OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR ADDITIONAL INFORMATION

REGARDING AMENDMENT TO OPERATE WITH DEBRIS IN PRIMARY COOLANT SYSTEM

RENEWED FACILITY OPERATING LICENCE TR-5

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

NATIONAL BUREAU OF STANDARDS REACTOR

DOCKET NUMBER 50-184

The U.S. Nuclear Regulatory Commission (NRC) staff is continuing its review of the National Institute of Standards and Technology (NIST, the licensee), Center for Neutron Research (NCNR), license amendment request (LAR), provided by letter dated October 19, 2022 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML22293B808), to modify renewed Facility Operating License number TR-5, to permit reactor operations with some debris from the February 3, 2021, event remaining in the primary coolant system.

As part of the licensee's recovery effort from the February 3, 2021, fuel failure event, some debris was removed from the reactor primary coolant system; however, some debris remains. Accordingly, the licensee requested by letter dated October 19, 2022, a license amendment to make specified changes to the NBSR Safety Analysis Report and allow reactor operation with the remaining debris in the primary coolant system.

Two branches within the Office of Nuclear Reactor Regulation are reviewing the LAR and determined the following information is needed to continue with the review. These requests for additional information (RAIs) were developed based on the listed regulations applicable to the LAR.

Division of Risk Assessment Radiation Protection and Consequence Branch (ARCB)

ARCB RAI 1: Cleanup of RCS

Basis for question: 10 CFR 20.1101(b) requires use of engineering controls to achieve doses to ALARA.

10 CFR 20.1101(b) states the following:

(b) The licensee shall use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).

Question 1. Cleanup of RCS

Section H of ECR No. 1251 states that some friable (mobile) particulate matter, sized 5 microns or less, may be present in the heavy water coolant/moderator.

a) Explain the U_3O_8 manufacturing process and as-manufactured fuel particle sizes.
Prior to mixing U_3O_8 fuel and the aluminum powder dispersant, the fuel particles are filtered through two sieves: one is 170 mesh (88 micron) to filter out larger particles and the other is a 325 mesh (45 micron) to filter out smaller particles. Thus, the majority of U_3O_8 fuel particles are between 88 and 45 micron. There may be as much as 10% of the fuel that is below 45 micron. Conservatively assuming a linear distribution of particles below 45 microns, only about 1% of fuel particles would be below 5 microns. This translates to less than 1 gram of sub-5 micron material from the failed fuel element.

b) Discuss and explain the melting point of aluminum vs uranium oxide. Discuss the likelihood of fuel (meat) melt (U_3O_8) during the event and the likely composition of the particulate matter generated during the event, e.g., aluminum cladding vs. U_3O_8 fuel meat.
The melting point of U_3O_8 is 1150°C (2102 °F) whereas the melting point of aluminum is about 660°C (1220 °F). As the U_3O_8 fuel particles are surrounded by aluminum, during the event, the aluminum would liquify well before the U_3O_8 would approach its melting point and serve as an excellent conductor of heat into the surrounding environment and would limit the U_3O_8 temperature rise. Thus, it is unlikely that the overall form or particle size of the U_3O_8 would be significantly altered. If the aluminum plus U_3O_8 fuel particles mixture would have reached a temperature significantly above 660°C (1220 °F) but still well below 1150°C (2102 °F), there would have been observable damage to the lower grid plate. However, as discussed in our submittal of June 29, 2022, no damage was observed.

c) Describe the impact of operating the reactor with friable uranium particles present considering the potential for the small uranium particles (fines) to fission when exposed to neutrons from the operating reactor.
As discussed in the restart plan and October 19, 2022, submittal to NRC, only a small amount of material remains in the system and special attention (in addition to the lowering of scram setpoints) will be given to effluent monitors during startup and operation. Should small unclad uranium particles make it into the core, appropriate actions will be taken by the operator to ensure that release limits are not approached.

d) Provide the current isotopic concentrations of radioactivity (soluble and insoluble) in the RCS coolant and in the D2O storage tank.

There has been no measurable concentration of uranium in the D_2O coolant system. Although a sample has not been taken directly from the storage tank, the D_2O in the system circulates through the tank and there is no reason to believe the samples taken aren't representative of the mobile material in the storage tank. There may be non-mobile fuel fragments in the storage tank. D_2O coolant system isotopic concentrations are seen in the attached results from the latest sample of primary coolant.

