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

REFERENCE: Docket 50-186
University of Missouri-Columbia Research Reactor
Renewed Facility Operating License No. R-103

SUBJECT: University of Missouri-Columbia Research Reactor
2018 Reactor Operations Annual Report

Enclosed is a copy of the 2018 Reactor Operations Annual Report for the University of Missouri-Columbia Research Reactor (MURR). This document is being submitted to the U.S. Nuclear Regulatory Commission in accordance with the MURR Technical Specification 6.6.e.

If you have any questions regarding the contents of this report, please contact Bruce Meffert at MeffertB@missouri.edu or by calling (573) 882-5118.

Sincerely,

Bruce A. Meffert
Reactor Manager

ENDORSEMENT:
Reviewed and Approved,

J. David Robertson
Reactor Facility Director

BAM/jlm

Enclosure

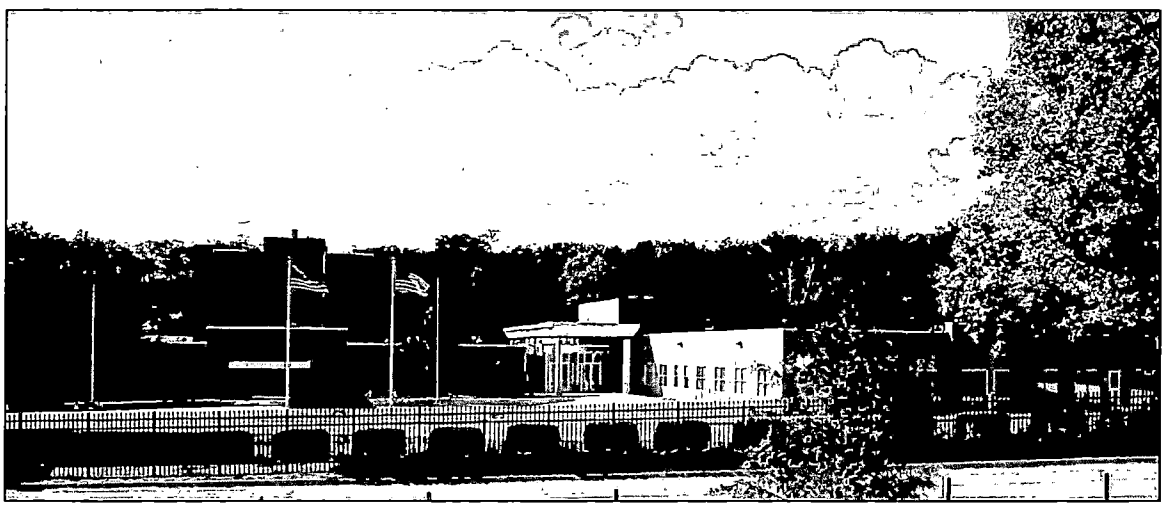
xc: Mr. Geoffrey Wertz, U.S. NRC
Mr. William Schuster, U.S. NRC

ADZD
NRR

UNIVERSITY OF MISSOURI-COLUMBIA RESEARCH REACTOR

REACTOR OPERATIONS ANNUAL REPORT

January 1, 2018 through December 31, 2018



UNIVERSITY OF MISSOURI-COLUMBIA
RESEARCH REACTOR

REACTOR OPERATIONS
ANNUAL REPORT

January 1, 2018 through December 31, 2018

Compiled by the Staff of MURR

Submitted by: Bruce a Meffert

Bruce A. Meffert
Reactor Manager

Reviewed and approved by:

J. David Robertson
Reactor Facility Director

UNIVERSITY OF MISSOURI – COLUMBIA
RESEARCH REACTOR

REACTOR OPERATIONS ANNUAL REPORT

January 1, 2018 through December 31, 2018

INTRODUCTION

The University of Missouri Research Reactor (MURR) is a multi-disciplinary research and education facility providing a broad range of analytical, materials science, and irradiation services to the research community and the commercial sector. Scientific programs include research in archaeometry, epidemiology, health physics, human and animal nutrition, nuclear medicine, radiation effects, radioisotope studies, radiotherapy, and nuclear engineering; and research techniques including neutron activation analysis, neutron and gamma-ray scattering, and neutron interferometry. The heart of this facility is a pressurized, reflected, open pool-type, light water moderated and cooled, heterogeneous reactor designed for operation at a maximum steady-state power level of 10 Megawatts thermal – the highest-powered university-operated research reactor in the United States.

The Reactor Operations Annual Report presents a summary of reactor operating experience for calendar year 2018. Included within this report are changes to MURR reactor operations and health physics procedures, revisions to the Safety Analysis Report (SAR), facility modifications, new tests and experiments, reactor physics activities, and environmental and health physics data.

This report is being submitted to the U.S. Nuclear Regulatory Commission (NRC) to meet the administrative requirements of MURR Technical Specification 6.6.e.

ACKNOWLEDGMENTS

The success of MURR and its scientific programs is due to the dedication and hard work of many individuals and organizations. Included within this group are: the University of Missouri administration; the governing officials of the State of Missouri; the Missouri State Highway Patrol; the City of Columbia Police Department; the Missouri University Police Department (MUPD); the Federal Bureau of Investigation (FBI); our regulators; those who have provided funding, including the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA); Argonne National Laboratory (ANL); Idaho National Laboratory (INL); Sandia National Laboratories (SNL); the researchers; the students; the Columbia Fire Department (CFD); the Campus Facilities organization; members of the National Organization of Test, Research and Training Reactors (TRTR); and many others who have made, and will continue to make, key contributions to our overall success. To these individuals and organizations, the staff of MURR wishes to extend its fondest appreciation.

Some of the major facility projects that were supported by Reactor Operations during this past calendar year included (1) replacement of the primary coolant heat exchanger HX503A plates; (2) chemical cleaning of primary coolant heat exchanger HX503B and pool coolant heat exchanger HX521 plates; (3) replacement of 12 paper and pen chart recorders with paperless chart recorders on all process instrumentation, nuclear instrumentation, and stack monitor channels; (4) replacement of the secondary coolant chemical control system; (5) replacement of the personnel entry (airlock) inner and outer door sealing gaskets; (6) replacement of the rod position indication system; (7) installation of a new control rod drive mechanism; (8) refurbishment of anti-siphon system isolation valves V543A and V543B; (9) replacement of the reactor pressure vessel cover backrings; (10) installation of a reactor containment building

differential pressure transmitter, remote indication, and alarm; and (11) implementation of facility security enhancements focusing on the requirements of 10 CFR 37.

The facility continues to actively collaborate with the Reduced Enrichment for Research and Test Reactors (RERTR) Program and four other U.S. high-performance research and test reactor facilities that use highly enriched uranium (HEU) fuel to find a suitable low-enriched uranium (LEU) fuel replacement. Although each one of the five high-performance reactors is responsible for its own feasibility and safety studies, regulatory interactions, fuel procurement and conversion, there are common interests and activities among all five reactors that will benefit from a coordinated, working-group effort. This past year, work focused on HEU-to-LEU transition core planning and the effects of fissile targets on the proposed LEU core for the purpose of producing molybedum-99.

Reactor Operations management also wishes to commend the three individuals who received their Reactor Operator certifications from the NRC. These individuals participated in a rigorous training program of classroom seminars, self-study, and on-the-job training. The results of this training are confident, well-versed, decisive individuals capable of performing the duties of a licensed operator during normal and abnormal situations.

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SECTION I

REACTOR OPERATIONS SUMMARY

January 1, 2018 through December 31, 2018

The following table and discussion summarizes reactor operations during the period from January 1, 2018, through December 31, 2018.

Month	Full Power Hours	Megawatt Days	Full Power (% of total time)	Full Power (% of scheduled*)
January	650.42	271.11	87.4	97.9
February	609.73	254.37	90.7	101.6
March	673.15	280.57	90.5	101.3
April	616.23	256.82	85.6	96.0
May	609.29	254.20	81.9	91.7
June	661.12	275.53	91.8	103.0
July	660.49	275.28	88.8	99.4
August	652.94	272.11	87.8	98.3
September	627.25	261.45	87.1	97.7
October	644.45	268.66	86.6	97.0
November	616.96	257.16	85.7	96.1
December	665.92	277.55	89.5	100.2
Total for the Year	**7,687.95**	**3,204.81**	**87.78**	**98.34**

* MURR is scheduled to average at least 150 hours of full power operation per week. Total time is the number of hours in the month listed or the year.

JANUARY 2018

The reactor operated continuously in January with the following exceptions: five shutdowns for scheduled maintenance and/or refueling, one shutdown for physics measurements, and one unscheduled/unplanned power reduction.

On January 5, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated as part of an unplanned power reduction to perform compliance procedure CP-17, "Emergency Power Generator Load Test," after a review of the December 2017 Compliance Procedure Status Report revealed that the 7.5-month "due no later than date" for performance of CP-17 was January 5, 2018. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. CP-17 was then completed satisfactorily. Permission to restart the reactor was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: replacing the reactor pool upper bridge radiation monitor upscale switch; replacing the pedestrian entry (airlock) inner door 277 drive sprocket; replacing the regulating blade drive mechanism cable; replacing the pool coolant demineralizer system inlet and outlet filters; loading new de-ionizing bed 'K' and placing it on pool coolant system service; and performing a reactivity worth measurement in accordance with reactor procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D)."

FEBRUARY 2018

The reactor operated continuously in February with the following exceptions: four shutdowns for scheduled maintenance and/or refueling. There were no unscheduled/unplanned power reductions this month.

Major maintenance items for the month included: replacing a relay in the drain collection tank control circuit; replacing primary coolant heat exchanger HX503A plates; and replacing the reactor containment building differential pressure gauge.

MARCH 2018

The reactor operated continuously in March with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and two unscheduled/unplanned power reductions.

On March 1, with the reactor operating at 10 MW in the automatic control mode, a 'Channel 4, 5 or 6 HI Power Rod Run-In' was automatically initiated from power range monitor nuclear instrumentation (NI) channel no. 6 (PRM-6). There was no indication of an elevated power level on any NI channel, including PRM-6. PRM-6 rod run-in (RRI) trip unit was replaced, and the drawer operations were tested satisfactorily with completion of compliance procedure CP-34, "Nuclear Instrumentation Power Range Monitor – Channel 6," and the applicable portions of compliance procedure CP-9, "Nuclear Instrumentation Scram and Rod Run-In." Permission to restart the reactor was obtained from the Reactor Manager, and the reactor was subsequently returned to 10 MW operation.

