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

April 14, 2021

Dr. Robert Dimeo, Director
National Institute of Standards and Technology
NIST Center for Neutron Research
U.S. Department of Commerce
100 Bureau Drive, Mail Stop 8561
Gaithersburg, MD 20899-8561

SUBJECT: NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY – U.S. NUCLEAR REGULATORY COMMISSION INTERIM SPECIAL INSPECTION REPORT NO. 05000184/2021201

Dear Dr. Dimeo:

This letter refers to the U.S. Nuclear Regulatory Commission (NRC) special inspection activities which began February 9, 2021, at the National Institute of Standards and Technology (NIST) Center for Neutron Research facility. Based upon an assessment of the criteria specified in NRC Management Directive 8.3, "NRC Incident Investigation Program," the NRC initiated a special inspection in accordance with Inspection Procedure 93812, "Special Inspection Team." The special inspection was initiated pursuant to the event notification (EN 55094) received from your staff on February 3, 2021, regarding the National Bureau of Standards test reactor (hereinafter NIST test reactor). This event notification was supplemented by a 14-day report dated February 16, 2021, and amended on March 4, 2021 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML21048A149 and ML21070A183, respectively), which described circumstances that led to your NIST staff declaring an alert as a result of detecting fission products in the helium sweep and ventilation exhaust systems. Additionally, on March 2, 2021, a related event notification (EN 55120) provided that, as a result of video surveillance and radiation readings, NIST determined that the February 3, 2021, event violated the reactor's fuel temperature safety limit. This notification was later supplemented by a 14-day report dated March 5, 2021 (ADAMS Accession No. ML21064A523).

Our inspection activities to date have confirmed the NIST test reactor remains safely shut down and that the event did not pose a risk to public health and safety. Our reviews of equipment performance, onsite records, and interviews with your NIST staff have shown that releases of radiation during the event were a small fraction of regulatory limits and have been terminated. We have performed confirmatory calculations that verified the dose consequence to members of the public for this event is less than 0.5 millirem (a standard chest X-ray is approximately 10 millirem)[1]. Furthermore, we found that your staff continues to deliberately assess and evaluate the facility conditions that led to the event to determine the causes and develop corrective actions. Our future inspection activities will verify that your staff completes thorough,

[1] https://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html

technically rigorous evaluations as you continue your event investigation. These inspection activities will also assess the development and implementation of your corrective actions.

Our early observations related to exceeding your safety limit have yielded a preliminary determination that the fuel temperature was likely high enough that it resulted in partial damage of a single fuel element (i.e., blistering, cracking, and melting). We note that based on your report of exceeding the safety limit referenced previously, NRC approval is required to restart the NIST test reactor. Any request to authorize restart would require NIST to conduct a thorough and effective root-cause determination, including the identification and implementation of appropriate corrective actions to prevent recurrence. We will communicate further regarding this process in future correspondence. Any potential apparent violations of NRC requirements (e.g., safety limit and associated limiting conditions for operations), as appropriate, will be discussed in the final inspection report.

On February 11, 2021, March 19, 2021, and April 9, 2021, the NRC performed interim debriefs with you and members of your staff. The inspection team documented initial observations from inspection activities conducted until this point in the enclosed interim inspection report. This interim inspection report could be supplemented by additional documentation before we issue a final inspection report at the completion of special inspection charter objectives. As we complete our inspections, we plan to provide an opportunity for public stakeholders to meet with NRC staff to discuss the results of our inspections and oversight of the NIST test reactor.

In accordance with Title 10 of the *Code of Federal Regulations* Section 2.390, "Public inspections, exemptions, requests for withholding," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the NRC's document system ADAMS. ADAMS is accessible from the NRC Web site at https://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

If you have any questions concerning this matter, please contact Mr. Travis Tate, Chief, Non-Power Production and Utilization Facilities Oversight Branch at (301) 415-3901.

Sincerely,

Mohamed K. Shams

Digitally signed by Mohamed K. Shams
Date: 2021.04.14 09:53:46 -04'00'

Mohamed K. Shams, Director
Division of Advanced Reactors and Non-Power Production and Utilization Facilities
Office of Nuclear Reactor Regulation

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

Enclosure:
As stated

cc w/enclosure: See next page

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SUBJECT: NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY – U.S. NUCLEAR REGULATORY COMMISSION INTERIM SPECIAL INSPECTION REPORT NO. 05000184/2021201 DATED: APRIL 14, 2021

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U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION

Docket No.:	50-184
License No.:	TR-5
Report No.:	05000184/2021201
Licensee:	National Institute of Standards and Technology
Facility:	Center for Neutron Research National Bureau of Standards Test Reactor National Institute of Standards and Technology Test Reactor
Location:	Gaithersburg, MD
Dates:	February 9 thru April 9, 2021
Inspectors:	Kevin Roche, Reactor Systems Engineer (Team Lead) Michael Balazik, Project Manager Phillip O'Bryan, Reactor Operations Engineer William Schuster, Reactor Inspector
Assisted by:	Richard Clement, Senior Health Physicist Edward Helvenston, Project Manager William Kennedy, Project Manager
Approved by:	Mohamed K. Shams, Director Division of Advanced Reactors and Non-Power Production and Utilization Facilities Office of Nuclear Reactor Regulation

