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

December 7, 2020

EA-20-144

Dr. Robert Bean, Director
Purdue University Radiation Laboratory
School of Nuclear Engineering
400 Central Drive
West Lafayette, IN 47904-2017

SUBJECT: PURDUE UNIVERSITY REACTOR – U.S. NUCLEAR REGULATORY COMMISSION SPECIAL INSPECTION REPORT 05000182/2020-201

Dear Dr. Bean:

This letter refers to the U.S. Nuclear Regulatory Commission (NRC) special inspection conducted during October 27 – November 6, 2020, at the Purdue University Reactor facility. The special inspection was conducted pursuant to event notification (EN 54958) on October 20, 2020, later supplemented on November 3, 2020, Agencywide Documents Access and Management System (ADAMS) Accession No. ML20311A264, describing the causes of, and corrective actions for, operating the Purdue research reactor at power levels in excess of the licensed maximum power level. The NRC inspectors discussed the preliminary inspection findings with you at the conclusion of the on-site portion of the special inspection on October 29, 2020. A final exit briefing was conducted via teleconference with you on November 6, 2020. The enclosed report presents the results of this special inspection.

Based on the results of this special inspection, two apparent violations and one Severity Level IV violation were identified by the NRC inspectors. The apparent violations are being considered for escalated enforcement actions in accordance with the NRC Enforcement Policy. The current Enforcement Policy is included on the NRC's Web site at https://www.nrc.gov/about-nrc/regulatory/enforcement/enforce-pol.html. The apparent violations are related to the Purdue research reactor exceeding the maximum licensed power level (License Condition 2.C.1) and operating the Purdue research reactor prior to completing the applicable surveillance testing for replaced equipment (technical specification 4.2.g). The Severity Level IV violation is related to Purdue inadequately posting a radiation area, as required by Title 10 of the *Code of Federal Regulations* (10 CFR), Part 20, "Standards for Protection Against Radiation." Purdue identified the first apparent violation and notified the NRC in EN 54958. NRC inspectors identified the second apparent violation and the Severity Level IV violation during this special inspection. The apparent violations and the Severity Level IV violation are discussed in the "Summary of Findings," section of the enclosed report. The circumstances surrounding these issues, the significance of the issues, and the need for lasting and effective corrective action were discussed with members of your staff at the special inspection exit meeting on November 6, 2020. As a result, it may not be necessary to conduct a predecisional enforcement conference (PEC) in order to enable the NRC to make an enforcement decision.

In addition, since your facility has not been the subject of escalated enforcement actions within the last 2 years and based on our understanding of your planned corrective actions, a civil penalty may not be warranted in accordance with Section 2.3.4 of the Enforcement Policy. The final decision will be based on you confirming on the license docket that the corrective actions previously described to the NRC staff have been or are being taken.

Before the NRC makes its enforcement decision concerning the apparent violations, we are providing you an opportunity to: (1) respond to the apparent violation(s) addressed in this inspection report within 30 days of the date of this letter, or (2) request a PEC. If a PEC is held, it will be open for public observation and the NRC will issue a press release to announce the time and date of the conference. If you decide to participate in a PEC, please contact Mr. Travis Tate at (301) 415-3901 within 10 days of the date of this letter. A PEC should be held within 30 days of the date of this letter.

If you choose to provide a written response for the apparent violations, it should be clearly marked as a "Response to Apparent Violations in NRC Special Inspection Report 05000182/2020-201; EA-20-144" and should include for each apparent violation: (1) the reason for the apparent violation or, if contested, the basis for disputing the apparent violation; (2) the corrective steps that have been taken and the results achieved; (3) the corrective steps that will be taken; and (4) the date when full compliance will be achieved. Your response may reference or include previously docketed correspondence, if the correspondence adequately addresses the required response. Additionally, your response should be sent to the NRC's Document Control Center, with a copy mailed to Dr. Mohamed Shams, Director, Division of Advanced Reactors and Non-Power Production and Utilization Facilities, Office of Nuclear Reactor Regulation, 11555 Rockville Pike, Rockville, MD 20852-2738 within 30 days of the date of this letter. If an adequate response is not received within the time specified or an extension of time has not been granted by the NRC, the NRC will proceed with its enforcement decision or schedule a PEC.

