UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 1, 2023

Dr. Thomas H. Newton, Deputy Director
National Institute of Standards and
Technology
NIST Center for Neutron Research
U.S. Department of Commerce
100 Bureau Drive, Mail Stop 6101
Gaithersburg, MD 20899-6101

SUBJECT: NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY – ISSUANCE OF AMENDMENT NO. 14 TO RENEWED FACILITY OPERATING LICENSE NO. TR-5 FOR THE NATIONAL BUREAU OF STANDARDS TEST REACTOR RE: REVISION TO THE SAFETY ANALYSIS REPORT TO OPERATE WITH DEBRIS IN THE PRIMARY COOLANT SYSTEM (EPID L-2022-LLA-0152)

Dear Dr. Newton:

The U.S. Nuclear Regulatory Commission (the Commission) has issued the enclosed Amendment No. 14 to Renewed Facility Operating License No. TR-5 for the National Institute of Standards and Technology National Bureau of Standards Test Reactor (NBSR). This amendment consists of changes to the NBSR safety analysis report (SAR) in response to the application dated October 19, 2022 (Agencywide Documents Access and Management System Accession No. ML22293B808), as supplemented by letter dated December 13, 2022 (ML22350A064). Specifically, the amendment modifies the SAR to address potential impacts to facility equipment as described in chapter 5 of the SAR and changes to the facility radiation sources as described in chapter 11 of the SAR as a result of some debris remaining in the NBSR primary coolant system following the February 3, 2021, event.

This license amendment will inform the decision of the Commission whether to approve restart under Title 10 of the *Code of Federal Regulations* section 50.36(c)(1) related to the February 3, 2021, event, but the restart decision will not solely rely on this license amendment.

A copy of the related safety evaluation is also enclosed. The Notice of Issuance will be included in the Commission's monthly *Federal Register* notice. If you have any questions, please contact me at (301) 415-3936, or by email to Patrick.Boyle@nrc.gov.

Sincerely,

Signed by Boyle, Patrick
on 02/01/23

Patrick Boyle, Project Manager
Non-Power Production and Utilization Facility
Licensing Branch
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

Docket No. 50-184
License No. TR-5

Enclosures:
1. Amendment No. 14 to Renewed
Facility Operating License No. TR-5
2. Safety Evaluation

cc:

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SUBJECT: NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY – ISSUANCE OF AMENDMENT NO. 14 TO RENEWED FACILITY OPERATING LICENSE NO. TR-5 FOR THE NATIONAL BUREAU OF STANDARDS TEST REACTOR RE: REVISION TO THE SAFETY ANALYSIS REPORT TO OPERATE WITH DEBRIS IN THE PRIMARY COOLANT SYSTEM (EPID L-2022-LLA-0152): DATED: FEBRUARY 1, 2023

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

DOCKET NO. 50-184

NATIONAL BUREAU OF STANDARDS TEST REACTOR

AMENDMENT TO RENEWED FACILITY OPERATING LICENSE

Amendment No. 14
License No. TR-5

1. The U.S. Nuclear Regulatory Commission (NRC, the Commission) has found that:

   A. The application for amendment to Renewed Facility Operating License No. TR-5, filed by the National Institute of Standards and Technology (the licensee) on October 19, 2022, as supplemented by letter dated December 13, 2022, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations set forth in Title 10 of the *Code of Federal Regulations* (10 CFR) Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, by Amendment No. 14, Renewed Facility Operating License No. TR-5 is hereby amended to authorize the revision to the facility safety analysis report as set forth in the application, as supplemented, and as evaluated in the NRC staff's safety evaluation issued with this amendment.

3. This license amendment is effective as of its date of issuance and shall be implemented within 30 days.

FOR THE NUCLEAR REGULATORY COMMISSION

Joshua M. Borromeo

Digitally signed by Joshua M. Borromeo

Joshua M. Borromeo, Chief
Non-Power Production and Utilization Facility
Licensing Branch
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

Date of Issuance: February 1, 2023

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 14 TO

RENEWED FACILITY OPERATING LICENSE NO. TR-5

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

NATIONAL BUREAU OF STANDARDS TEST REACTOR

DOCKET NO. 50-184

1.0 INTRODUCTION

By letter dated October 19, 2022 (Agencywide Documents Access and Management System Accession No. ML22293B808), as supplemented by letter dated December 13, 2022 (ML22350A064), the National Institute of Standards and Technology (NIST, the licensee) submitted a license amendment request (LAR) to modify the National Bureau of Standards Test Reactor (NBSR) safety analysis report (SAR). Specifically, the amendment would modify the SAR to address potential impacts to facility equipment as described in chapter 5, "Reactor Coolant Systems," of the SAR and changes to the facility radiation sources as described in chapter 11, "Radiation Protection and Waste Management," of the SAR as a result of some debris remaining in the NBSR primary coolant system following the February 3, 2021, event (see ML21274A018). The U.S. Nuclear Regulatory Commission (NRC, the Commission) staff utilized information from the NBSR license renewal SAR (ML041120161) in its review of the LAR.

The supplemental letter dated December 13, 2022, provided additional information that clarified the application, did not expand the scope of the application as originally noticed, and did not change the NRC staff's original proposed no significant hazards consideration determination as published in the *Federal Register* (FR) on November 17, 2022 (87 FR 69056).