On March 4, with the reactor operating at 10 MW in the automatic control mode, a Reactor Operator Trainee, while conducting a routine facility patrol, inadvertently switched the emergency power generator (EPG) out of automatic control for approximately 10 to 15 seconds before returning the EPG back to automatic control. The reactor was not shut down. Permission to continue operating the reactor was obtained from the Interim Reactor Facility Director. Inoperability of the emergency electrical power system during reactor operation resulted in a deviation from Technical Specification (TS) 3.6.a, and Licensee Event Report No. 18-01 was submitted to the NRC on March 15, 2018.

On March 19, during a normal reactor startup with the reactor subcritical and shim control blade height at 10 inches, a manual reactor scram was initiated when a control room operator observed anti-siphon system pressure decreasing approximately 2-3 psig every five minutes. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Attempts were made to manually seat anti-siphon system isolation valves V543A and V543B in the closed position but were unsuccessful. The primary coolant system was shut down and restarted, and control room operators observed anti-siphon system pressure for 10 minutes to verify the pressure was holding. Permission to perform a normal reactor startup was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: replacing the wide range monitor NI drawer cable; performing a zero and span on the wide range monitor NI channel; completing Modification Record 13-02, Addendum 1,

"Secondary Coolant System Chemistry Control;" and performing a reactivity worth measurement in accordance with reactor procedure RP-RO-202, "Measurement of Reactivity Worth of Movable Samples, RTP-6."

APRIL 2018

The reactor operated continuously in April with the following exceptions: five shutdowns for scheduled maintenance and/or refueling. An NRC inspector conducted a routine scheduled inspection of the Radiation Protection and Shipping Programs.

There were no unscheduled/unplanned power reductions this month. However, an unplanned extended maintenance period occurred from April 30 to May 2, 2018. The plates on primary coolant heat exchanger HX503B were replaced on April 30. Later on April 30, it was discovered that one or more replacement plates had leaked. The decision was made to coarsely clean the original plates and put them back into the heat exchanger. The reactor was returned to 10 MW operation on May 2, 2018.

Major maintenance items for the month included: replacing the pedestrian entry (airlock) outer door 276 sealing gasket; replacing primary coolant circulation pump P501A; repairing a leak in pool coolant hold-up tank T504; loading new de-ionizing bed 'L' and placing it on pool coolant system service; and mechanically cleaning the plates in primary coolant heat exchanger HX503B.

MAY 2018

The reactor operated continuously in May with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and 10 unscheduled/unplanned power reductions.

From May 21 through May 27, six different RRIs were automatically initiated with the reactor operating at 10 MW in the automatic control mode. For the first five RRI occurrences, no RRI annunciation accompanied the RRI, and no plant condition occurred that would have caused a RRI. On the sixth occurrence, a 'Channel 4, 5 or 6 HI Power Rod Run-In' annunciation was automatically initiated from PRM-6. There was no indication of an elevated power level on any other NI channel. On May 27, investigation concluded that all of the RRIs probably occurred due to increased noise from the PRM-6 detector and/or detector cable. The PRM-6 detector and associated cabling were replaced. Permission to restart the reactor was obtained from the Acting Reactor Manager, and the reactor was subsequently returned to 10 MW operation.

On May 25, with the reactor operating at 10 MW in the automatic control mode, an automatic reactor scram was initiated due to a momentary loss of normal electrical power. All immediate and subsequent actions of reactor emergency procedure REP-11, "Momentary Loss of Normal Electrical Power," were completed. The momentary electrical power loss was confirmed by calling the University of Missouri power plant and the issue was verified to be a fault at the power plant. Permission to restart the reactor was obtained from the Acting Reactor Manager, and the reactor was subsequently returned to 10 MW operation.

On May 27, with the reactor operating at 5 MW in the manual control mode during a normal reactor startup, an automatic reactor scram was initiated while paused to physically adjust the PRM-6 detector drywell. The scram was accompanied by a 'Channel 4, 5 & 6 Hi Power Scram' annunciation. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. The power transient was verified on the PRM-6 chart recorder and with no spike noted on PRM-4 or -5. Further investigation revealed that the bolt that holds down the U-clamp bracket on the PRM-6 drywell was loose, which allowed the drywell to move more than intended. The

bracket was tightened, and the drywell was successfully adjusted during the following startup. Permission to restart the reactor was obtained from the Acting Reactor Manager, and the reactor was subsequently returned to 10 MW operation.

On May 29, with the reactor operating at 10 MW in the automatic control mode, an automatic RRI was initiated due to control rod 'D' disconnecting from its drive mechanism electromagnet. The RRI was accompanied by a 'Rod Not In Contact With Magnet Rod Run-In' annunciation. While loading a silicon sample back into graphite reflector Y6 irradiation position, the sample holder wire caught the north sample rotator causing the holder to swing into control blade 'D' offset mechanism. This caused the control rod to disconnect from the control rod drive mechanism electromagnet. Permission to restart the reactor was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

On May 30, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated due to inoperability of control blades 'A,' 'B,' and 'C.' All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Immediately prior, while conducting the control blade operability TS 4.2.a surveillance, it was discovered that shim control blades 'A,' 'B,' and 'C' would not shim in the inward direction (outward direction was operable) when control rod operate switch 1S4 was manipulated. Troubleshooting determined a failure of control rod operate switch 1S4, and this component was replaced and retested satisfactorily. Permission to restart the reactor was obtained from the Interim Reactor Facility Director, and the reactor was subsequently returned to 10 MW operation. Inoperability of the control blades during reactor operation resulted in a deviation from TS 3.2.a, and Licensee Event Report No. 18-02 was submitted to the NRC on June 11, 2018.

Major maintenance items for the month included: replacing the pool coolant demineralizer system inlet filters; completing the biennial change-out of control blade 'B' offset mechanism; performing a reactivity worth measurement in accordance with reactor procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D);" replacing the RRI system non-coincidence logic unit and trip actuator amplifier; replacing control rod selector switch 1S3; replacing control rod operate switch 1S4; replacing PRM-6 RRI dual trip unit; and completing compliance procedure CP-26, "Containment Building Compliance Test."

JUNE 2018

The reactor operated continuously in June with the following exceptions: four shutdowns for scheduled maintenance and/or refueling, two shutdowns for physics measurements, and two shutdowns for license examinations. There were no unscheduled/unplanned power reductions this month. An NRC license examiner administered a reactor operator licensing examination. Dr. J. David Robertson was appointed the Reactor Facility Director on June 15.

Major maintenance items for the month included: performing a reactivity worth measurement in accordance with reactor procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B);" and performing a reactivity worth measurement in accordance with reactor procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D)."

JULY 2018

The reactor operated continuously in July with the following exceptions: five shutdowns for scheduled maintenance and/or refueling and two shutdowns for physics measurements. There were no unscheduled/unplanned power reductions this month.

Major maintenance items for the month included: replacing the pool coolant demineralizer system inlet filters; replacing the primary and pool coolant demineralizer flow recorder; conducting chemical cleanings of primary coolant heat exchanger HX503B and pool coolant heat exchanger HX521; loading new de-ionizing bed 'G' and placing it on pool coolant system service; replacing truck entry door 101 clutch pins; installing a desiccant air dryer in the reactor containment building supply and exhaust plenum backup doors compressed air supply line; replacing the pedestrian entry (airlock) outer door 276 seal air supply regulator and pressure relief valve; performing a reactivity worth measurement in accordance with reactor procedure RP-RO-202, "Measurement of Reactivity Worth of Movable Samples, RTP-6;" and performing a reactivity worth measurement in accordance with reactor procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

AUGUST 2018

The reactor operated continuously in August with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and two shutdowns for physics measurements. There were no unscheduled/unplanned power reductions this month.

Major maintenance items for the month included: replacing the pedestrian entry (airlock) inner door 277 sealing gasket; replacing the pressure vessel cover east backring; replacing the primary coolant reactor inlet and outlet temperature recorder; replacing the pool coolant demineralizer system inlet filters; completing Modification Record 96-02, Addendum 2, "Installation of Power Motion Inc. Rod Position Indication System;" performing a reactivity worth measurement in accordance with reactor procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D);" and performing a reactivity worth measurement in accordance with reactor procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

SEPTEMBER 2018

The reactor operated continuously in September with the following exceptions: four shutdowns for scheduled maintenance and/or refueling, two shutdowns for physics measurements, and two unscheduled/unplanned power reductions.

On September 5, with the reactor operating at 10 MW in the automatic control mode, an automatic containment isolation was initiated, which automatically shut down the reactor. All immediate and subsequent actions of emergency procedure EP-RO-12, "Reactor Isolation," were completed. Troubleshooting revealed that the radiation signal from containment building exhaust plenum no. 1 area radiation monitor decreased to a level that caused the electronic circuit to sense a failure on low level. The installed sources in both exhaust plenums nos. 1 and 2 had decayed significantly over several years. Replacement sources were installed. Permission to restart the reactor was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

On September 14, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated when the console operator discovered that the backup doors to the containment building ventilation supply and exhaust duct doors 504 and 505 closed. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Further investigation revealed that the compressed air supply line to the backup door air cylinders was damaged when an operator became entangled in an electrical extension cord that was attached to the air line. The air line was repaired, and operation of the backup doors was verified satisfactory by performing compliance procedure CP-20, "Backup Doors." Permission to restart the reactor was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: replacing the primary coolant system flow 'A' recorder; replacing the water pump on the diesel engine of the EPG; and performing two reactivity worth measurements in accordance with reactor procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

OCTOBER 2018

The reactor operated continuously in October with the following exceptions: five shutdowns for scheduled maintenance and/or refueling, one shutdown for physics measurement, and one unscheduled/unplanned power reduction. An NRC inspector conducted a routine scheduled inspection of Reactor Operations and Emergency Preparedness.

On October 13, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated as part of an unplanned shutdown with Reactor Manager concurrence. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Anti-siphon system isolation valves V543A and V543B were leaking causing air to collect within the reactor loop vent system tank. Solenoid-operated vent valve V552A would periodically open to vent the air out of the tank, which released small amounts of activated air to the facility ventilation exhaust stack. After the reactor and primary coolant system were shut down, the primary coolant system was restarted and secured several times until anti-siphon system isolation valves V543A and V543B were seated with minimal leakage noted. Permission to restart the reactor was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: completing Modification Record 18-02, "Fabrication of a New Control Rod Drive Mechanism;" replacing control rod 'B' drive mechanism; replacing the pool coolant heat exchanger inlet and outlet temperature recorder; replacing the pool coolant demineralizer system inlet filters; loading new de-ionizing bed 'K' and placing it on pool coolant system service; completing the biennial change-out of control blade 'D' offset mechanism; performing a reactivity worth measurement in accordance with reactor procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D);" and performing a reactivity worth measurement in accordance with reactor procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

NOVEMBER 2018

The reactor operated continuously in November with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and two unscheduled/unplanned power reductions.