If you choose to request a PEC, the conference will afford you the opportunity to provide your perspective on these matters and any other information that you believe the NRC should take into consideration before making an enforcement decision. The decision to hold a PEC does not mean that the NRC has determined that a violation has occurred or that enforcement action will be taken. This conference would be conducted to obtain information to assist the NRC in making an enforcement decision. The topics discussed during the conference may include information to determine whether a violation occurred, information to determine the significance of a violation, information related to the identification of a violation, and information related to any corrective actions taken or planned.

In addition, please be advised that the number and characterization of apparent violations described in the enclosed inspection report may change as a result of further NRC review. You will be advised by separate correspondence of the results of our deliberations on this matter.

In accordance with 10 CFR Part 2, "Agency Rules of Practice and Procedures," Section 2.390, "Public inspections, exemptions, requests for withholding," a copy of this letter, its enclosure(s), and your response, if you choose to provide one, will be made available electronically for public inspection in the NRC Public Document Room or from ADAMS, accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. To the extent possible, your response should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the public without redaction.

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,

/RA/

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

Docket No. 50-182
License No. R-87

Enclosures:
As stated

cc: w/enclosures: See next page

cc:

Mark Lundstrom, Dean of Engineering
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Clive Townsend, Reactor Supervisor
Purdue University
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400 Central Drive
West Lafayette, IN 47907

Test, Research and Training
Reactor Newsletter
Attention: Amber Johnson
Dept of Materials Science and Engineering
University of Maryland
4418 Stadium Dr.
College Park, MD 20742-2115

SUBJECT: PURDUE UNIVERSITY REACTOR – U.S. NUCLEAR REGULATORY COMMISSION SPECIAL INSPECTION REPORT 05000182/2020-201 DATED: DECEMBER 7, 2020

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ADAMS Accession No.: ML20332A083 *concurrence via e-mail NRC-002

OFFICE	NRR/DANU/PM*	RIII/DRP/B1*	NRR/DANU/LA*
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DATE	12/1/2020	12/1/2020	11/30/2020
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NAME	TTate	MShams	
DATE	12/2/2020	12/7/2020	

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NOTICE OF VIOLATION

Purdue University
Purdue University Research Reactor

Docket No. 50-182
License No. R-87

During a U.S. Nuclear Regulatory Commission (NRC) special inspection conducted during October 27 – November 6, 2020, a violation of NRC requirements was identified. In accordance with the NRC Enforcement Policy, the violation is listed below:

> Title 10 of the *Code of Federal Regulations* (10 CFR) Section 20.1003 defines a radiation area as "an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates."
>
> Section 20.1902(a) of 10 CFR, *"*Posting of radiation areas," states that, "[t]he licensee shall post each radiation area with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIATION AREA.""
>
> Contrary to the above, on several occasions between August 30, 2019, and September 15, 2020, Purdue did not post the reactor pool top area, which was a radiation area, with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIATION AREA." Specifically, the Purdue research reactor was operated during this time at power levels resulting in radiation dose rates in excess of 0.005 rem per hour at 30 centimeters from the reactor pool top. The reactor pool top is an area accessible to individuals and, despite indications that a radiation area existed at the reactor pool top, the area was not posted as a radiation area.

This is a Severity Level IV violation (Section 6.7).

Pursuant to the provisions of 10 CFR Section 2.201, "Notice of violation," the Purdue University Reactor facility is hereby required to submit a written statement or explanation to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, DC 20555-0001, within 30 days of the date of the letter transmitting this Notice of Violation (Notice). This reply should be clearly marked as a "Reply to a Notice of Violation," and should include: (1) the reason for the violation, or, if contested, the basis for disputing the violation or severity level, (2) the corrective steps that have been taken and the results achieved, (3) the corrective steps that will be taken, and (4) the date when full compliance will be achieved. Your response may reference or include previous docketed correspondence, if the correspondence adequately addresses the required response. If an adequate reply is not received within the time specified in this Notice, an Order or a Demand for Information may be issued as to why the license should not be modified, suspended, or revoked, or why such other action as may be proper should not be taken. Where good cause is shown, consideration will be given to extending the response time.