Enclosure

EXECUTIVE SUMMARY

National Institute of Standards and Technology
National Bureau of Standards Test Reactor
Interim Special Inspection Report No. 05000184/2021201

The U.S. Nuclear Regulatory Commission (NRC) program for overseeing the safe operation of research and test reactors is described in Inspection Manual Chapter 2545, “Research and Test Reactor Inspection Program.” In response to the event notification (EN 55094) by the National Institute of Standards and Technology (NIST), a Special Inspection Team (SIT) was established in accordance with NRC Management Directive 8.3, “NRC Incident Investigation Program.” The SIT is using a special inspection charter dated February 8, 2021, to conduct an onsite review following the event, which includes: 1) sequence of events; 2) licensee response to the event; 3) assessment of the consequences of the event; 4) adequacy of facility procedures; 5) maintenance or outage actions preceding the event; 6) the licensee root cause of the event; and 7) completed or planned corrective actions to prevent recurrence. The special inspection charter was revised on March 5, 2021, to expand the resources, technical expertise, and scope of the chartered activities as a result of a March 2, 2021, event notification (EN 55120).

This interim special inspection report documents the NRC staff’s initial inspection activities in accordance with the special inspection charter outlined objectives above. The NRC staff is continuing to inspect and could supplement this report with additional documentation before we issue a final inspection report subsequent to the completion of chartered inspection activities.

<u>Sequence of Events</u>

- A sequence of events leading up to and immediately following the event was developed.

<u>Licensee Response to the Event</u>

- The NRC-approved emergency plan and the implementing procedures were followed during the response to the event.

<u>Consequences of the Event</u>

- As a result of the event, members of the public and occupational workers remained safe, as any actual or potential radiation doses were within the regulatory limits established in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 20.

REPORT DETAILS

1. Introduction

a. Background

NIST operates the National Bureau of Standards test reactor (hereinafter NIST test reactor) at the NIST Center for Neutron Research (NCNR) located on the NIST campus in Gaithersburg, MD. The NIST test reactor is a heavy-water (D_2O)-moderated-and-cooled, enriched-fuel, tank-type reactor designed to operate at 20 megawatts thermal (MW(t)) power. The facility operates continuously during 7-week, 38-day operational cycles, followed by 10-day outages for performing refueling and maintenance activities.

b. Event Description

On February 3, 2021, following an outage for reactor refueling, NIST reactor operators were performing a normal reactor startup when the reactor automatically shut down in response to indications of high confinement exhaust stack radiation. Once the reactor was placed in a safe condition, all personnel evacuated the control room and reactor confinement. The reactor was then monitored by operators from the remote Emergency Control Station. NIST subsequently declared an alert in accordance with the emergency plan and procedures [Ref. 1]. During the event, six NIST personnel became externally contaminated and were monitored for internal exposure to radioactive materials. Following the event, environmental monitoring was performed at the confinement exhaust stack and 400-meter emergency planning site boundary, which is located within the fence line of the NIST Gaithersburg campus. Environmental sampling for radioactive material releases, as well as radiological surveys, confirmed that release amounts were a small fraction of alert or notification of unusual event criteria, which led to event termination later that day.

On March 2, 2021, a related event notification (EN 55120) [Ref. 2] informed the NRC that, as a result of video surveillance and primary coolant sample results, NIST determined that the February 3, 2021, event violated the reactor's fuel temperature safety limit.

c. NRC Response

The NRC chartered a SIT on February 8, 2021. Inspectors were onsite during the weeks of February 8, February 22, March 15, March 22, and April 5, 2021, to directly observe and inspect licensee event response, radiological surveys and sampling results, dose calculations, and investigation into the cause of the event. Between onsite inspections, the inspectors virtually attend daily status meetings and continue to inspect remotely. The inspection team will continue to evaluate the licensee's investigation and recommence onsite inspection activities as necessary until the inspection charter objectives are complete.

2. Sequence of Events

The inspectors interviewed licensee personnel and reviewed records to develop the sequence of events leading up to and immediately following the event described above. The inspectors note that event sequence times are considered approximate due to differences between recalled, recorded, or reported event times and unofficial data acquisition recorder times. All event sequence times listed below are provided in Eastern Standard Time (EST) (UTC-05:00).

<u>February 3, 2021</u>

09:10:00 During a reactor startup following a refueling outage, facility operators started to raise reactor power from 10 MW(t) to 20 MW(t).

09:10:45 After reactor power reached approximately 87 percent (17 MW(t)) an immediate decrease was observed in reactor power (no automatic actions, no manual operator action to reduce power) to approximately 50 percent power.

09:11:15 Fission Product Monitor (Radiation Monitor (RM) 3-2) (which samples helium from a layer of gas above the coolant in the reactor vessel) started to show an exponential increase in radioactivity.

