PURDUE
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SCHOOL OF NUCLEAR ENGINEERING

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November 3, 2020

SUBJECT: Written Conveyance of 14-Day Special Report, PUR-1, Docket 50-182

Dear Ms. Montgomery,

This letter and its attached report is to fulfill the requirements of PUR-1 Technical Specification 6.7b.1 which requires a written report be sent within 14 days to the U.S. Nuclear Regulatory Commission upon a reportable occurrence.

Please contact me with questions or if you need any further information.

I certify under penalty of perjury that the information in this document and attachments is true and correct to the best of my knowledge.

Sincerely,

Clive Townsend
PUR-1, Reactor Supervisor
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Enclosure: Special Report

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Introduction

Over the course of late 2019, the PUR-1 was calibrated according the restart procedure following the installation of a new instrumentation and control system. This involved the approach to power from a very low setting up to full power. To calibrate the reactor's power, a gold foil is placed near the core and the induced activity is proportional to the reactor flux. During this approach, the reactor operations staff was forced to stop due to a high radiation reading from the Pool Top RAM. The highest indicated operating power was 6-7.5 kW.

On Friday, October 9, 2020, an irradiation was done on a dual gold foil sample: one placed in the traditional drop tube location and a second in an irradiation port as part of preparation work for an experiment and to validate an MCNP model. The reactor was started after gold foil placement and it slowly approached 2.5%. A total run time of 30 minutes was completed and reactor data indicated an average power over that period of 1.18%. After shutdown, the gold foil in the irradiation port was removed and taken to the high purity germanium detector for analysis.

During this analysis, it appeared that the original reactor calibration factor (which relates the signal from the detector to reactor power) is incorrect by a factor of 3.04. If true, this would cause a safety system setting to be set to a non-conservative value. Work was taken to determine the root cause of this error and the most likely answer is a miscalculation of the efficiency of the High Purity Germanium Detector.

The PUR-1 Technical Specifications read: "There shall be a report not later than the following working day of any of the following… c) i. Operation with actual safety system settings for required systems less conservative than the limiting safety system settings specified in the technical specifications… ii) Operation in violation of limiting conditions for operation established in the technical specifications… vi) An observed inadequacy in the implementation of …procedural controls such that the inadequacy …could have caused the existence or development of an unsafe condition with regard to reactor operations."

Mitigating Circumstances

The Safety Analysis Report for the PUR-1 thoroughly reviews the safety basis for the facility and shows the extremely large safety envelope under which the facility operates. Several factors provide insight to this safety margin. First and foremost, the reactor was very carefully taken to incrementally higher powers. As these higher powers were achieved, an elevated radiation level was indicated which caused operators to stop their power steps and further evaluate. Upon consultation, it was determined that the reactor was safe to operate at the 50% power level and normal operations continued.

Lastly, at the highest indicated operating power level was 6-7.5 kW briefly and several times thereafter at powers of an indication of 5 kW. The Safety Analysis Report of the PUR-1 was performed at a power level of 12 kW with an instrument uncertainty of 50%, or an analysis at 18 kW. As stated in the basis for TS 2.2 Limiting Safety System Setting, the onset of nucleate boiling is calculated to occur at 98.6 kW, a further 5x margin of safety. Other transients indicated a

maximum clad temperature of 43.2 $°C$, a safety margin more than ten-fold over the Safety Limit of $530°C$.

Corrective Actions

PUR-1 uses a gold foil activation to perform the power calibration. This method has been in use since at least 1981. However, it appears that other similar research reactors use calorimetric methods to calibrate their power level. Consideration of an alternative method will be undertaken however, we believe the current method to provide a strong level of accuracy when performed correctly and the Technical Specifications as written today require a foil method. Additionally, there was no reference value to which old calibration values could be compared. The PUR-1 staff would traditionally compare a calibration data set with the prior year's but given that there were no prior years for the newly installed instrumentation and control, this was a first of its kind calibration. Subsequent calibrations will have a base value to which any new determination can be compared. If this were available, this potential calibration mistake would have been immediately rectified.

The specific miscalculation of the PUR-1 power can be traced to several root causes. The primary reason for the miscalculation appears to be from an error in the HPGe efficiency calculation. This efficiency measurement, and by extension the reactor's power, should have been independently verified. This would prevent a single error from propagating through the calibration process. Secondly, while it appears there was no error in the actual calculation, a more codified procedure would ensure that the measurements are performed in exactly the correct process. A new procedure for the power calibration that prevents incorrect calibration of the HPGe will be prepared, approved by the CORO and utilized to explicitly direct staff on how to translate raw measurements to real power. Finally, once the reactor has been calibrated, there will be historical values to which new calibrations can be compared. When taken together, these three corrective actions will prevent recurrence of this specific issue.

More broadly, facility wide, an initiative is underway to review other procedures which rely on "skill of the craft" knowledge to complete as well as to review the safety significance of those procedures which rely on a single data point to be carried out correctly. Procedures should be written such that a newly licensed reactor operator with moderate facility and technical knowledge would be able to successfully carry out the tasks described. This transition to highly prescriptive facility procedures will take time to fully identify all which require updates as well as gain insight as to the correct levels of detail. Finally, to downsize the amount of legacy documentation that distracts from important historical data, PUR-1 staff are in the process of evaluating storage methods to ensure relevant historical values are readily accessible.

Deficiency: No independent verification of reactor power level given gold activation data. **Corrective Action:** Procedure now requires an independent measurement of the gold foil activity and reactor power data.

Deficiency: Skill-of-the-craft used in converting foil activity to true reactor power. **Corrective action:** Significant and continuing improvements in procedures to reduce facility knowledge requirements for staff and operators.

Deficiency: Lack of historical reference values available for prior equipment limited availability of reference values. **Corrective Action:** New reference values will be available and used following initial power calibration

Additionally, work must be undertaken to ensure compliance with 10 CFR Part 20. In conjunction with the Radiological and Environmental (REM) staff, the PUR-1 staff will continue review policies and procedures around groups entering the reactor area, entering the reactor area while the facility is operating, as well as continuing to evaluate the dose rate to staff and members of the public during operations. In the early review of the event, some deficiencies in signage have been also noted. This will be rectified in accordance with the requirements in the CFR. Any person performing operations on a regular basis within the reactor room or as part of the trainee staff will undergo radiation worker certification and be designated as such.

Deficiency: Inadequate postings within reactor bay delineated radiation areas. **Corrective action:** Posting correct signage to ensure facility staff are aware of radiation fields and requirements.

Deficiency: Radiation area mapping not performed. **Corrective Action:** Implementation of additional procedures to perform radiation area mapping is underway to ensure correct signage and protocol are followed.

Going forward, the PUR-1 staff will follow a safety committee reviewed startup plan to return the facility to service without further limiting safety system settings less conservative than those outlined in the Technical Specifications. This will be done by lowering the reactor calibrated power by a factor of 10 (which will encompass the factor of three error) and reperform the power calibration starting from 1 Watt and increasing by factors of 10 up to 10 kW.