2.0 REGULATORY EVALUATION

The NRC staff reviewed the LAR and evaluated the proposed changes to the SAR based on the following regulations and guidance:

- Title 10 of the *Code of Federal Regulations* (10 CFR) Part 20, "Standards for Protection against Radiation," which provides, in part, the regulatory requirements for radiation protection at NRC-licensed facilities.

- Section 20.1101, "Radiation protection programs," paragraph (b) of 10 CFR, which requires that licensees use, to the extent practical, procedures and engineering controls

to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).

- Section 20.1101(d) of 10 CFR, which requires that licensees establish a constraint on air emissions of radioactive material to the environment such that an individual member of the public is not expected to receive a total effective dose equivalent in excess of 10 milli-roentgen equivalent man (mrem) per year from these emissions.

- Section 20.1201, “Occupational dose limits for adults,” of 10 CFR, which provides, in part, a requirement to control the occupational dose to individual adults to within annual dose limits.

- Section 20.1301, “Dose limits for individual members of the public,” of 10 CFR, which provides, in part, that licensees conduct operations so that the total effective dose equivalent to individual members of the public from the licensed operation does not exceed 100 mrem in a year.

- Part 50, “Domestic Licensing of Production and Utilization Facilities,” of 10 CFR, which provides, in part, the regulatory requirements for the licensing of non-power reactors.

- Section 50.34, “Contents of applications; technical information,” paragraph (b)(2) of 10 CFR, which requires in SARs a description and analysis of the structures, systems, and components (SSCs) 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. The description shall be sufficient to permit understanding of the system designs and their relationship to safety evaluations.

- Section 50.34(b)(2)(i) of 10 CFR, which requires in SARs that such items as the “reactor coolant system” be discussed insofar as they are pertinent.

- Section 50.34(b)(4) of 10 CFR, which requires in SARs a final analysis and evaluation of the design and performance of SSCs with the objective stated in 10 CFR 50.34(a)(4), which requires analysis and evaluation of the design and performance of SSCs, including determination of the margins of safety, that considers any pertinent information developed since the submittal of the preliminary SAR.

- Section 50.34(a)(1)(ii)(D) of 10 CFR, which requires in SARs, in part, that the safety features engineered into the facility as a barrier to release of radioactive material to the environment be evaluated against the postulated fission product release.

- Section 50.59, “Changes, tests, and experiments,” of 10 CFR, which states that a licensee may make changes in the facility as described in the SAR, make changes in the procedures as described in the SAR, and conduct tests or experiments not described in the SAR without obtaining a license amendment pursuant to 10 CFR 50.90, “Application for amendment of license, construction permit, or early site permit,” only if the changes meet the criteria specified in 10 CFR 50.59(c).

- NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria,” Chapter 14, “Technical Specifications” (ML042430048), which provides guidance to the NRC staff on reviewing non-power reactor license applications and SARs.

- American National Standards Institute, Inc./American Nuclear Society (ANSI/ANS) 15.11-1987, “Radiation Protection at Research Reactor Facilities,” which describes the elements of a radiation protection program and establishes guidelines necessary to provide an acceptable level of radiation protection for personnel at research reactor facilities and the general public consistent with keeping exposures and releases ALARA.

3.0 TECHNICAL EVALUATION

The NBSR is a 20-megawatt thermal (MWt) forced-flow reactor with aluminum clad plate fuel and that is moderated and cooled by heavy water (D_2O). On February 3, 2021, the NBSR experienced damage to one of its fuel elements. This resulted in, among other things, small pieces of molten fuel material exiting the top of the upper portion of the damaged fuel element and entering the NBSR primary coolant system. Following the February 3, 2021, event, NIST undertook actions to remove this debris from the primary coolant system; however, limited debris remains in the primary coolant system. Accordingly, the LAR proposes to revise chapters 5 and 11 of the SAR to take into consideration reactor operation with the debris that remains in the primary coolant system.

3.1 Assessment of the Primary Coolant System (SAR Chapter 5)

The NRC staff’s review in this section of the safety evaluation consists of the following:

- debris type that entered the primary coolant system;
- amount of debris remaining in the primary coolant system; and
- impact of the remaining debris on components in the primary coolant system.

Debris type that entered the primary coolant system

By letter dated June 29, 2022 (ML22187A127), the licensee provided an explanation of the February 3, 2021, event with respect to the debris that entered the NBSR primary coolant system. The licensee explained that the large globules of once-molten material observed on the lower grid plate after the February 3, 2021, event reached the lower grid plate by exiting through the nozzle region of the damaged fuel element and remained mostly in the immediate vicinity of the damaged fuel element. Based on the licensee’s descriptions and visual evidence from inspections and during clean-up activities (i.e., photos and videos), the NRC staff finds it reasonable that the large globules of once-molten material generally remained in the area of the lower grid plate and the damaged fuel element and did not enter the primary coolant system.