As U_3O_8 fuel particle sizes are specified to be between 88 microns and 45 microns, we believe the amount of fuel in the primary system, sized 5 microns or less, is below easily measurable quantities. In addition, the installation of the 20 micron element filters removed any particles larger than 20 microns and the 5 micron filters in the ion exchange system removed particles larger than 5 microns. As mentioned above less than 10% of the manufactured fuel is less than 44 microns and an insignificant fraction smaller than 5 microns.

e) Explain the basis for reactor water filtration in the RCS cleanup system using the relatively large, 5-micron filter pore size, considering filters with a smaller pore size are available for use and have been effective at nuclear power plants in removing fission products from reactor coolant.

5 micron filters were chosen to provide an optimum of filtration while allowing adequate flow through the purification system. The pumps, that serve the purification system, are in the lowest location of the reactor building. The flow of water travels through the filters and the ion exchanger before flowing to the highest point in the system. Changing the filter size with the current piping configuration would slow down the flow of water through the purification ion exchanger in the absence of a large change to the system. Significant slowing of the flow of water could make the system ineffective as a means of water purification. U_3O_8 fuel particle sizes are specified to be between 88 microns and 44 microns. Thus, the vast majority (greater than 99%) of fuel particles circulating in the system would easily be trapped in the 5 micron filters.

f) Describe the NIST the facilities available to handle and store of high activity waste once reactor operations have restarted and additional fission products are generated.

As we mentioned in our 11/17/22 submittal to NRC, we believe that there will be no significant release of fission products. Even if some fission products are released it will not result in any significant quantity of additional radioactive waste. We routinely handle high activity items in various shielded containers and areas, including all items that were used in cleanup from the February 3 event and high activity items, as part of our normal operating routine. Examples include old shim arms, upgraded reactor components, fuel element components, etc.

ARCB RAI 2: Occupational Dose

Basis for question: 10 CFR 20.1101(b) requires use of engineering controls to achieve occupational and public doses ALARA.

10 CFR 20.1101(b) states the following:

(b) The licensee shall use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).

Question 2. Occupational dose:

The revised FSAR section, 11.1.1.4.3.1 states “The presence of any additional fission products generated from this material being lodged in the core during operations would have a negligible effect on personnel doses.”

a) Describe the basis used to determine that occupational doses will be negligible during future operation.

   Much effort has been expended over the past year in reducing the remaining debris in the primary system, to the point where all friable material that can easily be removed has been. The possibility of material being released into the core and then again becoming lodged in the primary system where work will be performed is remote. Any increased effluents due to material being released into the core will be mitigated well before an increase in occupational doses would occur. Dose rates in the process room are routinely monitored by Health Physics. All personnel entering the process room are required to use a dose rate meter and an electronic dosimeter. Any non-routine work in the area is reviewed by Health Physics and a Radiation Work Permit is created to ensure doses remain ALARA.

b) Provide information on current radiological conditions in the process room and confinement building (radiation levels and contamination levels, including isotopic breakdown).

   The current dose rate in the process room is less than 10 mrem/hr in most areas. In fact, most areas have a lower dose rate then before the event, see attached process room survey. The highest dose rate in the process room is 2 R/hr on contact with the heat exchangers. The ambient dose rate near the heat exchangers is <50 mrem/hr. Levels of contamination in the process room are 100’s of dpm/100 cm^2 in most areas. The highest measured contamination level was 1250 dpm/100 cm^2. The contamination consists primarily of Ce-144, Pr-144, and Cs-137.

c) If there were fuel-related hot particles (e.g., Ce-144 and Pr-144), what effect would the higher energy beta particles have on occupational dose and on the conduct of the radiological protection program?