On November 9, with the reactor operating at 10 MW in the automatic control mode, an automatic reactor scram was initiated due to a loss of normal electrical power to the reactor containment and laboratory buildings. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Investigation revealed the supply breaker on a substation 'B' was tripped. The cause of the breaker trip was a malfunction inside a breaker located in motor control center no. 3. The failed breaker was disconnected, and power to the reactor containment and laboratory buildings was restored. Permission to restart the reactor was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

On November 20, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated as part of an unplanned power reduction due to abnormal noise coming from primary coolant circulation pump P501A breaker located in motor control center no. 5. All immediate and subsequent actions of reactor

emergency procedure REP-2, "Reactor Scram," were completed. When the primary coolant circulation pump was started, the breaker contact block most likely did not seat properly when the coil activated, which caused a significant buzzing noise. After the reactor was shut down, the primary coolant system was restarted allowing the primary coolant circulation pump P501A breaker contact block to seat properly. Permission to restart the reactor was obtained from the Lead Senior Reactor Operator, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: completing Modification Record 18-01, "Installation of Containment Differential Pressure Transmitter, Remote Indication, and Alarm;" transferring de-ionizing bed 'K' from primary coolant system service to pool coolant system service; loading new de-ionizing bed 'Y' and placing it on primary coolant system service; replacing the intermediate range monitor level recorder; replacing the secondary coolant system recorder; replacing the source range monitor level recorder; replacing the wide range level monitor recorder; replacing the reactor pressure vessel cover backrings; refurbishing anti-siphon system isolation valves V543A and V543B; replacing the primary coolant system flow 'B' recorder; and replacing the pool coolant demineralizer system inlet filters.

DECEMBER 2018

The reactor operated continuously in December with the following exceptions: five shutdowns for scheduled maintenance and/or refueling and one shutdown for physics measurement. There were no unscheduled/unplanned power reductions this month. An NRC license examiner administered a reactor operator and a senior reactor operator licensing examinations.

Major maintenance items for the month included: replacing the pool coolant system flow recorder; replacing both off-gas stack monitor recorders; refurbishing both primary coolant circulation pump bypass valves V538A and V538B; replacing the power range monitor level recorder; replacing the pool coolant demineralizer system inlet filters; completing Modification Record 99-01, Addendum 1, "Replace Process Instrumentation Recorders – 2018;" completing Modification Record 99-05, Addendum 2, "Replace Eberline Stack Monitor Recorder – 2018;" completing Modification Record 95-01, Addendum 2, "Replace Nuclear Instrumentation Recorders – 2018;" completing Modification Record 09-03, Addendum 2, "Replace Lab Impex Stack Monitor Recorder – 2018;" performing a reactivity worth measurement in accordance with reactor procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D);" and performing a reactivity worth measurement in accordance with reactor procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

SECTION II

MURR PROCEDURES

January 1, 2018 through December 31, 2018

As required by administrative MURR Technical Specification (TS) 6.6.e(5), this section of the Reactor Operations Annual Report includes a summary of procedure changes. These procedure changes were reviewed by the Reactor Manager or Reactor Health Physics Manager, as applicable, and others to assure compliance with the requirements of 10 CFR 50.59. These procedure changes were also reviewed by the Reactor Safety Procedure Review Subcommittee and/or the Isotope Use Procedure Review Subcommittee of the Reactor Advisory Committee to meet the requirements of TS 6.2.a(2).

A. CHANGES TO REACTOR OPERATIONS PROCEDURES

As required by the MURR TS, the Reactor Manager reviewed the Reactor Operations procedures and found them to be adequate for the safe and reliable operation of the facility.

There were 64 revisions issued to the Reactor Operations procedures, forms, policies, and charters. One new charter and one new procedure were issued, while one form and one procedure were obsoleted. The majority of these revisions were strictly format or editorial in nature, such as cover page changes. The following is a list of the new, revised, and obsoleted procedures, forms, policies, and charters:

Number	Name	Rev	Rev Date	Notes
AP-RO-105	MURR Operator Requalification Process	0	12/18/18	New Procedure
AP-RO-110	Conduct of Operations	25	07/12/18	Minor Editorial
AP-RO-110	Conduct of Operations	26	12/18/18	Minor Editorial
AP-RO-130	Crane Operation	9	10/03/18	Minor Editorial
AP-RR-003	10 CFR 50.59 Evaluations	12	12/12/18	Minor Editorial
AP-RR-014	On-Site Fingerprinting Program	1	10/02/18	Minor Editorial
AP-RR-033	Access Authorization Program for Irradiated Reactor Fuel in Transit	2	10/02/18	Minor Editorial
EX-RO-110	Pneumatic Tube System	1	12/10/18	Minor Editorial
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	5	01/04/18	Minor Editorial
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	6	03/16/18	Minor Editorial
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	7	05/10/18	Minor Editorial
FM-15	10 CFR 50.59 Qualified Reviewers List	23	07/12/18	Minor Editorial
FM-16	Primary - Pool Coolant Water Analysis	13	01/04/18	Obsoleted
FM-18	Deviation From Procedure Report	11	12/10/18	Minor Editorial
FM-19	Unscheduled/Unplanned Power Reduction Report	7	12/18/18	Minor Editorial
FM-21	ARMS Trip Setpoints	12	07/12/18	Cover Page
FM-21	ARMS Trip Setpoints	13	10/03/18	Minor Editorial
FM-43	Nuclear and Process Data Sheet	26	05/10/18	Minor Editorial
FM-43	Nuclear and Process Data Sheet	27	12/10/18	Minor Editorial

Number	Name	Rev	Rev Date	Notes
FM-56	Reactor Routine Patrol	23	05/10/18	Minor Editorial
FM-56	Reactor Routine Patrol	24	10/03/18	Minor Editorial
FM-57	Long Form Startup Checksheet	27	01/24/18	Minor Editorial
FM-57	Long Form Startup Checksheet	28	05/10/18	Minor Editorial
FM-57	Long Form Startup Checksheet	29	10/03/18	Minor Editorial
FM-57	Long Form Startup Checksheet	30	12/10/18	Minor Editorial
FM-58	Short Form Startup Checksheet	14	04/23/18	Minor Editorial
FM-58	Short Form Startup Checksheet	15	12/10/18	Minor Editorial
FM-90	Personal History Questionnaire (PHQ) and Self-Disclosure	9	08/07/18	Minor Editorial
FM-90	Personal History Questionnaire (PHQ) and Self-Disclosure	10	12/12/18	Minor Editorial
FM-143	1/M Graph	3	10/03/18	Minor Editorial
FM-152	Fuel Element Inspection	4	12/10/18	Minor Editorial
FM-200	Authorization to Conduct Background Investigation for Unescorted Access to MURR	2	08/07/18	Minor Editorial
LCC-001	Reactor Advisory Committee Charter	1	10/02/18	Cover Page
LCC-002	Reactor Safety Subcommittee Charter	1	05/09/18	Cover Page
LCC-003	Isotope Use Subcommittee Charter	1	05/09/18	Cover Page
LCC-004	Reactor Safety Procedure Review Subcommittee Charter	1	03/15/18	Cover Page
LCC-005	Isotope Use Procedure Review Subcommittee Charter	1	01/25/18	Minor Editorial
LCC-006	Reactor Action Subcommittee	0	10/02/18	New Charter
OP-RO-210	Reactor Startup - Normal	20	04/23/18	Minor Editorial
OP-RO-210	Reactor Startup - Normal	21	12/10/18	Minor Editorial
OP-RO-211	Reactor Startup - Hot	16	04/23/18	Minor Editorial
OP-RO-230	Changing Reactor Power Level	11	12/18/18	Minor Editorial
OP-RO-312	Nuclear Instrumentation Power Range Monitor - Channel 6	16	12/18/18	Minor Editorial
OP-RO-410	Primary Coolant System	16	05/10/18	Minor Editorial
OP-RO-420	Primary and Pool Water Analysis	10	01/04/18	Minor Editorial
OP-RO-480	Secondary Coolant System	22	01/12/18	Minor Editorial
OP-RO-480	Secondary Coolant System	23	07/12/18	Minor Editorial
OP-RO-516	Valve Operation Air System	13	08/09/18	Minor Editorial
OP-RO-520	Emergency Power Generator	17	12/10/18	Minor Editorial
OP-RO-525	Chill Water System	10	12/10/18	Minor Editorial
OP-RO-531	Primary and Pool Sample Station	15	07/12/18	Minor Editorial
OP-RO-555	Fire Protection System	16	04/23/18	Minor Editorial
OP-RO-555	Fire Protection System	17	12/18/18	Minor Editorial
OP-RO-730	Facility Exhaust System	18	05/10/18	Minor Editorial
OP-RO-741	Waste Tank System Operation	23	05/31/18	Minor Editorial
OP-RO-741	Waste Tank System Operation	24	12/18/18	Minor Editorial
POL-20	Special Nuclear Materials Manual	4	01/04/18	Minor Editorial
RM-RO-405	Reactor Demineralizer System	16	01/24/18	Minor Editorial
RM-RO-405	Reactor Demineralizer System	17	05/10/18	Minor Editorial
RM-RO-405	Reactor Demineralizer System	18	08/09/18	Minor Editorial
RM-RO-405	Reactor Demineralizer System	19	12/10/18	Minor Editorial

Number	Name	Rev	Rev Date	Notes
RP-RO-200	Measurement of Differential Worth of a Shim Blade, RTP-11 (D)	8	12/10/18	Minor Editorial
RP-RO-300	Receipt, Inspection and Accounting of Unirradiated Fuel	6	07/12/18	Minor Editorial
SM-RO-025	Removal, Transfer or Installation of an Offset Mechanism	3	10/01/18	Minor Editorial
SM-RO-100	Draining and Filling the Primary Coolant Side of Primary Coolant System Heat Exchangers	4	10/01/18	Minor Editorial
SM-RO-200	Manual Operation of Airlock Doors 276 and 277	5	01/31/18	Minor Editorial
SM-RO-200	Manual Operation of Airlock Doors 276 and 277	6	12/11/18	Minor Editorial
SM-RO-300	Control Console And Instrument Panel-Securing Power	13	06/28/18	Obsoleted

B. CHANGES TO EMERGENCY PLAN IMPLEMENTING PROCEDURES

As required by the MURR TS, the Reactor Manager reviewed the Emergency Plan implementing procedures and found them to be adequate for the safe and reliable operation of the facility.