The licensee also explained that as the February 3, 2021, event progressed the interaction of coolant with the molten fuel material contained within the damaged fuel element created sudden unstable steam flashes. The ensuing steam was then jetted through an array of slits in the upper portion of the damaged fuel element. The licensee confirmed that this array of slits remained intact by subsequent video observation of the top of the damaged fuel element. The steam flashes carried small pieces of the molten material through the top of the damaged fuel element, where the configuration of the slit array limited the size of the molten material pieces to 0.1 inch in at least one dimension. These pieces of molten material then circulated through the NBSR primary coolant system. The NRC staff reviewed SAR chapter 4, “Reactor Description,”

and SAR figure 4.2.3, “Fuel Element Assembly,” and confirmed the licensee’s description of the array of slits in the upper portion of the NBSR fuel elements. Based on the design of the fuel element assembly and the licensee’s video footage, the staff determined that it is reasonable that small pieces of molten fuel material exited through the top of the upper portion of the damaged fuel element, did not exceed 0.1 inch in at least one dimension, and entered the primary coolant system.

By letter dated June 29, 2022, the licensee explained the measures that it took to clean-up the once-molten fuel material from the damaged fuel element (i.e., debris) within the region of the NBSR reactor vessel and internals and primary coolant system. Additionally, by letter dated August 15, 2022 (ML22227A150), the licensee provided an updated status and additional details regarding the debris clean-up activities in the primary coolant system. The clean-up efforts by the licensee included the following:

- Picking up large (diameter (D) > 0.25 inch) particulate matter using foreign object search and retrieval (FOSAR) tools at the lower grid plate.
- Vacuuming smaller (0.06 inch < D < 0.25 inch) particulate matter using an eductor driven vacuum at the upper and lower grid plates (i.e., a vacuum wand driven by an eductor system operated by a pump that moved the D_2O already present in the reactor vessel).
- Installing 20-micron filters in all of the fuel element positions (note: U_3O_8 fuel particles are larger than 44 microns). When the pumps run, all primary coolant has to pass though these filters while being circulated and the four (parallel) primary pumps were run individually as well as in all possible permutations of one through four pumps.
- Ultrasonic cleaning of several hotspots in the process room, followed by running the primary pumps, which moved water through the 20-micron filters.
- Minor disassembly and/or replacement of plumbing components that showed major internal contamination (e.g., heat exchangers, pumps, check valves).
- Draining portions of the primary coolant system based on dose rates.
- Admitting carbon dioxide to the system in an attempt to float debris, which is then caught in the filters. Helium sparging was used to assist with the removal of carbon dioxide from the system.

The NRC staff notes that the filter elements installed in each of the fuel element position were capable of and reasonably ensured the removal of finer debris (D < 0.06 inch) from the damaged fuel element that circulated in the primary coolant system.

By letter dated August 15, 2022, the licensee summarized the results of its efforts to remove debris from the primary coolant system. The NRC staff notes the following regarding these results:

- All visible pieces of debris were removed from the reactor vessel and a full visual inspection of the vessel indicated no further debris.
- Filter elements captured debris when the primary pumps were run.
- Debris was measurably moved away from some of the hot spots in the process room and a reduction in dose rate was observed.
- Ultrasonic cleaning had limited effectiveness, but ultimately resulted in a reduction of the dose rate in a few areas of the process room.
- Helium sparging resulted in a reduction of the dose rate in a few areas of the process room, in particular the heat exchanger components; carbon dioxide sparging resulted in no significant change to the dose rate levels in the process room.

- Removal of accessible components and draining in specific locations of the primary coolant system had varying results with a minor reduction in the dose rates in some areas and a significant reduction in the dose rates in other areas, especially by the main heat exchanger HE-1C flange area.

Based on the above, the NRC staff determined that the clean-up actions taken by the licensee were effective in reducing dose rates in the process room and in removing debris from the primary coolant system that resulted from the February 3, 2021, event. However, given the uncertainty associated with the precise amount of fuel material from the damaged fuel element that (1) entered the primary coolant system and (2) was subsequently removed from the primary coolant system during clean-up activities, it is reasonably assumed that some debris remains in the system. Accordingly, the licensee is addressing this condition through proposed changes to SAR chapters 5 and 11.

Amount of debris remaining in the primary coolant system

In the LAR, the licensee stated that despite aggressive attempts to remove it, a small amount of debris remains in the primary coolant system. Furthermore, a conservative calculation, based on weighing the damaged fuel element, shows that the maximum possible quantity of debris that could have entered the primary coolant system is 66 grams. The licensee explained that this estimate does not account for the debris removed via the licensee's clean-up activities. The NRC staff notes that SAR sections 4.2.1, "Reactor Fuel," and 4.2.5, "Core Support Structure," provide information regarding the content and mass of the nuclear fuel and the fuel element, respectively. The staff also notes that the current licensing basis for the NBSR includes tolerances regarding the precise mass of the nuclear fuel and the fuel element. As such, the staff expects and finds it reasonable that there is variation in the total mass of each individual fuel element (including the nuclear fuel) used in the NBSR. Based on the variation in the total mass of each fuel element as discussed in the SAR, the staff finds it reasonable that the licensee determined the maximum possible quantity of debris in the primary coolant system by weighing the damaged fuel element and comparing it to its design basis. Additionally, the staff finds the licensee's assumption of 66 grams of fuel debris remaining in the primary coolant system to be conservative despite any variations in fuel element mass because this estimate does not account for the debris that was documented as being removed by the licensee's clean-up activities.