If you contest this enforcement action, you should also provide a copy of your response, with the basis for your denial, to the Director, Office of Enforcement, United States Nuclear Regulatory Commission, Washington, DC 20555-0001.

Because your response will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's document system (Agencywide Documents Access and Management System), accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html, to the extent possible, it should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the public without redaction. If personal privacy or proprietary information is necessary to provide an acceptable response, then please provide a bracketed copy of your response that identifies the information that should be protected and a redacted copy of your response that deletes such information. If you request withholding of such material, you must specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim of withholding (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If safeguards information is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21, "Protection of Safeguards Information: Performance Requirements."

In accordance with 10 CFR 19.11, "Posting of notices to workers," you may be required to post this Notice within two working days of receipt.

Dated this 7th day of December 2020

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

Docket No:	50-182
License No:	R-87
Report No:	05000182/2020-201
Licensee:	Purdue University
Facility:	Purdue University Research Reactor
Location:	West Lafayette, IN
Dates:	October 27 – November 6, 2020
Inspectors:	Phil O'Bryan Joshua Havertape
Approved by:	Travis Tate, Chief Nonpower Production and Utilization Facility Oversight Branch Division of Advanced Reactors and Non-Power Production and Utilization Facilities Office of Nuclear Reactor Regulation

Enclosure 2

SUMMARY OF FINDINGS

Purdue University
Research Reactor Facility
Special Inspection Report No. 05000182/2020-201

The U.S. Nuclear Regulatory Commission's (NRC's) program for overseeing the safe operation of research and test reactors is described in Manual Chapter 2545, "Research and Test Reactor Inspection Program." In response to event notification (EN 54958) by Purdue University, a Special Inspection Team was established in accordance with NRC Management Directive 8.3, "NRC Incident Investigation Program." The special inspection team used inspection procedure 69001, "Class II Research and Test Reactors," inspection procedure 93812, "Special Inspection Team," and a special inspection charter to conduct this special inspection.

NRC-Identified and Self-Revealing Findings

1. Apparent Violation: The Purdue University reactor facility (herein referred to as Purdue) operating license, condition 2.C.1, states that the Purdue University "is authorized to operate the facility at steady state power levels not in excess of 12 kilowatts (thermal)." Contrary to this, on several occasions between October 31, 2019, and September 15, 2020, Purdue operated in excess of 12 kilowatts (thermal).

   Purdue received a license amendment (Amendment No. 14, dated April 1, 2019) that allowed Purdue to install a digital instrumentation and control (I&C) system at their reactor facility. This installation included replacing the nuclear instrument (NI) system and detectors. Purdue performed the initial reactor startup after the digital I&C modification on August 27, 2019. After the reactor startup, Purdue performed several gold foil irradiations in order to calibrate the NI detectors. However, Purdue used an erroneous efficiency correction factor for the instrument used to count the gold foils. This error resulted in less conservative calculated values for actual reactor power by a factor of approximately three. Purdue then calibrated the NI detectors based on the incorrect calculation and NI indicated power was less than actual power by a factor of approximately three. Since Purdue operated the reactor several times between October 31, 2019, and September 15, 2020, at indicated power of 5 kilowatts (kW), and at a maximum indicated power of 7.4 kW on February 14, 2020, after accounting for the 300 percent error in indicated reactor power, the actual reactor power exceeded the maximum licensed power of 12 kW. Purdue discovered this error and license condition violation and notified the NRC on October 20, 2020.

   This is an apparent violation (AV) pending significance determination.

2. Apparent Violation: Purdue's technical specification (TS) 4.2.g states that, "Appropriate surveillance testing on any technical specification required system shall be conducted after replacement, repair, or modification before the system is considered operable and returned to service." Contrary to this, after replacement of the NI system and detectors, Purdue considered the NI system operable and returned it to service between August 27, 2019, and October 9, 2020, prior to completing the appropriate surveillance testing.