There were 21 revisions issued to the Emergency Plan implementing procedures, forms, and operator aids. The majority of these revisions were strictly format or editorial in nature, such as cover page changes. The following is a list of the revised procedures, forms, and operator aids:

Number	Name	Rev	Rev Date	Notes
EP-RO-001	Definitions	5	04/25/18	Minor Editorial
EP-RO-006	Radiological Emergency	9	04/25/18	Cover Page
EP-RO-014	Emergency Planning Zone and Site Area Evacuations	10	04/25/18	Minor Editorial
EP-RO-015	Emergency Notifications	17	04/25/18	Minor Editorial
EP-RO-015	Emergency Notifications	18	10/01/18	Minor Editorial
EP-RO-017	Emergency Air Sampling	8	04/25/18	Cover Page
EP-RO-017	Emergency Air Sampling	9	10/01/18	Minor Editorial
EP-RO-018	Emergency Radiation Exposure	8	04/25/18	Cover Page
EP-RO-019	Emergency Dosimeters	4	04/25/18	Cover Page
EP-RO-020	Emergency Equipment Maintenance	7	04/25/18	Minor Editorial
FM-104	Emergency Call List	34	01/02/18	Minor Editorial
FM-104	Emergency Call List	35	04/25/18	Minor Editorial
FM-104	Emergency Call List	36	10/01/18	Minor Editorial
FM-104	Emergency Call List	37	12/17/18	Minor Editorial
OA-10	Fire Extinguisher Locations and Types	15	12/17/18	Minor Editorial
OA-20	Emergency Equipment	23	01/02/18	Minor Editorial
OA-20	Emergency Equipment	24	04/25/18	Minor Editorial
OA-20	Emergency Equipment	25	12/17/18	Minor Editorial
REP-RO-100	Reactor Emergency Procedures	22	03/15/18	Minor Editorial
REP-RO-100	Reactor Emergency Procedures	23	06/14/18	Minor Editorial
REP-RO-100	Reactor Emergency Procedures	24	12/31/18	Minor Editorial

C. CHANGES TO RADIOLOGICAL CONTROL, BYPRODUCT MATERIAL SHIPPING, AND PREPARATION OF BYPRODUCT MATERIAL FOR SHIPPING PROCEDURES

As required by the MURR TS, the Reactor Health Physics Manager reviewed the radiological control procedures and the procedures for the preparation for shipping and shipping of byproduct materials.

There were 234 revisions issued to the radiological control, byproduct materials shipping, and preparation for shipping byproduct material procedures, forms, operator aids, and plans. One new operator aid and four new procedures were issued. The majority of these revisions were strictly format or editorial in nature, such as cover page changes. The following is a list of the new and revised procedures, forms, operator aids, and plans:

Number	Name	Rev	Rev Date	Notes
ACG-NAA-217	Processing High Purity Materials	9	05/09/18	Cover Page
ACG-NAA-218	Cleaning Options for High Purity Materials Processing	8	02/02/18	Cover Page
ACG-NAA-221	High Purity Materials Analysis Flux Monitor Measurement	10	02/02/18	Cover Page
ACG-NAA-222	Neutralization and Disposal of Waste Acids From High Purity Materials Processing	4	05/09/18	Cover Page
AP-HP-105	Radiation Work Permit	16	10/19/18	Minor Editorial
AP-HP-106	Health Physics Emergency Equipment Checks	1	02/19/18	Minor Editorial
AP-HP-115	Iodine 131 Bioassay	4	01/24/18	Cover Page
AP-HP-117	MURR Initial Radiation Worker Training Program	15	12/12/18	Minor Editorial
AP-HP-119	High Radiation Area Access	10	02/19/18	Cover Page
AP-HP-123	Visitor Dosimetry - Reception Desk	13	02/19/18	Minor Editorial
AP-HP-125	Review of Unplanned Radiation Exposure	7	02/02/18	Cover Page
AP-HP-129	Hot Cell HC-01 Control	16	05/25/18	Minor Editorial
AP-HP-129	Hot Cell HC-01 Control	17	06/21/18	Minor Editorial
AP-HP-135	Project Authorization Requests	1	04/05/18	Cover Page
AP-HP-150	Source Calibration	7	04/05/18	Cover Page
AP-RR-013	Access Authorization Program for Category 1 and/or Category 2 Quantities of Radioactive Material	2	10/03/18	Minor Editorial
AP-RR-013	Access Authorization Program for Category 1 and/or Category 2 Quantities of Radioactive Material	3	12/13/18	Minor Editorial
AP-SH-001	Administrative Procedure - Radioactive Material Shipping	12	12/10/18	Cover Page
BP-SH-005	Packaging of Type A Radioactive Material Using SAFKEG-LS and SAFKEG-HS	2	05/24/18	Cover Page
BP-SH-010	Packaging Radioactive Material for a Limited Quantity Shipment	9	10/19/18	Minor Editorial
BP-SH-011	Packaging of Type A Radioactive Material Using USA DOT 7A 55-Gallon	10	10/03/18	Minor Editorial
BP-SH-012	DOT-7A Package Certification	8	03/16/18	Cover Page
BP-SH-013	Packaging of Type A Radioactive Material Using USA DOT 7A 5- to 30-Gallon Reusable Drum	10	03/16/18	Cover Page
BP-SH-013	Packaging of Type A Radioactive Material Using USA DOT 7A 5- to 30-Gallon Reusable Drum	11	10/03/18	Minor Editorial
BP-SH-014	Packaging Type A Radioactive Material in an Overpack	8	03/16/18	Cover Page

Number	Name	Rev	Rev Date	Notes
BP-SH-017	Packaging of Reusable Type A Radioactive Material Using Tracerco LS-6	6	10/03/18	Minor Editorial
BP-SH-018	Packaging of Type A Radioactive Material Using USA DOT 7A NorthStar Medical Radioisotopes Package	6	04/23/18	Minor Editorial
BP-SH-018	Packaging of Type A Radioactive Material Using USA DOT 7A NorthStar Medical Radioisotopes Package	7	07/19/18	Minor Editorial
BP-SH-031	Packaging of Type A Radioactive Material Using DOT 7A 20WC-1	5	05/24/18	Cover Page
BP-SH-052	Radioactive Material Shipment Package Documentation and Labeling	18	06/21/18	Minor Editorial
BP-SH-059	Spectratek Services Reusable Packaging of Type A Radioactive Material	8	10/03/18	Minor Editorial
BP-SH-099	Packaging of Type A Radioactive Material Using USA DOT 7A MURR Model 1500	8	12/10/18	Cover Page
BP-SH-145	Packaging of Type A Radioactive Material Using USA DOT 7A F-458	3	06/21/18	Minor Editorial
BP-SH-192	Packaging of Radioactive Material Using USA DOT 7A Model MURR MAX	2	04/05/18	Minor Editorial
BP-SH-192	Packaging of Radioactive Material Using USA DOT 7A Model MURR MAX	3	05/24/18	Cover Page
BP-SH-192	Packaging of Radioactive Material Using USA DOT 7A Model MURR MAX	4	10/03/18	Minor Editorial
BP-SH-302	Packaging of Type A Radioactive Material Using USA DOT 7A MURR Model 6 or 12	11	10/03/18	Minor Editorial
BPB-SH-020	Receipt Inspection Of Type B Shipping Package	8	04/05/18	Cover Page
BPB-SH-023	Type B Equipment Calibration	7	05/10/18	Cover Page
BPB-SH-024	Type B USA/0697/B(U)-96 (F-458 Series) Packaging of Type B Radioactive Material	9	10/19/18	Minor Editorial
BPB-SH-025	Packaging of Type B Radioactive Material Using USA/0562/B(U)-96 (BEATRICE)	6	10/19/18	Cover Page
BPB-SH-027	Survey and Decontamination of Returned Shipping Containers	9	12/10/18	Minor Editorial
BPB-SH-028	Packaging of Type B Radioactive Material Using USA/9337/B(U)-96 (SAFKEG-LS) and USA/9338/B(U)-96 (SAFKEG-HS)	7	12/20/18	Cover Page
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	5	01/04/18	Minor Editorial
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	6	03/16/18	Minor Editorial
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	7	05/10/18	Minor Editorial
FM-13	Receipt of Radioactive Material	9	01/24/18	Cover Page
FM-17	Radiation Work Permit	15	02/02/18	Cover Page
FM-27	In-House Radioactive Shipping Request Form	18	03/16/18	Minor Editorial
FM-27	In-House Radioactive Shipping Request Form	19	07/19/18	Minor Editorial
FM-39	Control Checksheet for Packaging of Radioactive Material for a Limited Quantity Shipment	17	10/03/18	Minor Editorial
FM-52	Control Checksheet for Documentation and Labeling of Radioactive Material Shipment	21	06/21/18	Cover Page
FM-54	Report of Personnel Contamination	10	03/15/18	Cover Page

