MISSOURI S&T

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Nuclear Reactor Facility

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June 2, 2021

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: FOLLOW-UP REPORT ON VIOLATION OF MISSOURI S&T REACTOR (R-79) TECHNICAL SPECIFICATION (SURVEILLANCE REQUIREMENT) 4.6.2(1), EN-55266

Dear Sirs:

The Missouri University of Science and Technology Reactor ("MSTR" with License R-79, Docket No. 50-123) is hereby submitting a written report as a follow-up to our May 20, 2021 phone and email report. Both reports (this written report and the phone/email report) are in regard to the MSTR Technical Specification (TS) Violation identified as EN-55266. This report is required within 14-days of the initial event per MSTR TS 6.2. The attached document details the observed violation, the surrounding circumstances and root causes, as well as efforts taken and planned to restore compliance and prevent recurrence.

If you have any questions regarding this report, please contact either me, at 573-341-4291; or Dr. Joseph Graham, the Reactor Director, at 573-341-7759.

Sincerely,

Ethan Taber
Reactor Manager, MSTR

Joseph Graham, PhD
Reactor Director, MSTR

Enclosure

cc: Radiation Safety Committee (S&T)
Dr. Ayodeji Alajo, Interim Chair of NERS (S&T)
Mr. William Kennedy, Project Manager (NRC)
Mr. Phillip O'Bryan, Facility Inspector (NRC)

MSTR Licensee Event Report 21-02

A health physics and radiation protection inspection took place at the Missouri University of Science and Technology Reactor (MSTR) by the Nuclear Regulatory Commission (NRC) during the week of May 17, 2021. During the inspection, the inspector (Philip O'Bryan) remarked that inconsistencies and other errors were observed in the 2019 Argon-41 experimental release verification ("2019 Report"). In a follow-up evaluation of the 2019 Report by MSTR and Missouri S&T Environmental Health and Safety (EHS, responsible for Health Physics at MSTR) staff, the data, analysis, and results were determined to be non-credible.

Background

Argon-41 is a nuisance radioisotope commonly produced during the operation of nuclear reactors, with a half-life of 1.8 hours and undergoing β- decay (associated gamma of 1294 keV). The normal production route involves the neutron activation/irradiation of Argon-40 in air (~1.3% Argon-40 by mass), in both air-filled voids near the core and dissolved air in the coolant (especially in water-cooled and moderated reactors). Argon-41 exposure and release to both facility personnel and the public is regulated by the NRC in 10 CFR 20.

With a relatively short half-life, it is generally impractical to use a calibrated Argon-41 source for calibrating and performing efficiency calculations for spectroscopy detectors. Sodium-22 emits a similar gamma energy (1275 keV for Na-22 compared to 1294 keV for Ar-41) and has a significantly longer half-life of 2.6 years. Sodium-22 sources are commercially available in a variety of source configurations, such as a 4000 mL Marinelli beaker. The MSTR has used a NIST-traceable Amersham Na-22 source, with a reference activity of 19.2 kBq (±7.5%) on March 1, 1996, for all Argon-41 evaluations in the last 15 years. A 4000 mL air sampling tank matches the geometry of the Na-22 source, which is intended for use with a 3×3 NaI detector.

The MSTR produces Argon-41 through the aforementioned means, with the following primary sources:

- Experimental facilities
    - Air in thermal column spaces
    - Air in beam port

    - Air in core access elements (some in rabbit elements as well, but mitigated by use of ultra-high-purity nitrogen as transfer gas)
- Air dissolved in pool water

Due to the MSTR's low power of 200 kW and associated flux (in comparison to other research, test, and power reactors), non-negligible quantities of Argon-41 are only produced at substantial fractions of full power. Thus, per TS 3.5, "A ventilation fan with a rated capacity of at least 127.4 cubic meters per minute (m^3/min) (4,500 cubic ft per minute [cfm]) shall be turned on within 10 minutes after the reactor reaches full power." The fans reduce Argon-41 levels in the building (for occupational dose concerns) and mix in outside air to reduce the average activity of the exhaust plume (for release and public dose concerns). All three of the MSTR vent fans have a rated capacity at or above the 4,500-cfm mark (vent fans 1 and 2 are ~15,000 cfm while vent fan 3 is rated for 4800-5000 cfm), with vent fans 1 and 2 having dedicated ground-level intake louvers.