On August 27, 2019, Purdue restarted the reactor after an extended shutdown. During the extended shutdown, Purdue replaced the NI system, including the NI detectors. The plan to calibrate the NI detectors was contained in the Purdue startup plan titled "Purdue University Reactor Number One: Digital I&C Startup Plan and Checklist." This startup plan specified eight gold foil irradiations between initial criticality and 10 kW reactor power to complete the calibration of the NI detectors. Purdue did not complete the eight gold foil irradiations, however, due to unexpectedly high radiation levels at the top of the reactor pool. Nevertheless, Purdue declared the NI system operable and operated the reactor several times between August 27, 2019, and October 9, 2020, for reasons other than NI calibration (i.e., student and operator training, and experiments). This is an inspector identified issue.

3. Severity Level IV Violation: A radiation area is defined in 10 CFR 20.1003 as "an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates." Section 20.1902(a) of 10 CFR, "Posting of radiation areas," requires that "[t]he licensee shall post each radiation area with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIATION AREA."" Contrary to this, the licensee did not post the reactor pool top area, an accessible area with radiation dose rates in excess of 0.005 rem per hour, as a radiation area between August 30, 2019, and September 15, 2020.

   After the digital I&C installation, Purdue's reactor startup plan specified raising power incrementally for NI system calibration. The startup plan also specified that radiation dose rates were to be measured at various locations in and around the facility during power ascension to ensure no abnormalities existed. The highest radiation levels measured were at the reactor pool top, an area accessible to personnel. When indicated reactor power reached approximately 1 kW, the reactor pool top radiation level exceeded 0.005 rem per hour (5 mr/hr). Facility personnel were aware that the radiation levels exceeded 5 mr/hr but did not recognize that this required the area to be posted as a radiation area per 10 CFR 20.1902(a). The reactor was operated at or above 1 kW indicated reactor power several times between August 30, 2019, and September 15, 2020. This is an inspector identified issue.

REPORT DETAILS

1. Introduction

a. Background

Purdue renewed their research reactor operating license in 2016. The license renewal also increased the maximum allowed power level from 1 kW to 12 kW. However, since Purdue was also pursuing a license amendment to upgrade the I&C systems (License Amendment 14, dated April 1, 2019), they chose not to operate the reactor until they installed the new I&C system. This I&C system upgrade installed new digital I&C equipment, including a new NI system and NI detectors.

The Purdue NI system consists of four channels. Channel 1 is the startup channel and measures neutron flux level in counts per second (cps). This channel does not require calibration. Channels 2, 3, and 4 read in percent reactor power and they must be calibrated so that the measured neutron flux level (actual reactor power) is equivalent to the reactor power indicated by the instruments. All four NI channels, and their associated protective functions, are required to be operable by TS 3.2 when operating the reactor. The reactor limiting safety system setting, as defined by TS 2.2, is a reactor high power scram setting of 12 kW. This reactor scram is initiated by the NI system.

The digital I&C system upgrade was completed in 2019. Since the NI system instrumentation and detectors were new, Channels 2, 3, and 4 required calibration. Purdue calibrates the NIs using gold foil irradiation. Gold foil irradiation is performed by inserting a gold foil specimen into a tube in the vicinity of the reactor and irradiating it for a short period of time at a constant reactor power level. The radioactivity of the gold foil is then measured using a High Purity Germanium (HPGe) detector, and a reactor neutron flux rate is calculated. This calculated neutron flux rate is then used to determine a calibration factor for each NI channel requiring calibration. Finally, the calibration factor for each NI channel is used to adjust the NI channel and the channel is calibrated.

Purdue restarted the reactor on August 27, 2019, and used a startup plan titled “Purdue University Reactor Number One: Digital I&C Startup Plan and Checklist” as a procedure to perform various tests, including NI system calibration. This startup plan specified using gold foil irradiation at eight different reactor power levels from initial criticality to 10 kW reactor power.

b. Event Description

Purdue started the reactor on August 27, 2019, and, on August 29, 2019, performed the initial gold foil calibrations of the NIs. Between August 29, 2019, and February 14, 2020, NI detector calibrations were performed after initial criticality, at 100 watts (W), 500 W, 1 kW, 2 kW, and 5 kW indicated reactor power. However, while raising reactor power for the 7.5 kW indicated reactor power level calibration on February 14, 2020, the reactor automatically scrammed due to high radiation levels at the pool top area radiation monitor. Calibration activities were then suspended pending resolution of the high pool top

radiation levels. Between initial startup and October 9, 2020, the reactor was also operated for various other reasons such as academics, experiments, and operator training.