09:12:00 Stack Monitor (RM 4-1) (which samples air at a point located two-thirds of the way up the confinement exhaust stack) started to show an exponential increase in radioactivity.

09:12:15 Stack Monitor Alarm at 50,000 counts per minute (cpm) initiated a Major Reactor Scram signal (reactor automatically shuts down, confinement doors close, ventilation system realigns).

09:12:30 Irradiated Air Monitor (RM 3-4) and Normal Air Monitor (RM 3-5) (which samples air from ventilation systems serving different areas of the confinement building) started to show an exponential increase in radioactivity following realignment of the ventilation system to emergency mode, which recirculated air inside of the confinement building.

09:13:00 Facility operators started evacuating the confinement building and sounded the building evacuation alarm. Prior to evacuating, facility operators ensured the reactor was in a safe condition (i.e., reactor shut down, primary coolant pumps running to maintain cooling). The reactor was then monitored by operators from the remote Emergency Control Station located outside of the confinement building.

09:16:00 NIST declared an alert in accordance with emergency procedures.

09:45:00 NIST initially notified the NRC Operations Center.

10:06:00 Facility health physics personnel obtained 14-liter grab sample of air from the confinement exhaust stack.

10:40:00 Facility health physics personnel obtained initial 400-meter site boundary air samples and conducted radiation surveys.

12:26:00 Facility operations and health physics personnel re-entered the confinement building to start the shutdown cooling system, realign helium sweep system, and take samples.

15:32:00 Based on additional radiological sample results, NIST determined they did not meet the radiological conditions for an alert. NIST notified the NRC Operations Center and downgraded the alert to a notification of unusual event.

19:35:00 Based on additional radiological sample results, NIST determined they did not meet the radiological conditions for a notification of unusual event.

19:40:00 NIST notified the NRC Operations Center and terminated the event.

3. Licensee Response to the Event

a. Emergency Planning Response

The inspectors interviewed personnel and reviewed logs, records, and procedures to assess the licensee's emergency planning response to the event.

The inspectors noted the initial receipt of fission product monitor alarm at 50,000 cpm required operators, by NIST procedure, to observe other ventilation system radiation monitors for an increase in radioactivity and draw a helium sweep gas sample for analysis [Ref. 3]. Any ventilation system radiation monitor or analysis showing an increase in fission products required reactor shutdown and initiation of shutdown cooling by the operators. Additionally, NIST procedures direct operators to declare an alert, secure the reactor, ensure the confinement building is sealed, evacuate the confinement building as necessary, and continue to monitor ventilation system monitors when fuel cladding failure is suspected [Ref. 4]. The inspectors note that information gathered from NIST's ongoing analysis shows that a single fuel element is damaged, as discussed below in Section 4.c.i, Exceeding the Fuel Temperature Safety Limit.

The licensee did not complete all the procedural response steps to the fission product monitor alarm because they received the high confinement exhaust stack activity alarm and automatic safety system response (i.e., major scram) shortly after receiving the fission product alarm. However, operators ensured all the immediate actions were completed and the facility was in a safe condition, including maintaining cooling with normal operating pumps, prior to evacuating confinement. As discussed below, the operators later re-entered the confinement building to complete the follow-up actions.

Based on the inspectors' interviews of NIST operators, the inspectors found that the licensee's decision to evacuate all personnel from the confinement building was made based on all indications received and not a specific procedural criterion. The NIST confinement evacuation procedure directs operators to evacuate non-essential personnel when, in part, radiation levels could exceed 12.5 millirem/hour (mrem/hr) averaged over 8 hours or actual or projected radiation exposures could exceed 100 mrem in 8 hours [Ref. 5]. The NIST essential personnel evacuation procedure directs operators to evacuate when, in part, radiation could exceed 100 mrem/hr averaged over 3 hours or actual or projected radiation exposures could exceed 300 mrem (i.e., total dose received by personnel when responding to an emergency situation) [Ref. 6]. The inspectors determined that NIST operators evacuated non-essential personnel from the confinement building immediately after assessing all available indications. The inspectors determined that NIST operators evacuated all essential personnel from the confinement building only after ensuring the reactor was placed in a safe condition (i.e., reactor shut down, primary coolant pumps running to maintain cooling). Following confinement building evacuation, NIST operators monitored the reactor and confinement building conditions from the remote Emergency Control Station, which is located in the NCNR laboratory building directly adjacent to the confinement building.

The licensee determined subsequent re-entry into the confinement building was necessary to take helium sweep gas and primary samples and initiate shutdown cooling. Follow-up actions for a fuel cladding failure required operators and health physicists, by NIST procedure, to collect primary and helium sweep gas samples to analyze for fission products and evacuate essential personnel as necessary [Ref. 7]. The NIST essential personnel evacuation procedure directs operators to make provisions, prior to essential personnel evacuation if feasible, for shutdown cooling or emergency cooling and evacuate to the Emergency Control Station [Ref. 6]. However, as discussed above, the inspectors noted the NIST operators' decision to leave the main primary pumps running following shutdown and evacuate personnel from the confinement building in order to fully assess available indications and determine conditions for habitability of the confinement building. The inspectors found the licensee's decision to leave main primary pumps running and later start shutdown pumps following an unplanned reactor shutdown is permitted by procedure [Ref. 8].

