reactors in the context that the reactor cannot exceed its operating limits by design, due to the strong negative coefficient of reactivity associated with an increase in temperature. The reactor is self-limiting in power, without human intervention or the activation of engineered systems.

#6	The intervention by D. Winfield (CMD 23-H3.2) raised that there is no existing OLC for the maximum number of irradiation sample vials that are allowed simultaneously in the inner irradiation sites. Is there a maximum number of irradiation sample vials that are allowed simultaneously in the irradiation sites? If so, where is this limit documented?

There are 8 locations for sample irradiation around the core of the RMC SLOWOKE-2 reactor. The normal practice is one sample per location, however there is no limit specified on the number of samples that are simultaneously allowed in the irradiation sites. Practically, all samples that are irradiated on a day-to-day basis constitute negative reactivity insertion, and therefore loading the system with more samples becomes impractical. The safety analysis [3] limits the amount of fissile materials that can be inserted into irradiation sites, and all irradiation protocols must be reviewed and approved by facility management. The allowable amounts of fissile materials are further discussed under questions #1 and #7, and CNSC staff agree to include these limits as part of the OLCs listed in the LCH.

#7	The intervention by D. Winfield (CMD 23-H3.2) raised that there is no existing OLC for limiting the amount of fissile material that may be irradiated. Is there a limit for the amount of fissile material that may be irradiated? If so, where is this limit documented?

The RMC SLOWPOKE-2 safety analysis [3] specifies that the amount of fissile material permitted to be irradiated is 100 mg U-235, based on sample reactivity worth. The safety analysis further recommends that irradiation of fissile material in the plastic capsules be limited to 10 mg per sample due to heat generation and potential melting of the capsules.

The maximum excess reactivity of 4.3 mk specified in the OLCs is also relevant to this question, as this limit must not be exceeded under any circumstances. However, CNSC staff agree to include in the OLCs the limit on the amount of fissile material to be irradiated to a maximum reactivity worth of 100 mg U-235 equivalent, and to no more than 10 mg U-235 equivalent per sample.

#8	The intervention by D. Winfield includes several additional recommendations related to use of the graded approach and outdated document references, as summarized in section 7 (iv), (v), and (vi) of CMD 23-H3.2. Provide a response to each of these recommendations.

In addressing the intervenor's comments in section 7 of CMD 23-H3.2:

(iv) CNSC staff agree that CPR-77 is an outdated document and it will be removed from the RMC LCH. CNSC staff have also requested RMC to revise its safety analysis (SEP-5) before June 30, 2024, to reflect the current configuration and incorporate references that are current and relevant.

(v) Documents may be referenced in licensees LCHs either as compliance verification criteria or as guidance. RD-367, *Design of Small Reactor Facilities*, has not been part of the SLOWPOKE-2 reactor LCHs because of the simplicity and low risk of these reactors, and because the design has not been altered over the many years of operation. It is included however for the larger, more complex McMaster Nuclear Reactor. Also, the RMC LCH references REGDOC-2.4.1, *Deterministic Safety Analysis*, which goes beyond the scope of RD-367. However, CNSC staff will include RD-367 to the SLOWPOKE-2 LCHs as guidance, considering the relevance of some of the information and the graded approach that is afforded by the document.

(vi) CNSC staff understand that the intervenor refers to his earlier intervention documented in CMD 22-H8.14, regarding the 300-page ACR that a small facility has produced in the past (intervenor used SRBT as an example), which exceeded in length that of much higher-risk facilities and as such, a graded, risk-informed regulatory approach does not seem apparent. For that specific facility, the licensee addressed various concerns expressed by the public in its ACR, which contributed to its length.

The content of ACRs is suggested in REGDOC-3.1.2, *Reporting Requirements, Volume I: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills*. The document also specifies that *a graded approach, commensurate with risk, may be defined and used when applying the requirements and guidance contained in this regulatory document,* and the format follows the SCA framework. Graded approach is also discussed in REGDOC-3.5.3, *Regulatory Fundamentals*.

The SLOWPOKE-2 ACRs have been typically less than 30 pages. CNSC staff have determined that these reports comply with REGDOC-3.1.2, and that they are commensurate with the level of risk and the complexity of the facility.

The intervenor also questions the relevance of the SCA framework applied unilaterally over all classes of licences, and ratings, in the context of ACRs and Regulatory Oversight Reports (ROR). As part of its mandate, the CNSC strives to disseminate objective scientific, technical and regulatory information to the public. The SCA framework lends itself to promote effective communication of important aspects of operations of nuclear facilities. Further, the ACRs and RORs processes allow the application of a graded approach such that the focus is kept on important issues.

The CNSC continues to seek ways to improve the contents of ACRs, RORs and other media, and to examine the relevance of its framework in all aspects of licensing, compliance and reporting. In this perspective, we note the intervenor’s comment and will give it due consideration as part of continuous improvement.

Conclusion

CNSC staff conclude that the conclusions and recommendations made in CMD 23-H3 and supplemental CMD 23-H3.A remain valid. In light of the contribution of Dr. Winfield, CNSC staff will make the following modifications to the LCH, should the Commission renew the operating licence:

- CPR-77 will be removed from the LCH
- RD-367, *Design of Small Reactor Facilities*, will be added as guidance in the LCH under the Physical Design SCA
- An OLC will be added to the LCH under the Operating Performance SCA to limit the amount of fissile material to be irradiated to a maximum reactivity worth of 100 mg U-235 equivalent, and to no more than 10 mg U-235 equivalent per sample.

References

1. AECL-4770, The self-limiting power excursion behaviour of the SLOWPOKE reactor: results of experiments and qualitative explanation, by R.E Kay, J.W. Hilborn and N.B. Poulsen.
2. Commissioning of the RMC SLOWPOKE-2 reactor, Table 3, G.A. Burbridge, R.T. Jones, B.M. Townes, 1985.
3. SEP-5, Safety Assessment and Operating Envelope for the SLOWPOKE-2 Facility at RMC