Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

CMD 21-H107.5

File/dossier : 6.01.07
Date : 2021-08-16
e-Docs pdf : 6624621

Written submission from Helmy Ragheb

Mémoire de Helmy Ragheb

In the Matter of

À l'égard de

Application for a licence amendment to authorize activities related to the production and possession of Molybdenum-99 (Mo-99) at the Darlington Nuclear Generating Station (NGS)

Demande de modification de permis en vue d'obtenir l'autorisation de produire du molybdène 99 (Mo-99) à la centrale nucléaire de Darlington

Public Hearing - Hearing in writing based on written submissions

Audience Publique - Audience fondée sur des mémoires

September 2021

Septembre 2021

Canada

Comments on

Licence amendment application for the Darlington Nuclear Generating Station to carry out activities related to the production and possession of molybdenum-99 radioisotope

Helmy Ragheb, Ph.D, P.Eng.

August 15, 2021

Table of Contents

Executive Summary

On June 14, 2021, the Canadian Nuclear Safety Commission (CNSC) agreed to my participation in the CNSC's proceedings and review of Ontario Power Generation's (OPG) licence amendment application and related documentation, including OPG and CNSC Commission Member Documents. The review is to provide comments on the licence application through the lens of my professional background and experience. I wish to thank the CNSC for the opportunity to conduct this review and to share my observations and findings.

The review focused on the safety control areas, and made recommendations in specific areas, including the Operating Experience (OPEX), safety analysis and oversight of design performed by suppliers.

In the OPEX area, the review highlighted potential risks associated with reactor systems expected to be impacted by the installation and operation of the Mo-99 IIS, including Deuterium (D2) deflagration, workers exposure to radioactivity during the replacement or removal of adjuster rods. Systems on the path of the harvested targets of Mo-99 towards shipping, such as reactor building airlocks, may experience impairments due to frequent use by workers that may not be adequately trained. The recommendation made in this area is to ensure lessons learned are incorporated in the design and installation of the MO-99 IIS.

in 1989, two individuals received whole body doses in excess of the regulatory limits during removal of adjuster rods at Pickering NGS-A Unit 1

The review found that the design activity is not subject to the direct oversight of the CNSC but appears to be effectively delegated to OPG. Currently, according to CMD21-H107 Section 3.4, the role of CNSC is limited to verification that OPG has plans and processes in place to perform oversight of the work performed by contractors. Lack of direct CNSC oversight for design, raises concerns regarding direct reporting to CNSC of design errors discoveries, compliance of computer codes with standards and regulations, and inadequate "Design authority" of the licensee. It is recommended that the CNSC perform a focused review/audit of OPG's oversight on all phases of the design and associated safety analyses performed by the contractors for the Mo-99 IIS project. The review should be conducted with a view to ensure that computer codes, analysis and verification procedures, training and qualification programs for designers and analysts, which are developed and used by the contractors, are commensurate with the extent of work performed by OPG.

The review of the Safety Analysis area found that analyses do not cover the pre-operational phase which includes activities during the removal of the existing adjuster rods and the installation of Mo-99 IIS target elevator assemblies. The inclusion of pre-operational phase in the Safety Analysis is called for by the nuclear regulations,

regulatory documents, and international standards. It is recommended that CNSC staff, prior to their review of the installation and commissioning plans at Quality Release Hold Point (QRHP) #1, ensure that deterministic and probabilistic risk assessments, in accordance with REGDOC 2.4.1 and REGDOC 2.4.2, are performed for the activities associated with the pre-operational phase.

The impact of installing the Mo-99 IIS assemblies on the deterministic Safety Analysis of the Loss of Moderator Inventory (LOMI) event was assessed by OPG. The assessment concluded that there is no potential for hydrogen deflagration caused by the molybdenum targets because their surface temperature will remain below the self - ignition temperature for hydrogen. Despite the brevity of the information in OPG's application, my review made observations regarding some uncertainties in the Safety Analysis. It is recommended that CNSC staff verify that Safety Analysis models, codes, supporting experiments, and tools are modern and sufficiently applicable to the new material and geometry of the Mo-99 IIS assemblies. CNSC staff should exercise direct oversight on computer codes used or developed by OPG vendors for the deflagration analysis, and ensure they comply with OPG's software QA standards. The verification should ensure that potential sparking or static discharges due to movements of the target basket in the adjuster assembly port, or other parts of the target elevator assembly, had been considered in the scenario of D2 deflagration.

Application of CANDU Operating Experience (OPEX) to new designs

Although the production of Mo-99 in a CANDU reactor is considered a first-of-a-kind, with no direct Operating Experience (OPEX) for an equivalent system in an operating CANDU, the (OPEX) of the CANDU reactors in Canada offers ample of lessons learned from operational incidents that can be applied to the proposed Mo-99 IIS installation. These incidents highlight potential risks associated with reactor systems impacted by the installation and operation of the Mo-99 IIS. These systems include primarily the reactivity mechanism deck, moderator system and reactor building airlocks where the radioactive harvested targets are to be transported through. The following examples demonstrate relevant potential risks:

- Risk of Deuterium (D2) deflagration in the moderator cover gas space, reported in incidents involving failure of monitoring or control of moderator chemistry.
- Risk of workers exposure during the replacement or removal of adjuster rods.
- Risk of workers exposure to tritium during their work in the vicinity of the moderator rooms and reactivity mechanism deck area.
- Risk of impairment of reactor building airlocks due to increased frequency of use to transport the flasks of the harvested irradiated targets. OPEX showed, in an international incident, that inadequately trained workers failed door interlocks during the transport of a long flask, causing both airlock doors to open at the same time.