The inspectors noted the declaration of an alert, based on indications of increasing activity on the fission product monitor and stack monitor as described above, was directed by NIST procedure [Ref. 3] and consistent with the NRC-approved emergency plan [Ref. 9]. NIST emergency instructions direct the licensee operators to declare an alert following detection of fission products if fuel cladding failure is suspected. Emergency Plan Section 5.0, "Emergency Action Levels," directs the licensee operators to declare an alert for "[m]ajor fuel damage leading to projected dose levels in excess of those above." The inspectors note that this emergency action level is conservative because the maximum hypothetical accident, analyzed in Chapter 13, "Accident Analyses," of the licensee's safety analysis report [Ref. 10] and evaluated by the NRC staff [Ref. 11], produced calculated radiological effluent concentrations (EC) in air at the 400-meter site boundary that are a small fraction of alert levels as specified in the NRC-approved emergency plan.

The inspectors noted downgrading and terminating the event was performed in accordance with NIST procedure by taking radiological surveys and samples [Ref. 12]. The alert action level criteria are actual or projected measurements at the 400-meter site boundary which equal or exceed any of the following:

1. radiological effluent dose of 75 mrem in 24 hours
2. radiation levels of 20 mrem/hr
3. 250 times the ECs for argon (Ar), xenon (Xe), and krypton (Kr)
4. 500 times the ECs for other radioactive gases
5. 100 mrem thyroid committed dose equivalent (CDE)

The notification of unusual event action level criteria are actual or projected measurements at the 400-meter site boundary which equal or exceed any of the following:

1. radiological effluent dose of 15 mrem in 24 hours
2. 50 times the ECs for Ar, Xe, and Kr
3. 100 times the ECs for other radioactive gases

The inspectors found that radiological surveys performed by the licensee at the 400-meter site boundary during the event indicated that observed radiation levels remained consistent with background radiation readings (0.01-0.02 mrem/hr). Based on interviews with licensee staff, the inspectors noted that a radioactive noble gas release would produce a dose rate, observable during radiation surveys performed at the 400-meter site boundary. Since 1 times the EC of noble gases can be calculated to yield an expected dose rate of 0.0114 mrem/hr, 50 times the effluent concentration of noble gases would yield an observable dose rate of 0.57 mrem/hr at the 400-meter site boundary. Therefore, the inspectors confirmed that the observed radiation levels at the 400-meter site boundary were below the notification of unusual event action level criteria.

The inspectors found that the licensee collected air samples at the 400-meter site boundary and confinement exhaust stack throughout the day of the event and the days that followed the event. On the day of the event, air samples collected at approximately 15:00:00 EST from the 400-meter site boundary detected no nuclides other than those found naturally occurring in the environment. Air samples collected at approximately 17:15:00 EST from the confinement exhaust stack detected isotopes of krypton, rubidium, and xenon at 1.96 times the EC limit. The licensee corrected all the confinement exhaust stack samples for dilution to determine air ECs at the 400-meter site boundary. The inspectors found the calculated ECs indicated that releases were less than the NIST Emergency Plan action levels for both an alert and a notification of unusual event.

b. Safety System Response

The inspectors interviewed personnel and reviewed logs, records, and procedures to assess the response of the licensee's safety systems to the event. The inspectors determined that the fission product monitor (RM 3-2) alarmed as expected when detected activity indicated 50,000 cpm. The inspectors determined that the stack monitor (RM 4-1) alarmed as expected when detected activity indicated 50,000 cpm and provided a major scram signal to the safety system. The inspectors determined that, upon receipt of a major reactor scram signal, the automatic reactor protection system response (reactor automatically shuts down, confinement doors close, ventilation system realigns) occurred as required by design. Based on assessments performed to date, the inspectors found that the licensee's safety systems performed as designed; however, the inspectors note that additional inspection activities are ongoing in this area to fully assess adequacy of the safety system response.

c. Conclusion

Based on interviews and document review, the inspectors determined that the licensee followed the NRC-approved emergency plan and the licensee's approved emergency plan implementing procedures during the initial response to the event.

4. Consequences of the Event

The inspectors interviewed personnel and reviewed logs, records, and procedures to assess the licensee's analysis of the event consequences.

a. Dose Consequences

i. Public Dose

The licensee monitored radiological releases during the event by taking air samples at the 400-meter site boundary, air samples from the confinement exhaust stack, and counting charcoal and filter paper that continuously sample the stack. The licensee calculated release activity based on the measured concentrations [Ref. 13]. The licensee noted the use of several assumptions and challenges encountered while performing the calculations including the following:

1. because of Xe ingrowth, the Xe concentration increased with time
2. for nuclides with very short half-lives that were not detected in samples (e.g., Xe-137, Xe-138), activity was determined based on a comparison to release activity of measured nuclides (e.g., Kr-85metastable (m))
3. for Xe nuclides (e.g., Xe-131m, Xe-133, Xe-133m, and Xe-135) released while activity increased over time and ventilation operated in a low flow emergency mode (150 cubic feet per minute), activities were the maximum concentration and constant
4. for Xe nuclides released while ventilation operated at normal flow rates (18,000 cubic feet per minute), activity was based on a stack sample from February 6, 2021, when normal ventilation was restarted
5. for other nuclides (cobalt-60 and cesium (Cs)-138) where activity was only seen on one sample, the release activity was determined by multiplying the measured concentration with the ventilation flow rate and sampling time

The licensee performed an estimate of the projected calculated dose using the HotSpot version 3.1.2 computer modeling code, developed by Lawrence Livermore National Laboratory (LLNL) [Ref. 14]. LLNL documentation provided that the computer code was created to provide emergency response personnel and emergency planners with a set of software tools for evaluating incidents involving radioactive material. The HotSpot computer code atmospheric dispersion models are designed for near-surface releases, short-range (less than 10 kilometers) dispersion, and short-term (less than 24 hours) release durations in unobstructed terrain and simple meteorological conditions. These models provide a means for estimation of the radiation effects associated with the atmospheric release of radioactive materials.

The licensee included the following parameters when using the HotSpot computer code to model the release:

1. default wind parameters (i.e., a wind speed of 1 meter/second at a 10-meter reference height)
2. the leak path factor airborne fraction and respirable fraction of 1.00 since measurements were based on 30-meter confinement exhaust stack height
3. inversion was enabled with a default mixing height of 5,000 meters
4. Federal Guidance Report 11 dose conversion factor library was used
5. default time period of “initial release plus 4 days” for exposure duration
6. ground shine and resuspensions were included in calculating the total effective dose equivalent (TEDE)
7. no credit was taken for plume rise
8. breathing rate of 3.33E-04 cubic meters/second
9. atmospheric stability class A (very unstable) through F (stable)

Because the air samples at the 400-meter site boundary showed little to no appreciable ECs above background, the licensee based the public dose calculation from the event on the confinement exhaust stack air samples, extrapolated out to the 400-meter site boundary. The licensee calculated that the maximum TEDE at the 400-meter site boundary was less than 0.5 mrem. Additionally, the licensee noted the 400-meter site boundary is within the NIST Gaithersburg campus fence line and the dose to persons outside the fence line would be lower.

The inspectors compared licensee calculated public dose results with confirmatory calculations performed by NRC staff. The NRC staff modeled the release from the event using the same version of HotSpot computer code based on the licensee measured radioisotope activities. The NRC staff determined that the licensee used appropriate input parameters and assumptions to characterize the event. The NRC staff models calculated a TEDE of 0.45 mrem at the 400-meter site boundary. The NRC staff’s model also calculated a maximum TEDE of 0.56 mrem at 270 meters from the confinement exhaust stack, which is within the 400-meter site boundary.

Based on the above, the inspectors confirmed the highest calculated dose that could be received by a member of the public resulting from the event was less than 0.5 mrem TEDE. Therefore, the highest calculated dose resulting from the event would not result in a member of the public receiving a dose exceeding the regulatory limits (i.e., 100 mrem/yr, 2 mrem in any one hour in an unrestricted area) in Subpart D, “Radiation Dose Limits for Individual Members of the Public,” of 10 CFR Part 20, “Standards for Protection Against Radiation.” The inspectors also note that the air emissions of radioactive material to the environment remains below the 10 mrem/yr dose constraint stipulated in 10 CFR 20.1101, “Radiation protection programs,” paragraph (d).

The inspectors found that the licensee updated the original 14-day report submitted on February 16, 2021 [Ref. 15], to revise characterization of the initial 400-meter site boundary radiological samples taken on the day of the event. The update provided by the licensee [Ref. 16] accounted for the decay of a short-lived radioisotope increasing the concentration levels reported for Cs-138 (from 0.5 percent of the EC limit to 1.4 percent of EC limit specified in Appendix B, Table 2, Column 1 of 10 CFR Part 20). Additionally, the licensee initially reported sampling Xe-133 and Xe-135 at less than 0.1 percent of the EC limit in the initial report. However, further analysis by the licensee led to their conclusion that the initial 400-meter site boundary air sample was not accurate when compared to confinement exhaust stack air samples. The licensee re-calculated the ECs using assumptions based on an air sample taken from the confinement exhaust stack around the same time. The licensee calculated that Xe-133 and Xe-135 releases were no more than 10 percent of their respective EC limits. Although these updated calculations show an increased release of the aforementioned nuclides, the resulting air ECs remain a small fraction of the regulatory limits for the sum of all nuclides released. The inspectors note that these updated sample results do not impact the offsite public dose estimate because that calculation was originally based on the confinement exhaust stack air samples which were more conservative than the 400-meter site boundary air samples.