Impact of the remaining debris on components in the primary coolant system

Given the reasonably expected size (i.e., limited to 0.1 inch in at least one dimension) and the conservatively estimated quantity (i.e., 66 grams) of debris remaining in the primary coolant system (which has a nominal inventory of 11,100 gallons as described in SAR section 5.4.2, "System Description"), the following paragraphs contain the NRC staff's assessment related to the potential impact of this remaining debris on the components in the primary coolant system.

Main Heat Exchangers

The licensee explained that the NBSR has three main heat exchangers (i.e., HE-1A, HE-1B, and HE-1C) that are plate-and-frame type heat exchangers, where the primary sides of the heat exchangers are contained in welded cassettes and the only elastomer interface are O-rings surrounding the inlet and outlet ports between each cassette. SAR section 5.2.2.2, "Heat Sink (Main Heat Exchangers)," states that each heat exchanger consists of a carbon steel pressure plate, 132 cassettes (i.e., two stainless steel plates welded together to form a chamber through which reactor coolant flows), and another carbon steel pressure plate. The licensee explained

that radiation surveys have indicated the presence of some debris in these heat exchangers and that the licensee's clean-up activities have been unable to completely dislodge this debris. The NRC staff notes that SAR section 5.2.2.2 provides the design information (e.g., design pressure, temperature, pressure-drop on the primary and secondary sides, heat transfer rate, etc.) for the main heat exchangers and indicates that two of the three main heat exchangers (i.e., HE-1A and HE-1B) are sufficient to transfer all of the heat generated by the reactor to the secondary coolant and that main heat exchanger HE-1C acts as a spare.

The NRC staff determined that the remaining debris in the primary coolant system will not have an adverse effect on the heat removal capability and design function of the main heat exchangers because the size and quantity of the remaining debris is negligible compared to the nominal inventory of reactor coolant and the available surface area for heat removal in these components. Additionally, the staff determined that the impact of the remaining debris on the heat removal capability of the main heat exchangers would reasonably be expected to be consistent with the fouling of heat transfer surfaces that typically occurs from normal operation in heat exchanger components.

The licensee also explained that if the temperature of the reactor coolant entering the main heat exchangers exceeds the design limits established in SAR chapter 5, a reactor rundown would be triggered. The NRC staff notes that this safety function is designed to occur without operator involvement, but it would be expected that operators would also be aware of this situation and would take appropriate actions (e.g., reduce power). The licensee explained that since the main heat exchangers are fully instrumented to provide continuous logging of the relevant operating parameters (i.e., pressure-drop, flow, and temperature changes) the efficiency of the exchangers can be monitored and compared to the original design specification and data from before the February 3, 2021 event. Thus, the staff determined that instrumentation and measurements available for the main heat exchangers provide a means of performance monitoring to ensure that they function as designed and that, otherwise, appropriate automatic or manual actions will be taken consistent with the design basis of the NBSR.

Based on the above, the NRC staff concludes (1) that the main heat exchangers are capable of performing their intended design function, as described in SAR chapter 5, with the remaining debris in the NBSR primary coolant system resulting from the February 3, 2021, event because of the small size and quantity of the remaining debris as compared to the volume in the primary coolant system and the available surface area for heat removal in these components and (2) that the licensee has an appropriate means of performance monitoring to ensure the continued proper functionality of the main heat exchangers.

Pumps

The licensee explained that all of the pumps in the NBSR primary coolant system have been operating on a frequent basis since the insertion of filter elements in April 2022 as part of its clean-up activities. In particular, the licensee stated that the main primary pumps have been started and operated more than one hundred times in various combinations without incident.

In the LAR, the licensee stated that one primary pump suffers from an as-yet undiagnosed issue, in which the pump appears to be noisy. By letter dated December 7, 2022 (ML22342A506), the NRC staff requested additional information regarding whether this undiagnosed issue is a result of the debris in the primary coolant system from the February 3, 2021, event. By letter dated December 13, 2022, the licensee responded that radiation surveys around the pump do not indicate that there is fuel debris in or near the pump, which would be easily identified by increased radiation levels. Additionally, the licensee

explained that the diagnosis and repair of this pump (i.e., Pump #3) is scheduled to take place in the first quarter of calendar year 2023. The licensee also confirmed that all pumps that comprise the design basis of the primary coolant system are centrifugal pumps.

The NRC staff notes that the design and construction of centrifugal pumps makes them capable of pumping despite small amounts of solids suspended in the fluid; particularly if the solids are comprised of small particulates. Also, as discussed above, the reasonably expected size (i.e., limited to 0.1 inch in at least one dimension) and the conservatively estimated quantity (i.e., 66 grams) of debris remaining in the primary coolant system is small compared to the nominal inventory for the primary coolant system of 11,100 gallons. Therefore, the staff determined that there is reasonable assurance that the amount and consistency of the remaining debris in the primary coolant system is not sufficient to impact the function of the pumps within the primary coolant system. Additionally, given the pump type of the primary pumps, the lack of increased radiation levels in Pump #3, and the run-time of the primary pumps during the licensee's clean-up activities, the staff determined that it is reasonable that the noise issue with Pump #3 is not attributed to the remaining debris. Moreover, the staff determined that consistent with SAR section 5.2.2.3, "Pumps," the NBSR is designed to operate during normal operation with three primary pumps running to maintain the necessary flow (i.e., the fourth primary pump serves as an installed spare) until repair and maintenance of Pump #3 is completed. Taken together, the staff finds that there is reasonable assurance that the remaining debris in the primary coolant system will not have an adverse effect on the design function and ability of the pumps within the primary coolant system to circulate D_2O through the NBSR reactor.