All personnel have been made aware of the potential for hot particles. A thorough survey of the process room was made to identify any hot particles. When radiation work permits (RWP) are created, the potential for hot particles in considered depending on the work being performed. HP personnel have been instructed to consider the beta dose rate when conducting radiological surveys. Thus, both open and close window dose rate measurements are routinely made.

d) Given that reactor restart will potentially impact facility radiation levels and therefore worker dose, describe opportunities prior to restart to provide increased shielding to reduce general area dose rates on valves, crud traps, heat exchangers, etc.
   As we mentioned in our 11/17/22 submittal to NRC, reactor restart is not likely to significantly impact existing dose rates in plant areas. Analysis has shown any remaining material in the plant is not likely to be exposed to any significant neutron flux. The material in the plant is unlikely to move as numerous efforts have been made to move the remaining hotspots. Thus, it is unlikely that dose rates in the worker occupied areas will significantly increase after startup. Detailed surveys of work areas have shown that although doses are higher in a few areas than before the incident, the fields present will not present any hindrance to maintenance operations. The HP team will continue to monitor doses and will ensure any work performed continues to be ALARA. One of the longer-term items in our cleanup contract with Framatome is to build two easily flushable crud traps in low flow areas of the primary system.

ARCB RAI 3: Public Dose

Basis for question:

10 CFR 20.1101(d) states the following:

(d) To implement the ALARA requirements of § 20.1101 (b), and notwithstanding the requirements in §20.1301 of this part, a constraint on air emissions of radioactive material to the environment, excluding Radon222 and its daughters, shall be established by licensees other than those subject to § 50.34a, such that the individual member of the public likely to receive the highest dose will not be expected to receive a total effective dose equivalent in excess of 10 mrem (0.1 mSv) per year from these emissions. If a licensee subject to this requirement exceeds this dose constraint, the licensee shall report the exceedance as provided in § 20.2203 and promptly take appropriate corrective action to ensure against recurrence.

Stack Effluent Monitor Calibration

The stack effluent monitor is calibrated to Ar-41 and its efficiency factor (cpm/µCi/cc) is based on Ar-41. What is the correlation between the stack monitor's output (in unit of cpm based on Ar-41 calibration) to the monitor's output based on a fresh fission product mix of noble gases? Any correlation factor between Ar-41 and fission products depends on what mix of fission product gases is assumed. Thus, the possibility would always exist that the actual mix does not match the assumptions. In all cases, we believe it is more appropriate to collect samples for analysis, as outlined below.

How will accident dose assessment be performed given the difference in the efficiency factors for Ar-41 vs. a fresh mix of noble gas radionuclides?

As we mentioned in our 11/17/22 submittal to NRC, any significant rise in the stack count rate will result in a stack sample being immediately collected. The sample will be counted using a high purity germanium detector, which will allow for an accurate measure of the µCi/cc in the stack and an accurate assessment of the potential offsite dose consequences. In addition, there will be a real-time HPGe gamma spectroscopy system continuously monitoring the stack during start up to assess any potential fission product releases.

In the NIST document titled “Potential Release of Fission Products from the NCNR Reactor During Startup Operations,” the summary states: “The 5000 cpm limit on the reactor stack count rate would result in only an insignificant dose to the public of 0.2 mrem/day dose to the public. Thus, this limit is very conservative and protective to both the public and the environment.”

a) Explain how a 0.2 mrem/day dose to the public is very conservative in comparison to a 10 mrem/year annual ALARA dose constraint of 10 CFR 20.1101(d).
The 5000 cpm limit corresponding to 0.2 mrem/day is an instantaneous reading that would immediately require action (in this case, a major scram) to reduce the effluent dose rates, and thus would result in a total dose well below 0.2 mrem. This would naturally occur well before the 10 mrem/year limit would be approached (see below).

b) Provide a discussion of how facility operation would be modified if there are increased levels of effluents challenging the 10 mrem/year annual ALARA dose constraint of 10 CFR 20.1101(d).
If effluent levels are somewhat increased and subsequent operations continue to the point where it is determined that the 10 mrem/year annual limit would be approached, we will either reduce power or limit operations so as not to exceed the limit. This will be carefully monitored during and after reactor startup.

c) Describe potential or anticipated corrective actions to ensure against recurrence if the 10 mrem/yr. ALARA constraint is challenged.

If a sustained increase in effluent radiation levels is seen, a number of options would be pursued for mitigation, including further filtration or replacement of the D_2O inventory.

Division of New and Renewed Licenses - Vessels and Internals Branch (NVIB)

NVIB RAI 1: Degraded Pump Condition

Basis for question:

10 CFR 50.36(c)(2)(i) states in part:

Limiting conditions for operation are the lowest functional capability or performance levels of equipment required for safe operation of the facility.