In 2017, the MSTR management underwent significant changes, with a new Reactor Director (Dr. Joseph Graham) and the retirement of the long-time Reactor Manager (William Bonzer). Additionally, the administrative assistant position was cut, with a further cut planned to the designated Senior Reactor Operator (SRO) position. In 2019, the MSTR underwent complete turnover for full-time personnel, and all operators (full- and part-time) either completed their studies at Missouri S&T or resigned. The designated SRO (who had previously served as Interim Reactor Manager) agreed to return on staff part-time with limited availability, to ensure that the facility could operate to meet surveillance requirements (including operations in support of the 2019 Report) until the current Reactor Manager was licensed by the NRC. It is noted that a licensing examination was not available until mid-November 2019, and that staffing levels have still not recovered as of the writing of this report.

In 2019, the MSTR also started encountering numerous intermittent instrumentation issues, with the startup channel of particular concern during the timeframe of the 2019 Report. Per TS 3.1, "the reactor shall not be operated unless the channels described in [TS] Table 3.1 are operable," with a startup count rate channel (<2 counts per second) specified as one of the channels. Substantial noise was observed on the startup channel during several pre-startup checks and other maintenance, which prevented determining that the channel was operable and would have prevented the safe monitoring of the subcritical neutron multiplication

during startup. The faults were eventually traced (well after the Ar-41 measurements) to a combination of detector (fission chamber), cabling, connectors, and preamplifier issues. The intermittent issues caused the abort of several previous scheduled Ar-41 measurement attempts and caused the facility to near the five-year surveillance interval.

Regulatory Basis

Per MSTR TS 4.6.2(1), "An experimental verification of calculated release values shall be performed every 5 years and when a change in licensed power occurs." An experimental verification was performed October 27, 2014, with the most recent verification conducted October 24, 2019. As the 2019 Report and data was assessed to be non-credible, the MSTR would not have conducted the experimental verification within 5 years and is in violation of TS 4.6.2(1).

Root-Cause Analysis

Several factors have been determined to root causes of this violation:

1. **Infrequent performance of the surveillance lead to severe disorganization of equipment and knowledge atrophy.**

   Given the significant time intervals between measurement periods (five years) and lack of available space/resources on the Missouri S&T campus, the counting setup used by EHS for Ar-41 release verifications is not constantly maintained. The counting equipment and space is "stood up and torn down" for each surveillance, which typically involves:

   - Securing a room to store and use counting equipment
   - Gathering a shield assembly, detector, counting equipment (MCA, power supplies, etc.), and calibration source
   - Connecting, configuring, and calibrating the setup
   - Performing the measurements
   - Disassembly and storage of equipment

   Several errors observed in the 2019 Report may (at least partially) stem from this knowledge atrophy. This includes using incorrect, or at least inconsistent, energy calibrations throughout the evaluation.

2. **The associated procedure (MSTR SOP 654, "Measurement of ^{41}Ar Concentration in the Reactor Building Air," revised October 23, 2013) does not provide an adequate level of detail.**

   The existing Standard Operating Procedure is very sparse. Acceptance criteria on calibration and how to perform a full calibration/setup (e.g., gain, energy, and other parameters) if necessary, are not present in the existing SOP. While a counting setup schematic is available, no formal control or vetting is placed on this process.

3. **No formal training exists for performing health physics surveys, such as the Ar-41 evaluation.**

   Historically, the work experience and knowledge of Health Physics personnel was relied upon for performing surveys and evaluations, supplemented by general requirements specified in procedures. Informal, on-the-job training and shadowing was used to prepare for performing more complex tasks such as the Ar-41 measurement.

   The following example error from the 2019 Report is indicative of the need for such a process: A background/blank gamma-ray spectrum used in the determination of Ar-41 concentration had an incorrect energy calibration. This resulted in Ar-41 concentrations values that were determined almost entirely by the magnitude and shape of the background spectrum.