OPG's application Section 2.1.7 indicated that an OPEX review was conducted during various stages of the Mo-99 IIS project to identify previous applicable experience. No information was provided on the risks and lessons learned from this review, nor how the experience was incorporated in the design or the pre-operational phase of the Mo-9 IIS.

It is suggested that CNSC verify that the list of lessons learned from operational incidents involving risks relevant to the Mo-99 IIS project is comprehensive and that it includes incidents highlighting the risks of deuterium deflagration, workers exposure to radioactivity and impairment of reactor building airlocks.

Risks of Outsourcing the Design of Reactor Special Safety Systems

Good design is recognized as the first line of defence in the application of the defence-in-depth concept. Like every other Safety Control Area (SCA), public confidence is assured when the CNSC exercises direct oversight on the licensee's design programs. Currently, the design of any Special Safety System, such as the reactor containment, is subject to the direct CNSC oversight through the applicable regulations, specific regulatory requirements and CNSC audits.

The OPG application at hand involves a design of a system that forms part the reactor containment. Unlike other SCAs, the design and supporting safety analyses in this case are not performed by OPG, as licence holder, but by a contractor (BWXT-NEC) who is not a holder of a licence. Other activities such as installation, commissioning, and operation of the Mo-99 IIS, although performed by the contractor, yet they are under direct oversight of the CNSC by virtue of being performed on Darlington site. The design activities, however, are performed off-site and as a result, it is not subject to the direct oversight of the CNSC but appears to be effectively delegated to OPG.

Currently, according to CMD21-H107 Section 3.4, the role of CNSC staff is limited to verification that OPG has plans and processes in place to perform oversight of the work performed by contractors. That means the CNSC, as a regulator, has neither first-hand knowledge nor direct oversight for the design processes and practices at BWXT-NEC. Lack of direct oversight raises the following concerns:

1. Reporting of discovery of errors in design, defective material or unsafe condition may not be directly visible to the CNSC.
2. Ensuring compliance of computer codes with REGDOC-2.4.1 and CSA N286.7 "*Quality assurance of analytical, scientific and design computer programs for nuclear power plants* "is under the oversight of the licensee and not the CNSC.
3. The "Design authority" of OPG which should control and keep track of design documentation, design changes, computer code input data, may be lost to the suppliers who are now holders of the design data and history of design changes. With staff turnover at OPG, difficulties may arise in the future when initiating engineering changes, for example, in systems or components important to safety.

It is recommended that CNSC perform a focused review/audit of OPG's oversight on all phases of the design and associated safety analyses performed by the contractors for the Mo-99 IIS project. The review should be conducted with a view to ensure that computer codes, analysis and verification procedures, training and qualification programs for designers and analysts, which are developed and used by the contractors, are commensurate with the extent of work performed by OPG.

Safety Analysis for the pre-installation phase of Mo-99 IIS

Although the removal of the adjuster rods is considered a routine job, in 1989, two individuals received whole body doses in excess of the regulatory limits during removal of adjuster rods at Pickering NGS-A Unit 1. This was due to using an unshielded component not intended for reactor use to perform the job. The component had been meant for rehearsal use only. Despite the use of approved procedures, the preparation of radiological work plans and holding pre-job briefing, yet deficiencies in assessing the hazards were a key contributor to the over-exposures. The lesson learned from this incident was that Safety Analysis should encompass, not only the operational phase, but also the pre-operational and construction phases.

The inclusion of pre-operation phase in the Safety Analysis is called for by nuclear regulations, regulatory documents, and international standards. Paragraph 5(*i*) of the *Class I Nuclear Facilities Regulations* states that an application for a licence to construct a Class I nuclear facility shall contain, in addition to other information, "*the effects on the environment and the health and safety of persons that may result from the construction, operation and decommissioning of the nuclear facility, and the measures that will be taken to prevent or mitigate those effects*". In addition, REGDOC 2.4.1, Section 1.1 "Purpose" states: "*The purpose of Part I of this regulatory document is to help assure that during the construction, operation or decommissioning of an NPP, adequate safety analyses are completed ….*". As well, the definition of "Human Factors" in REGDOC 2.4.1 describes human performance as it relates to activities during construction, among other phases.

OPG application Section 2.4 "Safety Analysis" does not appear to have covered the pre-operational phase which should include analyses of activities during the removal of the existing adjuster rods and installation of Mo-99 IIS target elevator assemblies. Adequate analyses in compliance with REGDOC 2.4.1, therefore, should help identify risks of workers exposure to radioactivity in the "Reactivity Mechanism Deck" and in the vicinity of adjuster coolant supply lines that are known to be among the high activity areas in the reactor.