10 CFR 50.34(a)(1)(ii)((D) requires:
[The following power reactor design characteristics and proposed operation will be taken into consideration by the Commission:] The safety features that are to be engineered into the facility and those barriers that must be breached as a result of an accident before a release of radioactive material to the environment can occur. Special attention must be directed to plant design features intended to mitigate the radiological consequences of accidents. In performing this assessment, an applicant shall assume a fission product release from the core into the containment assuming that the facility is operated at the ultimate power level contemplated. The applicant shall perform an evaluation and analysis of the postulated fission product release, using the expected demonstrable containment leak rate and any fission product cleanup systems intended to mitigate the consequences of the accidents, together with applicable site characteristics, including site meteorology, to evaluate the offsite radiological consequences. Site characteristics must comply with part 100 of this chapter

Also, 50.34(a)(2) requires:
A description and analysis of the structures, systems, and components of the facility, with emphasis upon performance requirements, the bases, with technical justification therefore, upon which such requirements have been established, and the evaluations required to show that safety functions will be accomplished.

Background
As part of the licensee's recovery effort from the February 3, 2021, fuel failure event, some debris was removed from the reactor primary coolant system; however, some debris remains. Accordingly, the licensee requested by letter dated October 19, 2022, a license amendment to make specified changes to the NBSR Safety Analysis Report (SAR) and allow reactor operation with the remaining debris in the primary coolant system.

SAR Section 5.2.2.3.1 indicates that the four D2O Main Circulating Pumps are single-stage, shaft-sealed, centrifugal pumps operated in parallel to circulate the primary coolant from the Reactor Vessel to the Main Heat Exchangers, and that during normal operation, three pumps are run to maintain the necessary flow, with the fourth serving as an installed spare.

In its submittal, the licensee stated that "one primary pump suffers from an as-yet undiagnosed issue: the pump appears to be noisy" and indicated that it has contracted for pump repair services to inspect the pump and replace and/or repair as appropriate. The licensee affirmed that this is not a safety issue.

Issue

The licensee did not provide a basis that the as-yet undiagnosed issue in one of the primary pumps is not attributed to the remaining debris in the reactor primary coolant system from the February 3, 2021, fuel failure event. Therefore, the licensee has not justified that the root cause for this undiagnosed issue in one of the primary pumps is not applicable to the remaining three D2O main circulating pumps or the other pumps in the primary coolant system (e.g., redundant shutdown pumps, storage tank pumps, and experimental cooling pumps).

Additionally, the licensee has not provided a basis to support its statement that the "as-yet undiagnosed issue in one of the primary pumps" is not a safety issue.

Question 1 – Primary Pump Condition

Provide a status update, including a root-cause, for the undiagnosed issue in one of the primary pumps that appears to be noisy, which is discussed in the submittal dated October 19, 2022.

a) Clarify whether this undiagnosed issue in one of the primary pumps that appears to be noisy was present prior to the February 3, 2021, fuel failure event.
The noise issue was first reported on July 7, 2022. Prior to that, this pump had been operating normally. Note: Diagnosis and repair of this pump is scheduled to take place in the first quarter of CY2023.

b) Justify that this undiagnosed issue in one of the primary pumps is *not* attributed to the remaining debris in the reactor primary coolant system.

Radiation surveys around the pump do not indicate that there is fuel debris in or near the pump. If there was, increased radiation levels would be easily seen. All of the four primary pumps have been running routinely since March of 2022 (the affected pump, Pump #3, was not run after the noise issue was reported in July), and have shown no signs of trouble. There is no reason to believe that the issue with Pump #3 is anything but a normal maintenance issue.

c) If the undiagnosed issue *is* attributed to the remaining debris, justify that the remaining three D2O main circulating pumps or the other pumps in the primary coolant system (e.g., redundant shutdown pumps, storage tank pumps, and experimental cooling pumps) will not also be eventually impacted.

Not applicable.

d) Provide a basis to support the statement in the submittal dated October 19, 2022, that the undiagnosed issue in one of the primary pumps is not a safety issue.

As discussed in the October 19, 2022 submittal to NRC, ANY issue that reduces primary flow will be immediately detected by several redundant primary flow sensors and scram the reactor if flow drops below the setpoint (discussed in NBSR SAR section 13.2.4). This is no different than any other pump maintenance issue, including loss of power to the pump motor. It should be noted that there are four main pumps in the system and only three are used during normal full power operation. There is no reason to believe that this issue would lead to a common cause failure.