Based on the above, the NRC staff concludes that the pumps in the primary coolant system are capable of performing their intended design function, as described in SAR chapter 5, with the remaining debris in the NBSR primary coolant system resulting from the February 3, 2021, event because of the small size and quantity of the remaining debris as compared to the volume in the primary coolant system and because the design and construction of these pumps is tolerant of small amounts of solids suspended in pumped fluid.

Piping

The licensee explained that the NBSR primary piping system contains over 10,000 gallons of D_2O and that the piping diameter is generally a minimum of ½ inch and a maximum of 18 inches. The NRC staff notes that there is one additional class of piping that is associated with instrument lines that have no flow (i.e., pressure transducers) and that can be as small as ¼ inch in diameter. This class of piping is included in the evaluation in the "Instrumentation" subsection of this safety evaluation.

Additionally, the licensee explained that the NBSR emergency cooling system, as discussed in SAR section 6.1.1, "Emergency Cooling System," provides cooling for the reactor core and experiments should primary coolant be lost through leakage (e.g., a pipe rupture in the primary coolant system) and that the loss of water during a loss of coolant accident (LOCA) results in the draining of water from the Inner Reserve Tank (IRT) to the distribution pan above the fuel. The licensee stated that the nozzles from the IRT to the distribution pan are 0.72 inches in diameter and that the holes in the distribution pan have a nominal diameter of 0.316 inches.

As discussed above, the NRC staff determined that the licensee's estimate of the remaining debris in the primary coolant system is conservative and that it is reasonable that this remaining debris does not exceed 0.1 inch in at least one dimension. Therefore, the staff finds that there is reasonable assurance that the remaining debris in the primary coolant system will not have an

adverse effect on the design function and ability of the primary piping as a flow path to circulate D_2O through the NBSR reactor because the size and quantity of the remaining debris is negligible compared to the nominal inventory of reactor coolant and the piping size in the primary coolant system.

Based on the above, the NRC staff concludes that the primary piping system is capable of performing its intended design function, as described in SAR chapter 5, with the remaining debris in the NBSR primary coolant system resulting from the February 3, 2021, event because of the small size and quantity of the remaining debris as compared to the volume in the primary coolant system and the diameter of piping in the primary coolant system. Additionally, the staff concludes that the remaining debris will not prevent the design function of the IRT, as described in SAR chapter 6, because the size of the remaining debris is significantly less than the openings in the nozzles from the IRT and in the distribution pan.

Valves

The NRC staff notes that SAR chapters 5 and 6 provide a summary description of the valves, including their intended design function, contained in the NBSR primary coolant system. Based on these descriptions, the staff notes that the valves range in size from 1.5 inches to 18 inches. As discussed above, the staff determined that the licensee's estimate of the remaining debris in the primary coolant system is conservative and that it is reasonable that this remaining debris does not exceed 0.1 inch in at least one dimension. Therefore, the staff finds that there is reasonable assurance that the remaining debris in the primary coolant system is not of sufficient size and quantity to have an adverse effect on the ability of the valves in the primary coolant system to open and close and to seat properly consistent with their design function.

Additionally, the licensee explained that the following valve types in the NBSR primary coolant system are subject to periodic surveillance testing: emergency core cooling system valves; moderator dump valve; and primary coolant relief valve. For each of these valves, the licensee provided the recent test dates and relevant test procedure and confirmed that the valves passed their testing. The licensee explained that the functionality of the primary pump check valves is demonstrated every time that a recently started pump develops the expected system flow. If the expected system flow were not developed, the licensee explained that this would be indicative of bypass through an incompletely closed check valve. With respect to the active emergency core cooling system valves (LOCA valves), the licensee stated that these valves are opened and closed on a regular basis (i.e., daily when the building is opened and closed) and that the outside of these valves is fitted with a passive mechanical indicator to signify if the valves are not functioning as designed. Thus, the NRC staff finds that the periodic surveillance testing for the emergency core cooling system valves, moderator dump valve, and primary coolant relief valve, and the functional testing of the primary pump check valves and the LOCA valves, provide a means of periodic performance monitoring to ensure that these components function as designed.

Based on the above, the NRC staff concludes that the valves in the NBSR primary coolant system are capable of performing their intended design function, as described in SAR chapter 5, with the remaining debris in the primary coolant system resulting from the February 3, 2021, event because of the small size and quantity of remaining debris as compared to the volume in the primary coolant system and because the licensee has an effective means of periodic performance monitoring to ensure the continued proper functionality of the valves.

Instrumentation

In the LAR, the licensee explained that all of the instrumentation in the NBSR primary coolant system that performs a safety function is redundant and physically separate from other instrumentation. The licensee also confirmed that the instrumentation is tested at least quarterly and has shown no signs of degradation, even during the licensee's intense clean-up activities.

The licensee explained that temperature transducers, due to their construction, are insensitive to debris (i.e., typically the sensor is placed in a dry well) and that pressure and level transducers that are designed to read pressure (i.e., not by deducting flow) are attached to non-flowing lines. Based on the design of the NBSR temperature, pressure, and level instrumentation being insensitive to primary coolant flow (e.g., located in a drywell or attached to non-flowing lines), the NRC staff determined that these instruments will not be impacted by the remaining debris in the primary coolant system.