On October 9, 2020, a gold foil was irradiated to validate neutron flux levels for an experiment. The gold foil indicated that reactor power was higher than anticipated and the cause was investigated. On October 19, 2020, Purdue staff determined that an error occurred in calculating the HPGe detector efficiency factor used to calculate gold foil radioactivity level for the NI calibrations performed between August 29, 2019, and February 14, 2020. This error resulted in NI Channels 2, 3, and 4 were calibrated so that indicated reactor power level was less than actual power level by a factor of approximately three.

The HPGe detector efficiency determination is performed using a radioactive check source of known radioactivity level. The radioactive check source is counted in the HPGe detector and the measured radioactivity level is compared to the actual source radioactivity level. An efficiency factor is then calculated based on the difference between the measured and the actual radioactivity levels. Gold foils must be counted in the same position and distance from the HPGe detector for the efficiency factor to be valid for NI calibration calculations. On October 19, 2020, the HPGe detector efficiency calculations from August 2019 and October 2020 were compared. Purdue noted that the calculated HPGe detector efficiency factors differed by a factor of approximately three, and it was determined that the gold foils used for NI calibration starting in August 2019 were counted at a different HPGe shelf location (i.e. different distance) than the radioactive check source used for the HPGe detector efficiency calculation.

The NI calibrations performed between August 29, 2019, and February 14, 2020, were performed using the incorrect HPGe efficiency factor. Since the reactor was operated several times between October 31, 2019, and September 15, 2020, above 4 kW indicated power, the actual reactor power exceeded 12 kW during these operations. The highest actual reactor power reached was on February 14, 2020, and was between 18 kW (Channel 3 indication) and 22.2 kW (Channel 4 indication).

Sequence of Events

The inspectors interviewed licensee personnel, reviewed records, and observed demonstrations conducted by the licensee to develop the sequence of events leading up to and following the events described above.

4/1/2019	Digital I&C License Amendment approved.
Early 2019	(exact date unknown) the digital I&C system installation was completed.
08/27/2019	The reactor was started up for the first time after the extended shutdown using an auxiliary nuclear instrument and NI Channel 1.
08/29/2019	The first three gold foil irradiations were performed at approximately 1 W, 10 W, and 100 W calculated reactor power. NI Channels 2 and 3 calibrations were adjusted using an incorrect HPGe detector efficiency factor. The pool top radiation level for the calibrations was recorded as less than 1 milliroentgen per hour (<1 mr/hr).
08/30/2019	The fourth gold foil irradiation was complete at a calculated reactor power of approximately 500 W. NI Channels 2, 3, and 4 calibrations were adjusted. Radiation surveys at the reactor pool top determined that the radiation level was 3 mr/hr. Later that day, the reactor was started again and indicated reactor power was raised to approximately 1 kW. Pool top radiation surveys were not recorded.
8/31/2019 – 9/16/2019	The reactor was not operated.
9/20/2019	The fifth gold foil irradiation was performed at a calculated power of approximately 1 kW. NI Channels 2, 3, and 4 calibrations were adjusted. At 954 W, the pool top radiation level was measured to be 5 mr/hr. Later that day, the reactor was started, and calculated reactor power was raised to 2 kW for the first time. Pool top radiation levels were not recorded.
10/09/2019	The sixth gold foil irradiation was complete at a calculated reactor power of approximately 2 kW. No NI channel calibration adjustments were made based on this irradiation. The pool top radiation level was recorded as 13 mr/hr.
10/10/2019	Channel 2 calibration adjusted due to detector relocation. The reactor was started and operated at an indicated reactor power of 600 W, then shutdown. Pool area radiation monitor setpoints were adjusted to an alert setpoint of 30 mr/hr and scram setpoint of 50 mr/hr.