ii. Occupational Dose

At the time of the event, nine licensee staff trained as radiation workers were inside the confinement building. All licensee staff wore personnel dosimetry in the form of thermoluminescent dosimeter (TLD) badges and electronic pocket dosimeters (EPD). Four licensee staff evacuated the confinement building almost immediately following the beginning of the event and, based on EPD readings, received little to no discernable dose above that expected for normal operations. The remaining five licensee staff consisted of licensed reactor operators that evacuated the control room in a manner consistent with their emergency response roles and received radiation dose exposure levels expected based upon their stay time within the confinement building. The licensed reactor operators that remained to perform emergency response actions received whole-body doses ranging from 90.1 mrem to 182 mrem based on EPD readings, and whole-body doses ranging from 421 mrem to 1,169 mrem [Ref. 17] based on TLD readings. The inspectors note that the licensee assessed the difference between the dosimetry readings and attributed the cause to additional dose received from surface contamination present on the TLDs from the event. The TLDs remained contaminated for several days before being decontaminated and sent offsite for processing. The licensee determined to conservatively apply the TLD readings for the licensed operators as the dose of record, instead of attempting to perform a dose reconstruction. In addition, the five licensed operators who remained and one licensee staff member who evacuated immediately became externally contaminated. All six individuals were initially located inside the confinement building, in the control room at the time of the event. The licensee staff were decontaminated through the practice of decontamination showers. Any contaminated personal belongings (i.e., clothing) were decontaminated using standard practices.

At approximately 12:26:00 EST, four licensee staff re-entered the confinement building to start the shutdown cooling system, realign helium sweep system, and take primary and helium sweep gas samples. The licensee staff re-entered confinement wearing personnel protective equipment, including: coveralls with hood, gloves, and shoe covers/booties. During this re-entry, the licensee staff became contaminated on exposed areas of the skin and on arms inside of sleeves. The licensee staff were decontaminated through the practice of decontamination showers. Any contaminated personal belongings (i.e., clothing) were decontaminated using standard practices.

Following the event, the licensee also implemented bioassay protocols to determine any potential internal exposures. These bioassay protocols included whole body/lung counting, thyroid counting, nasal swabs, and urinalysis. Based on the bioassay results, the licensee determined that 1) whole body/lung and thyroid counts revealed no detectable licensed radioisotope activity; 2) nasal swabs revealed no radioactive contamination; and, 3) urinalysis distillation revealed the highest dose attributable to tritium uptake was 2 mrem to the exposed licensee staff.

Based on the above, the inspectors determined the highest measured occupational dose resulting from the event was less than 1.2 rem (1,200 mrem). Therefore, the highest occupational dose received would not result in a worker exceeding regulatory limits (i.e., 5 rem/year TEDE) in Subpart C, "Occupational dose limits for adults," to 10 CFR Part 20.

iii. Dose Consequence Comparison

The inspectors compared licensee public dose calculations and occupational dose results with the NRC staff evaluation from the facility license renewal issued in 2009 [Ref. 11]. The NRC staff evaluated the licensee's analysis of a maximum hypothetical accident scenario for the effects of such an event on the reactor fuel and the health and safety of facility personnel, the public, and the environment. The NRC staff's evaluation included independent dispersion calculations that verified the licensee's calculations of potential dose consequences to the public and to workers. For doses to members of the public, the NRC license renewal review's staff models calculated a whole body TEDE of 7 mrem and thyroid CDE of 0.1 mrem at the 400-meter site boundary. For doses to radiation workers, the NRC staff models calculated a maximum whole body TEDE of 4 rem and thyroid CDE of 20 mrem inside of the confinement building.

Based on the discussions in this section, the inspectors determined that the event consequences are a fraction of the postulated doses evaluated during the license renewal, which the NRC staff confirmed by independent calculations.

b. Environmental Consequences

The inspectors reviewed environmental radiation monitoring data and measurements conducted following the event.

Radiation dose data in unrestricted areas near the confinement building and along the NIST fence lines using real-time GammaTracer detectors indicated that the monitored radiation doses for the duration of the event remained consistent with normal environmental background radiation levels. Therefore, the inspectors verified that the dose to an individual present in an unrestricted area would not exceed 2 mrem in an hour as required by 10 CFR 20.1302, "Compliance with dose limits for individual members of the public," paragraph (b)(2)(ii).

The inspectors reviewed environmental soil and water sample results that the licensee collected following the event and compared with results from prior years. The licensee soil sample results showed naturally occurring isotopes and Cs-137 from atmospheric fallout (approximately 0.1 picocuries/gram), which were consistent with previous soil sample results. The licensee water sample results showed naturally occurring isotopes consistent with previous water sample results. Based on this review, the inspectors determined that there was no detectable impact to the sampled environment that occurred as a result of the event.

c. Other Facility Consequences

i. Exceeding the Fuel Temperature Safety Limit

On March 2, 2021, the licensee submitted a related event notification (EN 55120) [Ref. 2] which reported that, as a result of video surveillance and analysis of primary coolant samples, that a violation of the fuel temperature safety limit [Ref. 18] occurred during the February 3, 2021, event. This notification was later supplemented by a 14-day report dated March 5, 2021 [Ref. 19].