The NRC staff notes that the NBSR instrumentation related to the total primary flow, inner plenum flow, outer plenum flow, and vessel level are calibrated annually, which provides an additional opportunity to detect any anomalies, including those that may be associated with the remaining debris in the primary coolant system. Additionally, the staff finds that it is highly unlikely that the remaining debris would simultaneously and adversely affect all flow instrumentation for the primary coolant and thus obscure the licensee's ability to determine primary coolant flow because the instruments are physically separate and redundant. Moreover, the staff notes that these instruments have been functioning (without signs of degradation) and are tested at least quarterly, which provides an effective means of performance monitoring to ensure that they can perform their intended design function, as described in SAR chapter 5.

Based on the above, the NRC staff concludes that the instruments in the NBSR primary coolant system are capable of performing their intended design function, as described in SAR chapter 5, with the remaining debris in the primary coolant system resulting from the February 3, 2021, event because of (1) the small size and quantity of remaining debris as compared to the volume in the primary coolant system, (2) the separation and redundancy of instrumentation, (3) the design of the temperature, pressure, and level instrumentation being insensitive to primary coolant flow, and (4) the periodic performance monitoring that will ensure the continued proper functionality of the instrumentation associated with flow of the primary coolant.

Determination on the Proposed Revision to SAR Chapter 5

Based on the above, the NRC staff determined that the proposed revisions to SAR chapter 5 (i.e., SAR section 5.2.2.4.4, "Debris from February 3, 2021 Event") provided by the licensee's application dated October 19, 2022, are acceptable and that the heat exchangers, pumps, valves, piping, and instrumentation in the NBSR primary coolant system are capable of performing their intended design function, as described in SAR chapter 5, with the remaining debris in the primary coolant system resulting from the February 3, 2021, event. Thus, the staff concludes that, in accordance with 10 CFR 50.34(b)(2), SAR chapter 5, as amended, provides a description and assessment of the SSCs of the facility sufficient to permit understanding of the system designs and their relationship to safety evaluations.

3.2 Assessment of Fission Product Release Analysis (SAR Chapter 11) and Accident Analyses (Chapter 13)

In the LAR, the licensee stated that a maximum of 66 grams of fuel material from the damaged fuel element (i.e., debris) was released into the NBSR primary coolant system as a result of the

February 3, 2021, event. The licensee stated that it performed clean-up activities related to this debris, including:

- Operating the primary pumps with thirty 20-micron filters in the fuel positions.
- Ultrasound vibration of the plumbing in strategic positions while the primary pumps were running.
- Full drainage of the reactor into the storage tank followed by refilling the reactor through a 5-micron filter.
- Sparging with carbon dioxide, followed by sparging with helium of the entire primary water inventory.

Based on these clean-up activities, the licensee stated that it expects that some debris particulate matter sized 5-microns or less remains in the primary coolant system and that otherwise most of the remaining debris is non-friable (i.e., immobilized). Therefore, the licensee's analysis with respect to SAR chapters 11 and 13 involves an evaluation of the potential effects of friable (i.e., mobile) fuel material in the primary coolant system on the dose at the site boundary. As discussed above, the licensee's analysis with respect to SAR chapter 5 involves the separate evaluation of the potential effects of friable fuel material in the primary coolant system in a mechanical sense in that it might create an obstruction to an SSC that is important to the safe operation of the NBSR.

As stated in the LAR, the licensee performed a 10 CFR 50.59 evaluation and concluded that operation of the NBSR with fuel material in the primary coolant system necessitates an LAR. Specifically, since this is a change from the existing license basis, which is based on operation with fuel cladding intact, a change in the SAR is needed to describe reactor operations with the presence of the debris, which is essential unclad fuel. In the LAR, the license proposed changes to the SAR in order to describe this change in operation with unclad fuel material in the primary coolant system.

Evaluation of the Licensee's Ability to Meet the Public Dose ALARA Constraint

NIST estimated that during the February 3, 2021, event, a maximum of 66 grams of fuel material from the damaged fuel element was released into the primary coolant system. As described above, NIST performed clean-up activities to remove as much of this fuel material as practical from the primary coolant system.

During any reactor operation subsequent to the February 3, 2021, event, some of the remaining fuel material has the potential to become mobile and to be transported into the reactor vessel and/or there is the potential that some fuel material remains in the reactor vessel. The fuel material would then undergo fission reactions and, consequently, generate fission product radioactive noble gases. The licensee used the ORIGEN-2 computer code to estimate the fission product production rate for this analysis. The fission products would include the noble gases of krypton and xenon and iodines.

In an attachment to the LAR titled "Potential Release of Fission Products from the NCNR Reactor During Startup Operations" and dated July 21, 2022, NIST provided an assessment of the potential gaseous effluent releases and the dose consequences from the release of fission products from the NBSR reactor during startup operations subsequent to the February 3, 2021, event. The assessment was supplemented by another attachment to the LAR titled "Addendum to the Potential Release of Fission Products from the NCNR Reactor During Startup Operations" and dated October 13, 2022, where NIST provided its assumptions and estimates regarding the release of potential gaseous radioactive effluents.