Number	Name	Rev	Rev Date	Notes
FM-59	Control Checksheet for Spectratek Services Reusable Packaging of Type A Radioactive Material	11	10/03/18	Minor Editorial
FM-60	Control Check Sheet for Packaging of Type A Radioactive Material Using USA DOT 7A Model E-Box 030-181	8	07/19/18	Cover Page
FM-62	Radiation Instrument Certificate of Calibration	9	05/10/18	Minor Editorial
FM-67	Receipt of Radioactive Gemstone Shipping Containers	10	01/24/18	Cover Page
FM-69	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A 5- to 30-Gallon Reusable Drum	14	03/16/18	Cover Page
FM-70	Control Checksheet for Packaging of Type A Radioactive Material Using Tracerco LS-6 Reusable	6	10/03/18	Minor Editorial
FM-76	Personnel Contamination Log	6	05/25/18	Cover Page
FM-79	Lutetium Chloride Radiation Protection Data Sheet B	12	12/10/18	Minor Editorial
FM-80	Material License Project Review Report	8	12/20/18	Minor Editorial
FM-91	Declaration of Pregnancy	8	02/02/18	Cover Page
FM-94	Exclusive Use Shipment Controls	10	03/16/18	Cover Page
FM-96	Dysprosium Dissolution Data Sheet	4	02/26/18	Cover Page
FM-98	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A MURR Model 6 or 12	13	10/03/18	Minor Editorial
FM-99	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A MURR Model 1500	12	12/10/18	Cover Page
FM-107	Control Checksheet for Packaging Type A Radioactive Material in an Overpack	11	03/16/18	Cover Page
FM-109	Dy/Ho-166 Separation Data Sheet	3	10/01/18	Cover Page
FM-120	Individual Type B QA Training Certification	8	12/10/18	Cover Page
FM-126	Documentation of Compliance for DOT-7A Shipping Package	6	03/16/18	Cover Page
FM-131	Dissolution of Gadolinium Datasheet	2	05/11/18	Cover Page
FM-132	Nd Dissolution Data Sheet	3	02/26/18	Minor Editorial
FM-135	Control Checksheet for Packaging of Type B Radioactive Material Using USA/0562/B(U)-96 (BEATRICE)	7	10/19/18	Cover Page
FM-137	Type B Qualified Shipper List	21	01/04/18	Minor Editorial
FM-137	Type B Qualified Shipper List	22	02/19/18	Minor Editorial
FM-137	Type B Qualified Shipper List	23	03/29/18	Minor Editorial
FM-137	Type B Qualified Shipper List	24	06/29/18	Minor Editorial
FM-137	Type B Qualified Shipper List	25	07/19/18	Minor Editorial
FM-138	Control Checksheet for Leak Testing the SAFKEG-LS or SAFKEG-HS Shipping Package Using the CALT Leakage Testing Device	8	12/20/18	Cover Page
FM-139	Lutetium Chloride Radiation Protection Data Sheet C	6	04/05/18	Cover Page
FM-139	Lutetium Chloride Radiation Protection Data Sheet C	7	12/10/18	Minor Editorial

Number	Name	Rev	Rev Date	Notes
FM-141	Control Checksheet for Packaging of Type A Radioactive Material Using SAFKEG-LS and SAFKEG-HS	5	05/24/18	Cover Page
FM-144	Control Checksheet for Packaging of Type A Radioactive Material Using Tracerco LS-1	3	10/03/18	Minor Editorial
FM-145	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A F-458	3	06/21/18	Cover Page
FM-147	Control Checksheet for Packaging of Type A Radioactive Material Using Tracerco LS-15	4	08/07/18	Cover Page
FM-147	Control Checksheet for Packaging of Type A Radioactive Material Using Tracerco LS-15	5	10/03/18	Minor Editorial
FM-149	Personnel Radiation Dose Estimate	2	02/19/18	Cover Page
FM-151	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A 55-Gallon	14	10/03/18	Minor Editorial
FM-157	Control Checksheet for Type B USA/0697/B(U)-96 (F-458 Series) Radioactive Material Package	11	10/19/18	Minor Editorial
FM-159	Control Checksheet for Health Physics Review of Radioactive Material Shipment Documentation	10	04/05/18	Minor Editorial
FM-163	Control Checksheet for Type B Radioactive Material Using USA/9337/B(U)-96 (SAFKEG-LS) and USA/9338/B(U)-96 (SAFKEG-HS)	10	02/02/18	Minor Editorial
FM-163	Control Checksheet for Type B Radioactive Material Using USA/9337/B(U)-96 (SAFKEG-LS) and USA/9338/B(U)-96 (SAFKEG-HS)	11	12/20/18	Minor Editorial
FM-164	Authorization For Use of North Office Addition West Passageway (C2001)	5	04/05/18	Cover Page
FM-169	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A 20WC-1	5	05/24/18	Cover Page
FM-170	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A Northstar Medical Radioisotopes Package	5	04/05/18	Minor Editorial
FM-173	Control Checksheet for Health Physics Review of Excepted (Limited) Quantity Radioactive Material Shipment	2	03/15/18	Cover Page
FM-174	Instrument Pre-Start-Up Check Sheet	1	05/25/18	Cover Page
FM-175	Control Checksheet for Receipt Inspection of Customer Owned Type B Shipping Package	3	10/19/18	Cover Page
FM-176	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A Northstar Medical Radioisotopes Package with 7.5 Ci of Mo-99	3	12/20/18	Cover Page
FM-177	Control Checksheet for Receipt Inspection of SAFKEG LS and HS Type B Shipping Package	3	10/19/18	Cover Page
FM-178	Control Checksheet for Hot Cell HC-01 Access	4	01/04/18	Cover Page
FM-178	Control Checksheet for Hot Cell HC-01 Access	5	06/21/18	Minor Editorial
FM-179	Control Checksheet for Documentation and Labeling of Excepted (Limited) Quantity Radioactive Material Shipment	2	03/16/18	Cover Page
FM-192	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A Model MURR MAX	1	05/24/18	Cover Page

Number	Name	Rev	Rev Date	Notes
FM-192	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A Model MURR MAX	2	10/03/18	Minor Editorial
FM-194	Control Checksheet for Documentation and Labeling of Radioactive Material Shipment Packaged in an Overpack	1	10/19/18	Cover Page
GLP-MCE-002	Installation of Gamma Spectroscopy Detector	2	06/20/18	Minor Editorial
GLP-MCE-003	Performance Checks of the High Purity Germanium Detectors	5	09/27/18	Minor Editorial
GMP-BR-404	Mo-99 Process Cleaning and Line Clearance	6	08/22/18	Minor Editorial
GMP-BR-404	Mo-99 Process Cleaning and Line Clearance	7	10/23/18	Minor Editorial
GMP-BR-502	Sodium Iodide I-131 Solution Batch Record	4	04/10/18	Minor Editorial
GMP-BR-502	Sodium Iodide I-131 Solution Batch Record	5	06/11/18	Minor Editorial
GMP-MCE-122	Establishing Calibration Factors for Calicheck Dose Calibrator Linearity Test Kit	3	09/27/18	Minor Editorial
GMP-MCE-124	Cleaning, Maintenance and Operation of HC-08 A/B	8	01/23/18	Minor Editorial
GMP-MCE-124	Cleaning, Maintenance and Operation of HC-08 A/B	9	06/08/18	Minor Editorial
GMP-MCE-129	Operation and Maintenance for a Tuttnauer 3870 EA-B/L Electronic Tabletop Autoclave	5	09/27/18	Minor Editorial
GMP-PRC-201	Transfer of cGMP Lu-177 Chloride Product to Shipping	11	03/22/18	Minor Editorial
GMP-PRC-400	Transfer of cGMP Potassium Molybdate Final Intermediate Solution to Customer	2	08/21/18	Minor Editorial
GMP-QC-021	pH Determination of Lu-177 Chloride Solution by Microcombination pH Probe	5	01/12/18	Minor Editorial
GS-RA-014	Use and Operation of the I-131 Production Facility Lifting Crane	2	05/25/18	Cover Page
GXP-EPRT-067	New and/or Retrospective Installation, Operation, and Performance Qualification for a Capintec CRC-77tHR Dose Calibrator	0	06/13/18	New Procedure
GXP-MCE-123	Cleaning, Maintenance and Operation of Hot Cell HC-04	3	02/20/18	Minor Editorial
GXP-MCE-123	Cleaning, Maintenance and Operation of Hot Cell HC-04	4	05/16/18	Cover Page
HC-PSO-002	Hot Cell Preparation of Radioactive Material for Shipment	19	10/03/18	Minor Editorial
IC-HP-300	Calibration - Radiation Survey Instruments	9	06/07/18	Minor Editorial
IC-HP-313	Calibration - Eberline PCM-1 Contamination Monitor	1	02/19/18	Minor Editorial
IC-HP-340	Calibration - Bladewerx Saber BPM Air Monitor	1	04/05/18	Cover Page
IC-HP-341	Calibration -High Resolution Gamma Spectroscopy Systems	8	05/10/18	Cover Page
IC-HP-343	Calibration - Sodium Iodide Detector	6	03/15/18	Minor Editorial
IC-HP-346	Calibration - Lab Impex Smart MCA Continuous Air Monitor	4	03/30/18	Minor Editorial
IC-HP-346	Calibration - Lab Impex Smart MCA Continuous Air Monitor	5	07/19/18	Minor Editorial
IC-HP-348	Calibration - Canberra S5XLB-G	8	05/25/18	Minor Editorial
IC-HP-349	Calibration - Lab Impex Stack Monitor - Particulate Channel	9	01/04/18	Minor Editorial