4. **Staffing and instrumentation conditions at the reactor and EHS.**

   A combination of extremely low staffing and repeated nuclear instrumentation failures leading up to the Ar-41 measurement likely contributed to defects in sample collection and analysis.

   Only a single operator was available to support the effort, and EHS personnel were similarly limited.

Detailed analysis of specific errors made in 2019 and previous years is included in the attached document. Several follow-up Corrective Actions and Opportunities for Improvement are also provided in the attachment.

Corrective Actions

All targeted corrective actions are listed with an Estimated Time to Completion (ETC) and reflect anticipated facility operability and staff availability. The NRC shall be notified as soon as possible if the timeframes are determined to be unworkable.

To restore compliance with TS 4.6.2(1), the Argon-41 experimental process shall be performed as soon as practical following the restoration of the facility to an operable status. The facility is currently inoperable due an inoperable safety (nuclear instrumentation) channel following an apparent detector failure. A replacement detector has been provided by another research reactor, but a new dry-tube housing, insulators, and spacers are required prior to installation and operation. Additionally, a new Sodium-22 check source (Marinelli beaker geometry) will also be procured to support this effort. As stated in the May 20, 2021 report, the supporting efforts are expected to be in-place no later than July 31, 2021. (ETC Early Q3 2021)

Additionally, the following corrective actions have been performed or planned by the facility to address the root-causes and prevent recurrence:

1. **Infrequent performance of the surveillance lead to severe disorganization of equipment and knowledge atrophy.**

   To both ensure competency in performing the experimental verification and to enable additional flexibility with respect to the surveillance requirement deadline (see Root-Cause 4), the Argon-41 experimental verification should be performed on a three-year basis, with a five-year TS limit. (ETC July 31, 2024 and every 3 years thereafter)

2. **The associated procedure (MSTR SOP 654, "Measurement of ^{41}Ar Concentration in the Reactor Building Air," revised October 23, 2013) does not provide an adequate level of detail.**

   SOP 654 shall be revised to address the identified deficiencies. This includes additional attention in addressing differing counting setups. Other SOPs may be generated or updated to also assist in this process. Further details are provided in the attachment. (ETC July 31, 2021)

3. **No formal training exists for performing health physics surveys, such as the Ar-41 evaluation.**

   A training/qualification program for personnel performing Health Physics activities/surveys will be established. Additional/refined procedures and checklists will be generated as necessary. Knowledge and training requirements (including refresher training) for each survey type will be identified and addressed. (ETC of basic framework Q3 2021, with full implementation Q4 2021)

4. **Staffing and instrumentation conditions at the reactor and EHS.**

   A steady pipeline of reactor operators is anticipated over the next several years based upon current enrollment in the operator training program. This should reduce or eliminate the possibility of relying on a single operator to support all surveillances at power. (Already in effect)

   The MSTR is in the final stages of hiring another full-time employee, with the intention of them having primary responsibility for reactor instrumentation. (ETC Q3 2021)

   Additional review of the Ar-41 measurements and process is proposed, such that the data analysis of future Ar-41 measurements will be carefully reviewed and checked by a faculty member (or equally qualified person) with experience in radiation detection and measurement to ensure validity and acceptability of the methods used. The faculty member will be unaffiliated with the reactor or campus Environmental Health and Safety. Deficiencies and Opportunities for Improvement will be identified. By having multiple individuals reviewing procedures and reviewing the analysis it is probable that several simple errors would have been caught and corrected. (ETC Early Q3 2021 to coincide with upcoming Ar-41 evaluation)

Given the number and complexity of the proposed corrective actions, an organized Corrective Actions Program (CAP) is anticipated to be needed. This CAP would monitor progress in implementation, and following implementation, effectivity of the implemented change. Identified issues would be screened for safety significance and reportability and assigned to personnel for resolution. The CAP would be managed by an operations and

health physics personnel-based committee, with reports made to the Radiation Safety Committee. (ETC of basic framework by July 1, 2021, with full implementation Q3 2021)

While not a standalone corrective action, it is noted that the Radiation Safety Committee shall review this occurrence and corrective actions as required by MSTR TS 6.2.3(5) and 6.6.2(3). (ETC Q3 2021)