The licensee's analyses are based on an assumed 1 gram of fuel containing 0.117 grams of uranium (U)-235 in the reactor vessel at full power. After 6 days, the release rate of fission products begins to gradually decline as a result of U-235 burn up. The licensee's analyses are performed for 1 gram of unclad fuel material and provide fission product releases calculated using the ORIGEN-2 computer code.

Gaseous effluent at the NBSR is monitored by the facility radiation monitoring system. The LAR states that the facility's radiation monitors can detect these fission product gases in the coolant and in the effluent release pathways. The fission product radiation monitor is RM 3-2 and the effluent radiation monitors are RM 3-4, RM 3-5, and RM 4-1. The normal operating setpoints for these monitors are 50,000 counts per minute (cpm). However, NIST stated that during startup operations subsequent to the February 3, 2021, event, the setpoints will be reduced to 10 percent of the normal setpoints (i.e., reduced from 50,000 cpm to 5,000 cpm). The licensee also stated that any significant rise in the radiation monitor count rate will result in a stack gas sample being taken and measured using a gamma spectroscopy system to allow for an accurate estimate of the release. If the release of fission product noble gases exceeds the radiation monitor's setpoints, the monitor will cause the reactor to shutdown (scram) and confinement to be isolated per NBSR technical specifications 1.3.26.1, "Major Scram," 3.2.2, "Reactor Safety System Channels," and 3.7, "Radiation Monitoring Systems and Effluents."

In addition to the effluent monitors, radiation monitors for the helium sweep system are connected into the monitoring room for the discharge of the helium blowers and feed a count rate circuit to determine gaseous activity of the helium gas sweep. The procedures for investigating an elevated count rate on the helium sweep monitors include verification of other monitors and drawing a gas sample to analyze for fission products. NIST stated that if a definite increase in fission gas is detected, it will shut down the reactor.

NIST performed a dose calculation from potential effluent releases to members of the public at the NBSR emergency planning zone boundary using the HOTSPOT computer code. The LAR dated October 19, 2022, table 1, "Release Scenarios for Various Quantities of Fuel in the Highest Flux in the Vessel," provides the assumptions and calculations of potential offsite dose rates with fuel material in the primary coolant system. The table presents estimates of the dose rates in mrem/day and the numbers of operating days at 20 MWt that would be required to exceed the 10 mrem ALARA annual dose constraint in 10 CFR 20.1101(d).

Assuming that 1 gram of fuel material was transported to and remained in the reactor vessel, noble gas and iodine isotopes would be created. These effluent releases could result in an estimated daily dose rate of 0.94 mrem/day. This would allow for 10.6 operating days at 20 MWt before the 10 mrem ALARA annual dose constraint would be reached. Thus, it is possible that there could be gaseous effluents causing public dose challenging the 10 mrem/year ALARA dose constraint in 10 CFR 20.1101(d).

In its December 13, 2022, response to an NRC staff request for additional information, the licensee stated, in part, that:

> 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, [the licensee] will either reduce power or limit operations so as not to exceed the limit. This will be carefully monitored during and after reactor startup.

The NRC staff reviewed the supporting analysis on the potential release of fission products from the NBSR during startup operations subsequent to the February 3, 2021, event and the resulting potential for dose to members of the public. The staff reviewed the information provided in the LAR, as supplemented, and the supporting NIST documents to assess the potential radiological consequences of operation with fuel material in the primary coolant system. The staff determined that the assumptions used by the licensee are reasonable, and that the use of the ORIGEN-2 and HOTSPOT computer codes is adequate to ascertain the potential effluent releases and the potential offsite doses.

The NRC staff notes that the licensee has the potential to operate the NBSR with effluent releases exceeding the 10 CFR 20.1101(d) ALARA dose constraint. If the ALARA dose constraint is exceeded, the regulations require that the license report the exceedance and promptly take appropriate corrective action to ensure against recurrence. Evaluations of the licensee's performance including those timeframes during and/or soon after any startup of the NBSR will be performed as part of the NRC's ongoing enhanced oversight of the NBSR (see ML22206A012).

The LAR proposes to revise SAR section 11.1.1 to describe the effect of fuel material in the primary coolant system. Specifically, the proposed changes to the SAR describe the potential for fission products to be generated in the reactor vessel from fuel material in the reactor vessel. The proposed changes further describe the capability of monitors to detect these fission products, the use of the lower radiation monitor scram setpoints (i.e., 5,000 cpm) during startup, and that the reactor operator would take action to shut down the reactor upon the detection of excessive fission product gases. Based on the above, the NRC staff concludes that these proposed changes to the SAR are acceptable with respect to the licensee's ability to meet the ALARA public dose constraint in 10 CFR 20.1101(d).

Evaluation of Occupational Dose

Compliance with the requirement of 10 CFR 20.1101(b) that the licensee achieve occupational doses and doses to members of the public that are ALARA requires the use of procedures and engineering controls based upon sound radiation protection principles. The NRC staff reviewed the LAR for information related to maintaining occupational doses ALARA.

The LAR provides information on the amount of friable (i.e., mobile) fuel material that could potentially reach the NBSR reactor vessel. The licensee stated that it performed clean-up activities to remove as much fuel material from the primary coolant system as practical. However, given the potential for fuel material remaining in the primary coolant system, the facility could experience increased radiological challenges.