Number	Name	Rev	Rev Date	Notes
IC-HP-350	Calibration - Lab Impex Stack Monitor Iodine Channel	6	01/04/18	Minor Editorial
IC-HP-351	Calibration - Lab Impex Stack Monitor - Gas Channel	6	01/04/18	Minor Editorial
IC-HP-352	Calibration - Lab Impex Stack Monitor - Flow Calibration	7	01/04/18	Minor Editorial
IC-HP-353	Calibration - Lab Impex Monitor - DP2001	3	02/19/18	Cover Page
IC-HP-359	Calibration - Ludlum Model 177 Frisker	3	02/02/18	Minor Editorial
IC-HP-361	Calibration - Canberra GEM V Portal Monitor	2	05/25/18	Cover Page
IC-HP-363	Eberline BC-4 Beta Swipe Counter - Calibration	2	02/02/18	Cover Page
IC-HP-364	Calibration - Ludlum Model 3030 Swipe Counter	2	02/02/18	Cover Page
IC-HP-365	Calibration - Thermo PM-12 Portal Monitor	2	02/19/18	Minor Editorial
IC-HP-366	Eberline Model PM-7 Portal Monitor Calibration	1	02/02/18	Cover Page
IC-HP-367	Calibration - I-131 Bioassay Detection System	3	05/25/18	Minor Editorial
IC-HP-368	Calibration - ALMO-6 Radiation Monitoring Instrument	1	02/02/18	Cover Page
IRR-PSO-112	Preparing Shipping Paperwork	10	07/20/18	Minor Editorial
OA-8	Importing Authority Notification for the Netherlands	1	10/03/18	Minor Editorial
OA-26	NRC 749 Manual License Verification Report for Category 2 Materials	1	12/13/18	Cover Page
OA-60	Packaging of Type A Radioactive Material Using USA DOT 7A Model E-Box 030-181	2	07/19/18	Cover Page
OA-99	Packaging of Type A Radioactive Material Using USA DOT 7A MURR Model 1500	2	08/07/18	Cover Page
OA-128	Packaging of Type A Radioactive Material Using USA DOT 7A MURR Model H or I	2	05/24/18	Cover Page
OA-192	Packaging of Type A Radioactive Material Using USA DOT 7A Model MURR MAX	0	06/08/18	New Operator Aid
OP-HP-200	Air Sampling - Containment Building Tritium	8	02/02/18	Cover Page
OP-HP-221	Environmental Sample - Analysis	8	05/10/18	Cover Page
OP-HP-222	Air Sampling - Containment Building Ar-41	9	02/19/18	Cover Page
OP-HP-224	Spent Fuel Shipping Cask Air Sample Analysis	6	05/25/18	Cover Page
OP-HP-228	Performing Iodine 131 Bioassay Measurements	6	12/11/18	Minor Editorial
OP-HP-236	Respirator Selection, Issuance, and Wearing	2	04/23/18	Cover Page
OP-HP-300	Receipt of Radioactive Material	11	02/02/18	Cover Page
OP-HP-306	Health Physics Daily Facility Checks	9	02/19/18	Minor Editorial
OP-HP-306	Health Physics Daily Facility Checks	10	10/19/18	Minor Editorial
OP-HP-352	Particulate and Iodine Filter - Analysis	6	02/02/18	Cover Page
OP-HP-353	Waste Tank Sample - Analysis	9	05/10/18	Cover Page
OP-HP-354	North Office Addition Waste Tank System Filter Replacement	3	10/03/18	Minor Editorial
OP-HP-355	North Office Addition Waste Tank System Operation	5	10/03/18	Minor Editorial
OP-HP-356	Operation - Lab Impex Stack Monitor: Filter Change and Source Checks	8	01/04/18	Minor Editorial
OP-HP-356	Operation - Lab Impex Stack Monitor: Filter Change and Source Checks	9	03/22/18	Minor Editorial
OP-HP-358	Operation - Lab Impex Smart MCA Continuous Air Monitor Filter Change and Source Check	1	02/02/18	Cover Page

Number	Name	Rev	Rev Date	Notes
OP-HP-358	Operation - Lab Impex Smart MCA Continuous Air Monitor Filter Change and Source Check	2	05/10/18	Minor Editorial
OP-HP-359	Bag-In Bag-Out for Changing Bank Exhaust Filters	0	03/22/18	New Procedure
OP-HP-365	Iodine 131 Processing Hot Cells Radiation Monitor (ALMO-6)	2	12/11/18	Cover Page
OP-HP-420	Decontamination of Enclosed Processing Units	6	02/19/18	Minor Editorial
OP-HP-420	Decontamination of Enclosed Processing Units	7	12/20/18	Minor Editorial
OP-HP-500	Operation of the Hot Cell (HC-09) Interim Storage Silo	2	02/19/18	Cover Page
OP-HP-500	Operation of the Hot Cell (HC-09) Interim Storage Silo	3	07/19/18	Cover Page
PLAN-130	10 CFR 37 Security Plan for the University of Missouri Research Reactor	1	04/23/18	Minor Editorial
PRC-RRD-001	Preparing and Submitting a Radioactive Sample for Packaging	6	02/26/18	Cover Page
PRC-RRD-105	Dysprosium Dissolution	4	02/26/18	Minor Editorial
PRC-RRD-106	Separation of Dy/Ho 166	3	10/01/18	Cover Page
PRC-RRD-217	Dissolving Lu-177	3	05/11/18	Minor Editorial
PRC-RRD-218	Lu-177 Distribution	9	02/26/18	Minor Editorial
PRC-RRD-219	Lu-177m Processing	4	12/20/18	Minor Editorial
PRC-RRD-313	Au Dissolution	6	10/01/18	Minor Editorial
PRC-RRD-314	Neodymium Dissolution	7	12/11/18	Minor Editorial
PRC-RRD-316	Concentration of PM-149	7	10/18/18	Minor Editorial
PRC-RRD-317	Ce-Oxide Dissolution	2	02/26/18	Minor Editorial
PRC-RRD-317	Ce-Oxide Dissolution	3	12/11/18	Cover Page
PRC-RRD-318	Dissolution of Copper Nitrate	3	02/26/18	Minor Editorial
PRC-RRD-402	Dissolving Sm-153	7	05/11/18	Minor Editorial
PRC-RRD-414	Dissolution of Gadolinium Nitrate	7	02/26/18	Cover Page
PRC-RRD-420	Rh-105 Processing	8	10/18/18	Full Review
PRC-RRD-421	Dissolving Re-186	7	12/20/18	Minor Editorial
PRC-RRD-424	Dissolving Platinum Powder	3	05/11/18	Minor Editorial
QA-SH-002	Sodium Iodide Spectral Qualitative Analysis for Excepted, License-to-License, Type A, and Type B Radioactive Material Shipments	9	04/05/18	Minor Editorial
QA-SH-002	Sodium Iodide Spectral Qualitative Analysis for Excepted, Type A, and Type B Radioactive Material Shipments	10	12/10/18	Minor Editorial
QA-SH-003	Release of NorthStar Mo-99 Product Vessels	0	12/13/18	New Procedure
QAB-SH-002	Procurement of Type B Packages	6	03/16/18	Cover Page
QAB-SH-003	Material Control for Type B Shipping Program	8	03/16/18	Cover Page
QAB-SH-004	Type B Program Vendor Qualification	8	02/19/18	Cover Page
QAB-SH-005	Type B QA Personnel Training	5	07/19/18	Minor Editorial
QAB-SH-007	Leak Testing the SAFKEG-HS or SAFKEG-LS Shipping Package Using the CALT Leakage Testing Device	7	12/20/18	Cover Page
QAB-SH-008	Training for Type B Shipment Leak Test Performers	3	10/19/18	Cover Page
RCP-PSO-002	P-33 Glove Box Can Opening	9	12/10/18	Minor Editorial
RCP-PSO-003	P-33 Purification Set-Up	12	12/21/18	Minor Editorial

Number	Name	Rev	Rev Date	Notes
RCP-PSO-020	Selenium-75 Process	3	12/10/18	Minor Editorial
RCP-PSO-400	Operation and Cleaning of Shielded Mo-99 Transfer Box	0	10/18/18	New Procedure
RM-HP-102	Stack Monitor Preventative Maintenance - Lab Impex	3	02/02/18	Cover Page
RM-HP-102	Stack Monitor Preventative Maintenance - Lab Impex	4	12/11/18	Minor Editorial
RP-HP-100	Contamination Monitoring - Performing a Swipe	8	02/02/18	Cover Page
RP-HP-105	Transfer of Radioactive Material Within the Facility	13	12/11/18	Cover Page
RP-HP-115	Returning Lead Pigs to Service	7	05/10/18	Cover Page
RP-HP-120	Personnel Radioactive Contamination	13	03/15/18	Minor Editorial
RP-HP-120	Personnel Radioactive Contamination	14	06/21/18	Minor Editorial
RP-HP-125	Radiation Monitoring - Performing and Documenting a Survey	5	02/19/18	Cover Page
RP-HP-125	Radiation Monitoring - Performing and Documenting a Survey	6	10/03/18	Minor Editorial
RP-HP-130	Receipt of Unirradiated Fuel	9	04/23/18	Cover Page
RP-HP-135	Room 114 Entry - Self Monitored	8	04/05/18	Cover Page
RP-HP-137	Handling Radioactive Material in the Reactor Pool	16	02/02/18	Cover Page
RP-HP-137	Handling Radioactive Material in the Reactor Pool	17	04/23/18	Minor Editorial
SEP-RR-130	Security Event Procedures	2	12/21/18	Cover Page
SI-PSO-009	Operation of the Can Press	4	06/21/18	Minor Editorial
SV-HP-100	Reactor Chemistry Isotope Counter Trending and Investigative Level Determination	9	02/02/18	Cover Page
SV-HP-105	Sealed Calibration Source - Leak Check	10	04/23/18	Cover Page
SV-HP-110	Environmental Sampling	9	05/10/18	Cover Page
SV-HP-115	Building Exhaust Stack Effluent - Tritium Monitoring	6	02/19/18	Cover Page
SV-HP-115	Building Exhaust Stack Effluent - Tritium Monitoring	7	08/07/18	Minor Editorial
SV-HP-117	Secondary Coolant and Sump Water Analysis	7	05/10/18	Cover Page
SV-HP-119	Property Release	11	04/05/18	Minor Editorial
SV-HP-119	Property Release	12	12/11/18	Minor Editorial
SV-HP-121	Building Exhaust Stack Effluent - Ar-41 Monitoring	8	05/10/18	Cover Page
SV-HP-135	Containment Air - Emergency Remote Sampling	6	12/11/18	Cover Page
TPZ-PSO-002	Irradiation of Gemstone Irradiation Containers	9	03/15/18	Minor Editorial
TPZ-PSO-003	Loading Gemstone Shipping Drums	7	03/15/18	Minor Editorial
TSP-02	Transportation Security Plan	9	12/11/18	Minor Editorial
WM-SH-100	Radioactive Waste - Preparation and Storage	11	03/16/18	Cover Page
WM-SH-105	Radioactive Waste Processing	14	07/19/18	Cover Page
WM-SH-110	Radioactive Waste - Barrel Analysis for Shipment and Disposal	4	12/10/18	Cover Page
WM-SH-115	Iodine I-131 Waste Handling	3	02/02/18	Cover Page

SECTION III

REVISIONS TO THE SAFETY ANALYSIS REPORT

January 1, 2018 through December 31, 2018

On August 31, 2006, MURR submitted a request to the U.S. Nuclear Regulatory Commission (NRC) to renew Amended Facility Operating License No. R-103 for another twenty years of operation, at which time MURR also provided its proposed Safety Analysis Report (SAR). On January 4, 2017, the NRC issued Renewed Facility Operating License No. R-103.

During 2017 and 2018, thousands of person-hours were spent by MURR staff to update the August 31, 2006, SAR with all of the facility changes and modifications that had occurred between 2006 and 2017, and with applicable information from the hundreds of MURR responses to NRC Requests for Additional Information during the relicensing process. MURR expects to complete the SAR revisions and updates during the first half of 2019.

During calendar year 2018, modifications or changes to the facility occurred that required the following revisions to the SAR, as submitted to the NRC in 2006 for relicensing. The following changes have been reviewed, in accordance with 10 CFR 50.59, by licensed staff and members of the Reactor Safety Subcommittee; determined not to involve a change to the MURR Technical Specifications; and approved by the Reactor Manager.