10/15/2019 – 10/29/2019	The reactor was operated three times. No calibration adjustments or gold foil irradiations were performed.
10/30/2019	The seventh gold foil was irradiated at a calculated reactor power of approximately 2 kW. No radiation surveys were documented.
10/31/2019	Channels 2, 3, and 4 calibration adjustments were made based on the irradiation performed on 10/30/2019. The reactor was started for the next gold foil irradiation at 5 kW, but the reactor scrammed before reaching 5 kW due to a high radiation scram signal from the pool top radiation monitor. Purdue determined that the scram signal was erroneously generated at 20 mr/hr. This was the first time that the reactor was operated above 4 kW calculated reactor power, which correlated to an actual reactor power of greater than 12 kW – Purdue's maximum licensed power level.
11/1/2019 – 12/11/2019	The reactor was operated regularly for student and operator training.
12/12/2019	The eighth gold foil was irradiated at a calculated reactor power of approximately 5 kW. No radiation survey documented.
12/13/2019	Channels 2, 3, and 4 calibration adjustments were made based on the gold foil irradiation performed on 12/12/2019. The reactor was started and operated at 5 kW calculated reactor power.
12/14/2019 - 1/28/2020	The reactor was not operated.
1/29/2020 - 2/12/2020	The reactor was operated several times for student and operator training.
2/14/2020	The reactor was started, and an attempt was made to raise reactor power to 7.5 kW. However, the reactor experienced a high pool radiation level scram prior to reaching 7.5 kW. Recorders indicated that the pool top radiation level briefly reached the scram setpoint of 50 mr/hr. The highest indicated reactor power was 6 kW on NI Channel 3 and 7.4 kW on NI Channel 4. The highest actual reactor power reached was between 18 kW (Channel 3 indication) and 22.2 kW (Channel 4 indication).
2/14/2020 - 3/12/2020	The reactor was operated four times for student and operator training.
3/13/2020 - 9/8/2020	The reactor was not operated. A camera inspection of the reactor on 8/11/2020 revealed no abnormalities.
09/09/2020 - 9/18/2020	The reactor was operated three times for student and operator training.

10/9/2020 The ninth gold foil was irradiated at approximately 250 W indicated reactor power to verify neutron flux levels for an experiment.

10/19/2020 Purdue determined that the HPGe detector efficiency factor determination used for NI calibrations was incorrect by a factor of approximately three in the nonconservative direction (i.e. indicated power was lower than actual power by a factor of three).

2. Adequacy of Facility Procedures for Nuclear Instrument Calibration

The Purdue procedure for NI calibration is Standard Operating Procedure 4 (SOP-4), "Power Calibration by Gold Foil." While reviewing this event, Purdue found that SOP-4 was inadequate because it did not require an independent operator to verify key parameters and calculations. SOP-4 also relied on "skill of the craft," and did not include detailed procedural steps for portions of the calibration process.

For example, one person determined HPGe detector efficiency and performed the detector efficiency factor calculation. This person relied only on his knowledge of HPGe detector operation and did not use a procedure. The calculated efficiency factor was then recorded in a notebook. Although it was the habit of Purdue operators to have the calculations second checked, this was not a requirement. The lack of a required independent verification introduced opportunities for errors and inconsistencies in the key parameters and calculations to not be captured. NRC inspectors agreed with Purdue's assessment of this procedure.

The Purdue start up plan, "Purdue University Reactor Number One: Digital I&C Startup Plan and Checklist," specified how the reactor would be started and tested after the digital I&C modifications, including methodology for performing the gold foil NI calibrations. NRC inspectors found that this procedure contained weaknesses including 1) lack of guidance on TS operability requirements after NI system replacement, 2) lack of guidance for determining radiation levels inside the reactor bay when raising reactor power beyond previous maximum power levels and ensuring all areas met posting requirements of 10 CFR 20.1902, "Posting Requirements," 3) lack of guidance for required actions if procedural steps could not be completed, if other actions were taken that could affect NI calibration, or if the procedure was suspended, and 4) lack of guidance for the use of diverse reactor parameters, such as radiation levels, control rod bank height, and gold foil activity levels from historical NI calibrations to verify indications of reactor power.