As described in subparagraph (c)(1)(i)(A) of 10 CFR 50.36, "Technical specifications," safety limits for nuclear reactors are limits upon important process variables (e.g., power, temperature, flow) that are found to be necessary to reasonably protect the integrity of certain physical barriers (e.g., fuel cladding) that guard against the uncontrolled release of radioactivity. In order to minimize the possibility that a safety limit is exceeded, limiting safety system settings and limiting conditions for operation are also established and required by the licensee's technical specifications. Limiting safety system settings for nuclear reactors are settings for automatic protective devices that will correct the abnormal situation before a safety limit is exceeded. Limiting conditions for operation are the lowest functional capability or performance levels of equipment required for safe operation of the facility.

NIST technical specification (TS) 2.1, "Safety Limit," requires that: "[t]he reactor fuel cladding temperature shall not exceed 842°F (450°C) for any operating conditions of power and flow." The fuel temperature safety limit is set to maintain the integrity of the aluminum fuel cladding, which requires that the cladding remain below the blistering temperature of 842°F (450°C) [Ref. 18]. Exceeding 842°F (450°C) may cause the fuel cladding to start blistering. During the blistering process, cracks will develop in the fuel cladding that can release gaseous fission products [Ref. 11].

In accordance with NIST TS 6.6.1, "Actions to be Taken in the Event the Safety Limit is Exceeded," paragraph (3) [Ref. 18], and 10 CFR 50.36, paragraph (c)(1), the licensee notified the Commission. The event notification (EN 55120) and 14-day report stated the licensee's conclusion that in-core video footage and primary coolant samples indicate that a single fuel element[2] is damaged and that parts of the fuel element (i.e., fuel plates) have likely exceeded the fuel temperature safety limit.

The licensee's investigation of the event has included visual inspections through the use of remote video surveillance equipment. The inspectors have been onsite

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[2] A NIST fuel element is made up of fuel plates, curved and flat unfueled plates, and upper and lower cast pieces (i.e., handling and nozzle adapters). Each element has an upper section and a lower section, with seventeen fuel plates per section. Each fuel plate is approximately 13 inches in length by 2.7 inches in width by 0.05 inches in thickness (33 cm length by 7 cm width by 0.13 cm thick). The two sections are separated by a 7-inch (17.78 cm) gap (i.e., a volume without fuel plates). The NIST test reactor core consists of 30 fuel elements that are held in position by upper and lower grid plates [Ref. 10].

observing the licensee during most of these activities. The inspectors observed one fuel element in a position that indicated it was not fully seated in its normal position within the grid plates. Specifically, this fuel element was slightly raised and angled and sitting outside of the nozzle opening on the lower grid plate. The inspectors also observed the presence of a small amount of material that was once molten deposited on the lower grid plate surfaces near the displaced fuel element nozzle. While actual conditions inside the fuel element during the event are still under investigation, the inspectors note that the aluminum alloy used for fuel cladding would melt if temperatures reached a range of 1076°F - 1202°F (580°C - 650°C). Although the inspectors have observed the licensee's remote visual inspection activities, additional information is needed to draw definitive conclusions about the condition of the fuel element and deposited material. Based on primary coolant and confinement exhaust stack air sample results, inspectors' observations, and interviews with NIST staff, the inspectors preliminarily determined the fuel temperature safety limit was exceeded for at least a single fuel element (likely the displaced fuel element), resulting in fuel plate damage (i.e., blistering, cracking, and melting) in that element. At the time of this report, the inspectors note that the licensee is still investigating the positioning and condition of the fuel element.

The preliminary determination regarding exceeding the safety limit is consistent with the licensee's event report [Ref. 2] and evidence of fission products in the reactor coolant and confinement exhaust stack. The preliminary determination led to an added focus area for ongoing inspection activities and the team has added appropriate resources and expertise to assess NIST's response. Based on observations to date, the inspectors have noted NIST's approach for examining and handling the damaged fuel element has been appropriate. The inspectors also note that the discussion in Section 4, Consequences of the Event, above (characterizing isotopes released during the event, as well as dose estimates to the public and facility staff), remains accurate in light of the preliminary safety limit violation and fuel damage determination.

In accordance with NIST TS 6.6.1, paragraph (1) [Ref. 18], and 10 CFR 50.36, paragraph (c)(1), exceeding a safety limit requires the reactor to be shut down, as well as requiring NRC authorization to restart operation. The inspectors verified that the NIST test reactor shut down at the time of the event on February 3, has remained in a shutdown condition, and has not restarted. Additionally, the inspectors note that the licensee has started to conduct video inspection and removal of intact fuel elements from the reactor core. The offload of intact fuel elements also prevents the restart of the reactor at this time. Any request to authorize restart would require yet-to-be produced supporting information, such as root-cause determinations and identification and implementation of appropriate corrective actions to prevent recurrence.