CHAPTER 3 – DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

Section 3.5.2, first paragraph, fourth sentence (page 3-30)

Revise to read: "Each drive mechanism consists of a single-phase motor connected to a lead screw assembly through a reduction gear box and adapter."

CHAPTER 4 – REACTOR DESIGN

Section 4.2.2.1, fourth paragraph, second sentence (page 4-15)

Revise to read: "Each control blade drive mechanism consists of a 0.02-HP, 115-volt, one-amp, single-phase, 60-cycle motor connected to a lead screw assembly through a reduction gear box and adapter."

Section 4.2.2.1, fourth paragraph, fourth sentence (page 4-15)

Delete

Section 4.2.2.1, last paragraph, second sentence (page 4-17)

Revise to read: "Signals from the shaft encoder are converted into actual rod position by the Rod Position Indication (RPI) chassis mounted into the control room instrument panel."

CHAPTER 6 – ENGINEERED SAFETY FEATURES

Section 6.2.3, second paragraph (page 6-5)

Insert new sentence at end of paragraph to read: "One line used for containment DP instrumentation exits the containment structure through one of the penetration plates."

Section 6.2.3.1, Table 6-1 (page 6-6)

Insert new row to read:

Containment DP Instrumentation	Manual Valve	1

Section 6.2.4, second paragraph, third sentence (page 6-13)

Revise to read: "Air is supplied to the pneumatic cylinders from the facility main air compressors and the emergency air compressor via a point-of-use air dryer to prevent moisture accumulation."

CHAPTER 7 – INSTRUMENTATION AND CONTROL

Section 7.3.1, Table 7-3 (pages 7-12 to 7-15)

Delete "2 Source Range Monitor Level Recorder"

Revise No. 3 to read: "Intermediate Range Monitor Level Recorder"

Revise No. 4 to read: "Source and Wide Range Monitors Level Recorder"

Revise No. 5 to read: "Power Range Monitor Level Recorder"

Revise No. 85 to read: "Primary Coolant T_h - T_c Recorder"

Revise No. 87 to read: "Pool Coolant T_h - T_c Recorder"

Revise No. 89 to read: "Primary Coolant System Flow Recorder"

Revise No. 90 to read: "Pool Coolant System Flow Recorder"

Revise No. 91 to read: "Primary & Pool Coolant Demineralizer Flow Recorder"

Revise No. 108 to read: "Secondary Coolant System Recorder"

Revise No. 128 to read: "Off-Gas Radiation Monitor Recorder"

Revise No. 130 to read: "Off-Gas Radiation Monitor Recorder"

Insert "135 Containment Differential Pressure Indication/Alarm"

Section 7.4.2.1, first paragraph, last sentence (page 7-22)

Revise to read: "A paperless recorder mounted on the instrument panel records Channel 1 source range level and transfers the data to a server for archiving."

Section 7.4.2.2, first paragraph, last sentence (page 7-22)

Revise to read: "A paperless recorder mounted on the instrument panel records Channel 2 and 3 intermediate range levels and transfers the data to a server for archiving."

Section 7.4.2.3, first paragraph, last sentence (page 7-23)

Revise to read: "A paperless recorder mounted on the instrument panel records Channel 4, 5, and 6 power range levels and transfers the data to a server for archiving."

Section 7.5.2, second paragraph, third sentence (pages 7-25 to 7-26)

Revise to read: "Each control rod drive mechanism consists of a 0.02-HP, 115-volt, one-amp, single-phase, 60-cycle motor connected to a ball-bearing lead screw assembly through a reduction gear box and adapter."

Section 7.5.2, second paragraph, sixth sentence (page 7-26)

Delete

Section 7.5.6 (pages 7-35 to 7-36)

Revise, in its entirety, to read:

"Control rod position indication is provided by a system of microcomputer controlled instruments located in the reactor control room. The Rod Position Indication (RPI) system is designed to provide the following:

- Continuous precision rod position indication; and
- Security against tampering or inadvertent alteration by use of tiered password control.

The RPI system consists of the following major components: five encoder transducers, one mounted on each control rod drive mechanism; a chassis with installed hardware; and a remote Operator Display Assembly (ODA).

Signals from the encoders are converted to relative control rod positions by the Programmable Logic Controller (PLC) in the RPI chassis. The chassis, mounted in the instrument panel, contains an AC to DC power supply, circuit breaker, a network switch for module communication, a Human Machine Interface (HMI), and a PLC consisting of the following components: a fieldbus logic controller, five Synchronous Serial Interface (SSI) encoder input modules, one digital input module, one digital output module, and an end module. All inputs for the system are through either the HMI on the front panel of the chassis, or the HMI serving as the ODA.

The ODA is a second HMI identical in every way to the front panel of the chassis. The ODA is connected to the chassis through a communication cable and a power cable. The power for the ODA is from the power supply in the main rack mounted chassis.

The RPI system consists of three main screens. Along the bottom of each screen are three menu navigation buttons, and they are as follows:

1. Alarms: The alarms screen shows a log of all faults and alarm situations. This log requires a user password to clear the alarm log.
2. Auto Run: The default screen is the "AUTO RUN" screen which displays the five control rod positions. It will also display calculated control rod travel speed when enabled.
3. Setup: The setup screen requires a user login to access. A User login will allow the zero position of the control rods to be set. The remainder of the settings require an Admin login.

The system defaults to the "Auto Run" screen after a timeout of five minutes in the setup menu."

Section 7.6.2.1, second paragraph, first sentence (page 7-37)

Revise to read: "Reactor inlet and outlet temperatures are recorded with a paperless recorder mounted on the instrument panel which transfers the data to a server for archiving."

Section 7.6.2.1, second paragraph, third sentence (page 7-37)

Revise to read: "The output signal from the RTD Transmitter for TE 901A is directed to an Adder-Subtractor Module (ASM) and the recorder."

Section 7.6.2.2, second paragraph, first sentence (page 7-38)

Revise to read: "Pool coolant heat exchanger inlet and outlet temperatures are recorded with a paperless recorder mounted on the instrument panel which transfers the data to a server for archiving."

Section 7.6.2.2, second paragraph, third sentence (page 7-38)

Revise to read: "The output signals from the RTD Transmitters for TE 901D and TE 901C are then directed to an Adder-Subtractor Module (ASM) and the recorder."

Figure 7.7 (pages 7-39/40)

Update with Print No. 41, Sheet 2 of 4, "10MW Process Instrumentation Control & Interlock (Temperature Inst.)," Rev. 28 dated 01/10/19

Figure 7.8 (pages 7-41/42)

Update with Print No. 41, Sheet 3 of 4, "Process Instrumentation Control & Interlock," Rev. 37 dated 01/10/19

Figure 7.9 (pages 7-43/44)

Update with Print No. 41, Sheet 4 of 4, "10MW Process Instrumentation Control & Interlock," Rev. 5 dated 01/10/19

Section 7.6.4.1, second paragraph, first sentence (page 7-46)

Revise to read: "Primary coolant system flow is recorded with a paperless recorder mounted on the instrument panel which transfers the data to a server for archiving."

Section 7.6.4.1, second paragraph, third sentence (page 7-46)

Revise to read: "The output signal (10 to 50 *m*A) generated by each flow transmitter is directed to a Square Root Converter which provides a linear output signal for the recorder and a Dual Alarm Unit."

Section 7.6.4.1, last paragraph, first sentence (page 7-48)

Revise to read: "Primary coolant demineralizer flow is recorded with a paperless recorder mounted on the instrument panel which transfers the data to a server for archiving."

Section 7.6.4.1, last paragraph, third sentence (page 7-48)

Revise to read: "The output signal generated by the flow transmitter is directed to a Square Root Converter which provides a linear output signal for the recorder."

Section 7.6.4.2, second paragraph, first sentence (page 7-48)

Revise to read: "Pool coolant system flow is recorded with a paperless recorder mounted on the instrument panel which transfers the data to a server for archiving."

Section 7.6.4.2, second paragraph, third sentence (page 7-48)

Revise to read: "The output signal generated by the flow transmitter is directed to a Square Root Converter which provides a linear output signal for the recorder."

Section 7.6.4.2, last paragraph, first sentence (page 7-49)

Revise to read: "Pool coolant demineralizer flow is recorded with a paperless recorder mounted on the instrument panel which transfers the data to a server for archiving."

Section 7.9.5.1, last paragraph, fourth sentence (page 7-67)

Revise to read: "The output from each radiation detector is displayed on a local meter in counts per minute (cpm) and on a paperless recorder mounted on the instrument panel in the reactor control room which transfers the data to a server for archiving."

SECTION IV

PLANT AND SYSTEM MODIFICATIONS

January 1, 2018 through December 31, 2018

For each facility modification described below, MURR has on file the safety screen or evaluation, as well as the documentation of review, performed pursuant to 10 CFR 50.59.

MODIFICATION RECORD 13-02, ADDENDUM 1

Secondary Coolant System Chemistry Control

This Modification Record documents changes to the secondary coolant system chemistry control program. MURR made the decision to switch to a different chemical vendor (Nalco) and adopted their chemical control, storage, and delivery systems. This included modifications to the chemical injection locations within the secondary coolant system. The transition to Nalco included the adoption of 3D TRASAR technology. This included the replacement of two Honeywell controllers with a 3D TRASAR controller, as well as the Nalco series of chemicals and chemical delivery components. The 3D TRASAR controller monitors the water parameters and Nalco chemical product concentrations in a sample stream of the secondary coolant. The controller determines the level of scaling, microbiology, and corrosion stress conditions of the secondary coolant system. It also provides control signals for chemical dosing pumps and the blow down valve, in order to maintain optimal chemistry conditions. Finally, the controller is capable of sending monitored data to the Nalco server for trending and Nalco support.

MODIFICATION RECORD 96-02, ADDENDUM 2

Installation of Power Motion Inc. Rod Position Indication System

This addendum to Modification Record 96-02, "Rod Position Indication Change from Veeder-Root to Encoder Type," documents the change from the General Electric rod position indication system to a component-based system. The new system, which was collaboratively designed by Power Motion Inc. and MURR, is a collection of discrete components that can be replaced or upgraded individually rather than a complete system made of largely proprietary components. The main drawer has a touch screen interface on the front panel to serve as the primary display. An identical remote display is mounted in the reactor control console and has both power and signal wires provided from the main drawer. The touch screen operator terminals allow either screen (primary or remote) to operate the programmable logic controller functions and access to the setup menus.