3. Licensee Response to the Event

Maximum reactor power level was incrementally raised over several months after the Purdue reactor restart. As the maximum power was raised, Purdue operators noticed pool top radiation levels were higher than expected. In fact, Purdue realized that they would not be able to complete high power NI calibrations without causing pool top radiation monitor alarms and protective action (high radiation scram). On October 10, 2019, Purdue raised the pool top radiation alarm setpoint to 30 mr/hr and the pool top high radiation scram setpoint to 50 mr/hr – the highest radiation scram setpoint allowed by TS. Purdue could not definitively explain the high radiation levels. Potential reasons discussed by the Purdue staff included having a new pool top radiation monitor which

was in a different location than the old radiation monitor, and irradiation ports streaming radiation through the pool water.

On February 14, 2020, the reactor scrammed due to a high pool top radiation level while attempting to raise reactor power to 7.5 kW indicated reactor power. Purdue responded to the February 14, 2020, pool top high radiation reactor scram by suspending reactor operations above 5 kW indicated reactor power, which they believed was the highest reactor power for which a successful NI calibration was performed. They also relocated irradiation ports away from the reactor to reduce streaming radiation. Purdue reported that relocating irradiation ports reduced the pool top radiation level but did not record the magnitude of the reduction. Reactor operations continued until October 9, 2020, when a gold foil was irradiated and indicated that actual reactor power was significantly higher than indicated reactor power.

NRC inspectors found that there were opportunities for Purdue to more comprehensively investigate the cause of the high pool top radiation levels and failed to do so. NRC inspectors determined that formal investigative techniques, such as a fault tree analysis, were not used. NRC inspectors noted that Purdue was disadvantaged in their investigation by not having comparable historical NI data because all components of the NI system were newly installed.

4. Root Cause Determination and Contributing Causes

Purdue determined that the root cause of the event was an error in the calculation of the HPGe efficiency factor. Purdue also identified the following contributing causes:

1) The HPGe detector efficiency factor determination was not independently verified,
2) The HPGe detector efficiency factor was determined without the use of a procedure, and
3) The previous NI system calibration settings were not relevant to the new NI system calibration settings, and therefore, no historical information was available to determine if settings were reasonable.

Purdue also determined that the cause of the failure to post the reactor bay as a Radiation Area was caused by a lack of procedures to determine radiation levels in the reactor bay after power uprate.

NRC inspectors agree with the causes listed above and identified the following additional contributing causes of the event:

1) “Skill of the craft” in lieu of procedural use is common at Purdue,
2) Radiation surveys were informally performed in the reactor bay and operators failed to record radiations levels on several occasions during power ascension,
3) Purdue reactor management considered the NI system to be operable before the NI system was calibrated at reactor power levels above 5 kW, and
4) The Reactor Safety Committee did not formally review each startup plan delay and procedural deviation.

5. Corrective Actions

Purdue implemented, or plans to implement, the following corrective actions:

1) SOP-4 was revised to require two independent determinations of the HPGe detector efficiency factor, two independent measurements of gold foil radioactivity level, and two independent calculations of reactor power for NI calibrations,
2) The startup plan was revised to include:
    a. requirements for measuring radiation levels during power ascension and verifying postings in the reactor bay and in adjacent areas of the facility,
    b. steps to conservatively increase the initial NI calibration factors by a factor of 10 and reperforming all gold foil calibrations,
    c. directions to not allow reactor operations for anything other than NI calibration,
    d. directions for using NI channel data from previous reactor operations as a cross check of reactor power, and
    e. a requirement that members of the Reactor Safety Committee review and approve deviations from the startup plan.
3) Other reactor procedures will be reviewed to identify when the procedure relies excessively on “skill of the craft” assumptions,
4) Radiation survey requirements will be specified in facility procedures and reactor operators in training will be qualified as radiation workers.
5) Purdue TSs will be amended prior to startup to clarify allowances for reactor operation in order to calibrate repaired, replaced, or modified NI channels.

NRC inspectors found that these corrective actions are adequate to prevent recurrence of the event.

6. Related Actions that Contributed to the Event

As discussed in Section 5 of this report, there were several factors that contributed to the event. Additionally, NRC inspectors noted that Purdue’s actions were often not consistent with the NRC’s policy statement on nuclear safety culture. The NRC defines nuclear safety culture as: “the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment.”

With regards to identifying NI calibration errors, NRC inspectors found that Purdue demonstrated weaknesses with the following nuclear safety traits:

1) Problem Identification and Resolution, defined as “Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance,” and
2) Questioning Attitude, defined as “Individuals avoid complacency and continually challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action.”