At the time of this report, the licensee was still in the early stages of characterizing the extent of the impact on the facility and will continue to investigate. The inspectors will also continue to assess the licensee's investigation into the facility exceeding its TS safety limit and will discuss the event, possible causes, and any potential apparent violations of NRC requirements (e.g., TS safety limit and associated limiting conditions for operations), as appropriate, in more detail in the final inspection report. This issue will be tracked as an unresolved item (URI 05000184/2020201-01).

d. Conclusions

Based on interviews and document review, the inspectors found that doses to members of the public and occupational workers were a small fraction of the regulatory limits established in 10 CFR Part 20. The inspectors also found that the air ECs were a small fraction of the limits specified in Appendix B of 10 CFR Part 20. The licensee has not completed a final analysis of all of the consequences as a result of the event; therefore, the inspectors will finalize their independent assessment and discuss in detail in the final inspection report provided at the completion of the special inspection activities.

5. Adequacy of Facility Procedures

The inspectors are still conducting assessments in this area of the special inspection charter. The inspectors will complete the assessment and discuss in detail in the final inspection report provided at the completion of special inspection activities.

6. Related Actions that Contributed to the Event

At the time of this report, the licensee just started the beginning stages of the event investigation and root cause determination, which will be used by both the licensee and NRC to determine if there were any related actions that contributed to the event.

While the inspectors have observed the licensee's initial remote visual inspections of the reactor (i.e., fuel elements, reactor core internals, and other components), there is not enough information at this time to draw definitive conclusions on any related actions that contributed to the event.

The inspectors are still conducting assessments in this area of the special inspection charter. The inspectors will complete the assessment and discuss in detail in the final inspection report provided at the completion of special inspection activities.

7. Root Cause Determination and Contributing Causes

At the time of this report, the licensee started the beginning stages of the event investigation and root cause determination. The licensee noted that the event investigation will likely take several months to complete. The licensee stated that they plan to conduct a multi-part investigation that will include an: 1) internal reactor operations group; 2) internal reactor audit committee; and, 3) external independent audit committee.

While the inspectors have observed the licensee's initial remote visual inspections of the reactor (i.e. fuel elements, reactor core internals, and other components), there is not enough information at this time to draw definitive conclusions on the root cause or contributing causes of the event.

The inspectors will conduct an independent assessment of the licensee's root cause determination along with future inspection activities in this area of the special inspection charter. The inspectors will complete the assessment and discuss in detail in the final inspection report provided at the completion of special inspection activities.

8. Corrective Actions

The licensee’s corrective actions for this event will be developed following the event investigation and root cause determination.

The inspectors will conduct an independent assessment of the licensee’s proposed corrective actions along with future inspection activities in this area of the special inspection charter. The inspectors will complete the assessment and discuss in detail in the final inspection report provided at the completion of special inspection activities.

9. Debrief

The inspectors discussed preliminary observations during interim debrief meetings with NIST Center for Neutron Research management on February 11, 2021, March 19, 2021, and April 9, 2021.

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PARTIAL LIST OF PERSONS CONTACTED

Licensee

T. Barvitskie	Health Physicist
S. Dewey	Chief, Health Physics
R. Dimeo	Director, NCNR
J. Hudson	Training Supervisor
S. MacDavid	Supervisory Electronics Technician
T. Newton	Deputy Director, NCNR and Chief, Reactor Operations and Engineering
B. Remley	Health Physicist
R. Strader	Chief, Reactor Operations (Acting)
J. Tracy	Health Physicist

INSPECTION PROCEDURES USED

IP 93812	Special Inspection
IP 69004	Class I Research and Test Reactor Effluent and Environmental Monitoring
IP 69006	Class I Research and Test Reactor Organization and Operations and Maintenance Activities
IP 69007	Class I Research and Test Reactor Review and Audit and Design Change Functions
IP 69008	Class I Research and Test Reactor Procedures
IP 69009	Class I Research and Test Reactor Fuel Movement
IP 69010	Class I Research and Test Reactor Surveillance
IP 69011	Class I Research and Test Reactor Emergency Preparedness
IP 69012	Class I Research and Test Reactor Radiation Protection

ITEMS OPENED, CLOSED, AND DISCUSSED

Opened

05000184/2021201-01	URI	Assessment of licensee’s fuel cladding temperature analysis (TS 2.1, “Safety Limit”)

LIST OF ACRONYMS USED

10 CFR	Title 10 of the *Code of Federal Regulations*
Ar	Argon
ADAMS	Agencywide Documents Access and Management System
°C	degrees Celsius
Cs	Cesium
CDE	Committed Dose Equivalent
cpm	Counts Per Minute
EC	Effluent Concentration
EPD	Electronic Pocket Dosimeters
EST	Eastern Standard Time
°F	degrees Fahrenheit
IP	Inspection Procedure
Kr	Krypton
LLNL	Lawrence Livermore National Laboratory
mR	Milliroentgen
mrem	Millirem
MW(t)	Megawatt (thermal)
NBSR	National Bureau of Standards Reactor
NCNR	NIST Center for Neutron Research
NIST	National Institute of Standards and Technology
NOUE	Notification of Unusual Event
NRC	U.S. Nuclear Regulatory Commission
RM	Radiation Monitor
SIT	Special Inspection Team
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent Dosimeter
TS	Technical Specification
URI	Unresolved Item
Xe	Xenon