It is recommended that CNSC staff, prior to their review of the installation and commissioning plans at Quality Release Hold Point (QRHP) #1, ensure that deterministic and probabilistic risk assessments, in accordance with REGDOC 2.4.1 and REGDOC 2.4.2, are performed for the activities associated with the pre-operational phase.

Risk of hydrogen deflagration in moderator cover gas space

What is cover gas space?

The cover gas, in a typical CANDU reactor, occupies a space on top of the moderator that acts as a cushion of gas mixture within the Calandria which contains the fuel channels and reactivity devices. The cover gas allows for the expansion and contraction of the moderator heavy water and absorbs pressure transients, such as may occur during the liquid injection of shutdown system No. 2. Following a loss of moderator inventory (LOMI) the formation of a flammable cover gas mixture on top of the moderator is likely to occur, especially if the reactor was operating with moderator chemistry exceeding limits, such as during a reactor start-up with poison still present in the moderator. Under these circumstances, there is potential for deuterium (D2) deflagration if ignition sources exist.

How is deflagration risk assessed?

The traditional approach to assess the risk of deflagration in CANDU reactors uses analytical models and several computer codes to assess the parametric effects on conditions giving rise to hydrogen deflagration. Among these are the following two parameters:

1. The composition of the cover gas mixture, to ensure the deuterium (D2), oxygen (O2) and nitrogen (N2) concentrations at or below specified values to prevent flammable gas mixtures of D2 and O2; and
2. The surface temperature of the uncovered devices during LOMI to ensure it will be maintained below the ignition temperature, which may be determined by experiments simulating the uncovered devices.

With introduction of the Mo-99 IIS assemblies, which will replace four adjuster assemblies, the assessment of the deflagration risk faces several challenges. OPG did not provide information on the extent to which the current safety analysis models, codes and tools have been changed or adapted to the new material and geometry of the Mo-99 IIS assemblies. The following paragraphs discuss these challenges.

Gas mixture composition

Although the first parameter (Gas mixture composition) can be monitored and controlled during operation, uncertainties may exist in the prediction of the flammable mixture of D2 and O2. This could be due to the use of outdated computer codes or the use of newly developed codes by vendors. OPG did not provide specific information on any codes used or developed by its vendors and whether they have been subject to OPG's software QA standards. Concerns about the vendor oversight have been discussed in a previous paragraph under "Risks of Outsourcing the Design of Reactor Special Safety Systems".

Surface temperature of uncovered devices

The second parameter (device temperature) does not appear to have been adequately assessed. The OPG application contains little information on the Safety Analysis and methodologies used in assessing the risk of deuterium deflagration as they apply to Mo-99 system configuration. OPG's application in Section 2.4.3 provides a qualitative statement that there is no potential for hydrogen deflagration event following a postulated loss of moderator inventory (LOMI). CMD Section 3.5 explains that following a postulated LOMI event, there is no potential for a hydrogen deflagration event caused by the molybdenum targets because their surface temperature will remain below the self-ignition temperature for hydrogen. There is no information on whether new modelling and experiments have been developed to assess surface heating of the Mo-99 IIS elevator assemblies, which should be significantly different from models and experiments that have been used to support the existing adjuster rods, due to differences in geometry and material.

Sources of Ignition

The recognized source of ignition in the analysis of deflagration is the heated surfaces of the uncovered reactivity devices and Calandria vessel. Among other potential sources for ignition in the cover gas space is the electrical sparks or static discharge, which were traditionally excluded as a source of ignition the analysis for the existing design with adjuster rods, since the electric motors associated with reactivity devices are located outside the Calandria. But with the newly installed Mo-99 system, with different material and geometry, OPG did not provide in its application information on whether the sparking or static discharges due to movements of the target basket in the adjuster assembly port, or other parts of the target elevator assembly, had been considered in the scenario of D2 deflagration.

Mo-99 IIS configuration in the "Idle" state

According to Section 2.3.2.3 of OPG application, only in response to a unit transient requiring staff assembly and accounting, will the Mo-99 IIS be left in the "idle" state. That means, during LOMI, the Mo-99 IIS which may not require staff assembly or accounting, will continue to operate. Under this circumstance, the configuration of Mo-99 target elevator assembly assumed in the analysis of potential deflagration during LOMI is not known. On the other hand, if the Mo-99 IIS is left in the idle state, difficulties arise in assessing the risk of deflagration, since OPG's application does not provide the configuration or the definition of the "idle" state.

It is recommended that CNSC staff verify that safety analysis models, codes, experiments, and tools are modern and sufficiently applicable to the new material and geometry of the Mo-99 IIS assemblies. CNSC staff should exercise direct oversight on computer codes used or developed by OPG vendors for the deflagration analysis, and ensure they comply with OPG's software QA standards. The verification should ensure that the sparking or static discharges due to movements of the target basket in the adjuster assembly port, or other parts of the target elevator assembly, had been considered in the scenario of D2 deflagration.