With regards to excessive “skill of the craft” use and procedural deviations, NRC inspectors found that Purdue demonstrated weaknesses in the nuclear safety trait of Work Processes, defined as “The process of planning and controlling work activities is implemented so that safety is maintained.”

7. Consequences of the Event

The NRC inspectors determined that there were no actual nuclear safety consequences as a result of this event. The NRC inspectors found the Purdue reactor safety analysis demonstrates that the reactor fuel will not exceed its temperature safety limit of 530 degrees centigrade at a reactor power of 98.6 kW. Since the highest actual reactor power reached during the event was approximately 22.2 kW, no fuel damage is expected. The NRC inspectors found that a fuel inspection performed by Purdue in August 2020, reactor pool water chemistry analyses, and facility radiation surveys confirm that no fuel damage occurred. NRC inspectors determined that there are no other reactor components susceptible to damage at a reactor power level of 22.2 kW. Since the NI system would have initiated a reactor scram during an over-power scenario at 36 kW actual reactor power (three times an indicated reactor power setpoint of 12 kW), the reactor fuel would also be undamaged during this type of accident.

The NRC inspectors determined that radiation levels in the reactor bay during the event contributed to slightly higher dose rates for personnel in the reactor bay during reactor plant operations, but these doses were within regulatory limits established in 10 CFR Part 20, “Standards for Protection Against Radiation,” as measured by personnel dosimetry. The highest dose rate at the reactor console occurred when the reactor operated at 22.2 kW actual reactor power on February 14, 2020. The area radiation monitor in the vicinity of the console recorded the dose rate as 0.13 mr/hr above background level during this time period. This dose rate, and the dose rates at lower reactor power levels, would contribute only a small amount to operators’ doses for the relatively short time that the operators were at the console (typically 1 to 2 hours).

The NRC inspectors determined that area radiation monitors located on the walls of the reactor bay read <0.1 mr/hr throughout the event. Therefore, dose rates in uncontrolled areas did not exceed the regulatory dose rate limit of 2 mr/hr. NRC inspectors found dosimeters located in adjacent spaces also showed that the maximum dose in any uncontrolled area, assuming constant occupancy, did not exceed the regulatory limit of 100 millirem. Actual occupancy in adjacent, uncontrolled spaces was much less than this. Therefore, inspectors found that radiation dose consequences of this event were insignificant.

8. Exit Interview

The NRC inspectors conducted an inspection debrief with Purdue reactor management at the conclusion of the onsite portion of the special inspection on October 29, 2020. NRC inspectors discussed the inspection results in an inspection exit meeting at the conclusion of the special inspection with Dr. Bean, Facility Director and members of his staff on November 6, 2020.

PARTIAL LIST OF PERSONS CONTACTED

Licensee Personnel

R. Bean	Facility Director
C. Townsend	Reactor Supervisor
D. Storz	Reactor Instrumentation Specialist

Other Personnel

M. Tang	Interim Radiation Safety Officer

INSPECTION PROCEDURES USED

IP 69001	Class 2 Research and Test Reactors
IP 93812	Special Inspection

ITEMS OPENED, CLOSED, AND DISCUSSED

OPENED

50-182/2020-201-01	AV	Exceeding Maximum Licensed Power Level (License Condition 2.C.1)
50-182/2020-201-02	AV	Operating with Inoperable Nuclear Instrumentation (TS 4.2.g).
50-182/2020-201-03	VIO	Failure to Post a Radiation Area (10 CFR 20.1902(a))

Licensee Documents Reviewed

- Purdue University Reactor Number One: Digital I&C Startup Plan and Checklist, Revision 0
- Purdue University Reactor Number One: Operating Principles and Core Characteristics Manual, Revision 0
- Purdue University Reactor Number One, Standard Operating Procedure 4, SOP-4, Power Calibration by Gold Foil, Revision 1
- Reactor Console Logbook from August 22, 2019, to October 23, 2020
- Report on Reactor Operations for January 1, 2019, to December 31, 2019
- Purdue University Reactor Water Analysis Report, dated October 12, 2020