To better understand the impacts for occupational dose, the NRC staff requested additional information about the radiological environment of the NBSR facility subsequent to the February 3, 2021, event. The staff also asked whether the licensee had considered the use of filtration smaller than the 5-micron filters that were used during the clean-up. In its December 13, 2022, response, the licensee stated that 5-micron filters were chosen because NIST had determined that 99 percent of the fuel particles would be captured by this 5-micron pore size filter. The licensee also stated that based on the NBSR's current piping design, using a filter pore size smaller than 5-micron would reduce the flow of water through the ion exchanger and filter, making it ineffective as a means of water purification. The licensee stated that due to the efforts to remove the fuel material from the primary coolant system, the radiation levels in the facility have been reduced to ALARA and are below historical radiation levels due to radioactive decay.

Given the efforts that have been completed to remove the fuel material from the primary coolant system and that the U-235 is expected to be of a particle size greater than 5 microns, the licensee does not anticipate substantial movement of fuel material into the reactor vessel. Therefore, the licensee does not expect an increase in occupational dose during operations subsequent to the February 3, 2021, event. The licensee further stated that radiation levels in the process room are routinely monitored and that all personnel entering the process room are required to use dose rate meters and to wear personal electronic dosimetry.

The NRC staff also requested information on how the licensee plans to address radiological concerns related to hot particles that could be found during operations subsequent to the February 3, 2021, event. The licensee stated that a thorough survey was made to identify any hot particles. The licensee also stated that the potential for hot particles is considered when radiation work permits are created. Additionally, health physics personnel are instructed to consider the beta dose rate when conducting radiological surveys.

The NRC staff reviewed SAR chapter 11, which describes the radiological controls program at the NBSR. The staff reviewed radiological data at the time of the February 3, 2021, event and current radiological conditions. In addition, the staff reviewed radiation levels, air sampling data, contamination levels, occupational doses, and waste management practices. The staff also reviewed SAR chapter 12, “Conduct of Operations,” and determined that NIST has established an organization structure to support safe plant operations. The NIST Health Physics (HP) organization is an independent line operations organization reporting to upper management at NIST. The HP organization is supervised by a Senior Health Physicist and staffed with professional health physicists and health physics technicians. The radiation protection program meets the guidelines of ANSI/ANS-15.11-1987. The HP organization conducts training and indoctrinations for personnel assigned to the facility and for visitors to the facility. The HP organization ensures compliance with 10 CFR Part 19, “Notices, Instructions and Reports to Workers: Inspection and Investigations,” and 10 CFR Part 20. Finally, the HP personnel work closely with Reactor Operations, Engineering, researchers and users, and management. An HP representative serves on the Safety Evaluation Committee, and the HP personnel provide necessary and timely information to assist the Director and the Chief Nuclear Engineer in carrying out their responsibilities under the NRC license.

Based on the above, the NRC staff concludes that, even with fuel material remaining in the primary coolant system, NIST has a sufficient radiological control program in place and implemented to meet the requirement of 10 CFR 20.1101(b) that the licensee achieve occupational doses and doses to members of the public that are ALARA; therefore, SAR chapter 11, as proposed to be amended, is acceptable.

Evaluation of Accident Analyses (SAR Chapter 13)

SAR chapter 13, “Accident Analyses,” includes accidents that result in the release of radioactivity: (1) a maximum hypothetical accident (MHA) and (2) a LOCA. Section 13.2.1, “Maximum Hypothetical Accident (MHA),” of the SAR describes the MHA scenario. The SAR states that the dose at the site boundary from an MHA is 6.8 mrem in 30 days. Section 13.2.3, “Loss of Primary Coolant,” of the SAR describes the LOCA scenario. A LOCA at the NBSR is a major rupture of the cold leg of the primary system, which leads to draining the reactor core. Prior to the February 3, 2021, event, if the entire reactor coolant inventory were to leak out in this manner, a person at the site boundary would receive a dose of less than 6.5 mrem.

For the MHA, when considering the fuel material remaining in the primary coolant system, the licensee determined that the potential increase to public dose at the site boundary would

be 0.13 mrem. For a LOCA, when considering the fuel material remaining in the primary coolant system, the licensee determined that the potential increase to public dose at the site boundary would also be 0.13 mrem. Even with these potential increases, the dose consequences would remain less than the 10 CFR 20.1101(d) regulatory guideline value applicable to the NBSR MHA and LOCA of 10 mrem per year.

The NRC staff reviewed the NIST analyses and SAR chapter 13 and determined that the licensee's analyses reasonably estimate the potential increases in public dose during accidents as a result of the fuel material remaining in the primary coolant system and that, even with these potential increases, the ALARA public dose constraint in 10 CFR 20.1101(d) is met. Therefore, operation of the NBSR with fuel material in the primary coolant system would not violate 10 CFR 20.1101(d) with respect to accidents.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Maryland State official was notified of the proposed issuance of the amendment on January 19, 2023. The State official did not provide any comments.

5.0 ENVIRONMENTAL CONSIDERATION

The amendment changes requirements with respect to the installation or use of facility components located within the restricted area as defined in 10 CFR Part 20. The NRC staff has determined that the amendment involves no significant increase in the amounts and no significant changes in the types of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendment involves no significant hazards consideration, as published in the FR on November 17, 2022 (87 FR 69056), and there has been no public comment on such finding. Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendment.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) there is reasonable assurance that such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

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