MODIFICATION RECORD 18-02

Fabrication of a New Control Rod Drive Mechanism

This Modification Record documents the fabrication of a new control rod drive mechanism (CRDM). The previously installed CRDMs have been in operation for nearly 52 years with minimal preventive maintenance performed on them over that time period. Although they were fairly reliable, the objective of fabricating a new CRDM is to systematically remove from service each installed CRDM with the intent to completely refurbish them and return them back to service. This also creates a readily available spare CRDM should one fail.

MODIFICATION RECORD 18-01

Installation of Containment Differential Pressure Transmitter, Remote Indication, and Alarm

This Modification Record documents the addition of a remote indication of reactor containment building differential pressure (DP) and a low level alarm inside the control room, which enhances the ability of the operators to determine containment integrity status at all times. This facilitates a quicker response to any degradation of containment DP, up to and including shutting down the reactor if containment integrity is lost. Two DP indicating transmitters are mounted in parallel, inside the reactor containment building to allow for isolation during calibration and testing. These are located on the beamport floor, near the utility entry seal trench. The low pressure side of the transmitters are open to containment atmosphere. The high pressure side of the transmitters are routed to a common containment wall penetration. This penetration passes through the east wall of the containment structure into the laboratory building basement, near the utility entry seal trench. One of the transmitters provides a local indication of containment DP in the reactor containment building basement, and transmits a 4 to 20 mA signal to a remote process controller mounted on the control room instrument panel. The second transmitter also provides a local indication and can be rotated into the primary role. This provides operational flexibility should one of the transmitters fail, and to facilitate removing them from service for calibration. The process controller has its own direct current power supply from lighting panel LP-21 and provides an alarm on the auxiliary annunciator when DP conditions reach a low level condition.

MODIFICATION RECORD 99-01, ADDENDUM 1

Replace Process Instrumentation Recorders - 2018

This addendum to Modification Record 99-01, "Replace Process Instrumentation Recorders," documents the replacement of the primary coolant reactor inlet and outlet temperature; pool coolant heat exchanger inlet and outlet temperature; primary coolant flow through heat exchanger HX503A; primary coolant flow through heat exchanger HX503B; pool coolant flow; primary coolant and pool coolant demineralizer flow; and secondary coolant flow, inlet temperature, and outlet temperature strip-chart, pen recorders with new paperless recorders. With the exception of the secondary coolant flow, inlet temperature, and outlet temperature recorder, all the recorders were Honeywell DPR 100C chart recorders. The secondary coolant flow, inlet and outlet temperature recorder was a Yokogawa model μR1000 recorder. The process instrumentation recorders were in need of replacement due to their age, unavailability of spare parts, and the expense of purchasing pens and paper for the charts. The replacement recorders are Yokogawa model DX1006N paperless recorders and are equivalent or superior in performance to the previous recorders. The new recorders display parameter indication locally, provide relay outputs for alarms, are capable of mathematical calculations with the parameter data, and are connected to a network computer system which archives the data and allows for trending, reformatting, and analysis of the data at any time after data collection. Overall, the replacement paperless recorders should be more reliable than the previous recorders as indicated by other research reactor facilities that have already converted to paperless recorders.

MODIFICATION RECORD 99-05, ADDENDUM 2

Replace Eberline Stack Monitor Recorder - 2018

This addendum to Modification Record 99-05, "Installation of Eberline Model PING-1A Stack Monitor," documents replacement of the strip-chart, three-pen recorder for the Eberline stack monitor. The previously installed M-TEK 2803 three-pen chart recorder was replaced by a Yokogawa paperless recorder. The previous stack monitor recorder was in need of replacement due to obsolescence, unavailability of spare parts, and the expense of purchasing pens and paper for the recorder. The replacement Yokogawa model DX2008 paperless recorder is superior in performance. It

displays parameter indications in the control room, provides additional high activity alarms to assist operators in determining the extent of a release, and is connected to an air-gap network computer system, which archives the data and allows for trending, reformatting, and analysis of the data at any time after data collection.

MODIFICATION RECORD 95-01, ADDENDUM 2

Replace Nuclear Instrumentation Recorders - 2018

This addendum to Modification Record 95-01, "Replacement of Nuclear Instruments," documents the removal of the strip-chart, pen recorders for the source range nuclear instrumentation (NI) channel no. 1 (SRM-1), wide range NI channel (WRM), intermediate range NI channel nos. 2 and 3 (IRM-2 and IRM-3), and power range NI channel nos. 4, 5, and 6 (PRM-4, PRM-5, and PRM-6). The Yokogawa strip-chart, pen recorders used for recording the WRM; IRM-2, -3; and PRM-4, -5, -6 signals were replaced by Yokogawa paperless recorders. The current Speedomax H one-pen chart recorder for SRM-1 was removed and that space in the instrumentation cabinet was blanked off. The SRM-1 and WRM signals are now displayed on a single Yokogawa paperless recorder. The NI recorders were in need of replacement due to their age, unavailability of spare parts, and the expense of purchasing pens and paper for the charts. The replacement recorders are Yokogawa model DX2008 paperless recorders and are equivalent or superior in performance to the previous recorders. The new recorders display parameter indication locally, provide relay outputs for interlocks, and are connected to a network computer system which archives the data and allows for trending, reformatting, and analysis of the data at any time after data collection.

MODIFICATION RECORD 09-03, ADDENDUM 2

Replace Lab Impex Stack Monitor Recorder - 2018

This addendum to Modification Record 09-03, "Lab Impex Stack Monitoring System," documents the replacement of the M-TEK 2803 three-pen chart recorder for the Yokogawa paperless recorder. The previous stack monitor recorder was in need of replacement due to obsolescence, unavailability of spare parts, and the expense of purchasing pens and paper for the recorder. The replacement Yokogawa model DX2008 paperless recorder is superior in performance to the previous recorder. The new recorder displays parameter indication in the control room, provides additional high activity alarms to assist operators in determining the extent of a release, and is connected to an air-gap network computer system, which archives the data and allows for trending, reformatting, and analysis of the data at any time after data collection.

SECTION V

NEW TESTS AND EXPERIMENTS

January 1, 2018 through December 31, 2018

No new tests or experiments were initiated or approved during this period under a Reactor Utilization Request (RUR); however, the following amendments were made to existing RURs in order to either improve the production of the desired isotopes or to improve the efficiency of the processes:

RUR 282, AS AMENDED

Osmium Irradiation

This RUR amendment authorizes the irradiation of up to 75.0 mg of enriched osmium (enriched in Os-189) in the flux trap region of the reactor for research and development activities.

RUR 435, AS AMENDED

Molybdenum Oxide Irradiation

This RUR amendment authorizes the use of quartz as secondary encapsulation for irradiating natural molybdenum oxide in the graphite reflector region of the reactor in support of product development activities.

RUR 440, AS AMENDED

Irradiation of Tellurium Oxide

This RUR amendment authorizes the use of single aluminum encapsulation for the irradiation of tellurium dioxide in the graphite reflector region of the reactor in support of product development activities.

In addition, MURR continued to participate in molybdenum-99 research and development, and production activities by performing test and production irradiations and target processing using various methodologies.

Each of these tests or experiments has a written safety evaluation on file and a 10 CFR 50.59 Screen, if applicable, to assure that the test or experiment is safe and within the limits of the Technical Specifications. The safety evaluations have been reviewed by the Reactor Manager, Reactor Health Physics Manager, Assistant Reactor Manager-Physics, and the Reactor Safety Subcommittee, as applicable.

SECTION VI

SPECIAL NUCLEAR MATERIAL AND REACTOR PHYSICS ACTIVITIES

January 1, 2018 through December 31, 2018

INSPECTIONS

The U.S. Nuclear Regulatory Commission (NRC) conducted one routine inspection reviewing Special Nuclear Material (SNM) activities. All records and activities were found to be in compliance with NRC rules and regulations. No violations were noted.

MISCELLANEOUS SNM SHIPMENTS

Four unirradiated low-enriched uranium (LEU) targets were shipped to the MARIA Reactor in Poland on behalf of Northwest Medical Isotopes, LLC, for molybdenum-99 research.

REACTOR CHARACTERISTICS MEASUREMENTS

Sixty-three refueling evolutions were completed in 2018. Reactor core excess reactivity verifications were performed for each refueling. The largest measured excess reactivity was 3.88%. MURR Technical Specification (TS) 3.1.a requires reactor core excess reactivity above reference core condition to be less than 9.8%.

REACTIVITY MEASUREMENTS

Differential blade-worth measurements of seven shim control blades were performed following either a planned replacement of a control blade or characterization of the burn-in effect of a new control blade.

Six reactivity measurements were performed to determine the reactivity worth of all samples, including the sample holder, loaded in the flux trap region.

One reactivity measurement was performed to determine the reactivity worth of a newly fabricated flux trap region sample holder.

Three reactivity measurements were performed to determine the reactivity worth of the small flux trap tube sample holder loaded with the maximum number of samples in order to confirm that their reactivity worth is less than the TS movable experiment limit.

Two reactivity measurements were performed to investigate the reactivity worth impact of a target can design change as well as target mass changes of iridium samples irradiated in the flux trap region.

SECTION VII

RADIOACTIVE EFFLUENT

January 1, 2018 through December 31, 2018

TABLE 1
SANITARY SEWER EFFLUENT

Descending Order of Activity Released for Nuclide Totals > 1.000E-05 Ci

Nuclide	Activity (mCi)
H-3	2.52E+02
S-35	1.33E+01
Co-60	9.46E+00
Zn-65	4.56E+00
Cr-51	2.59E+00
Ca-45	1.60E+00
P-32	1.54E+00
Tc-99m	7.25E-01
Fe-59	6.78E-01
Sb-124	5.57E-01
Mo-99	4.37E-01
Cd-109	2.17E-01
Sc-46	2.14E-01
Mn-54	2.10E-01
Na-24	1.07E-01
Pd-109	1.02E-01
Co-58	4.12E-02
I-124	3.64E-02
Lu-177	2.99E-02
Sb-122	1.60E-02
I-131	1.15E-02
Total H-3	**2.52E+02**
Total Other	**3.64E+01**

Sanitary Sewer Effluents are in compliance with 10 CFR 20.2003, "Disposal by Release into Sanitary Sewerage."

TABLE 2
STACK EFFLUENT

Ordered by % Technical Specification Limit

Isotope	Average Concentration (μCi/ml)	Total Release (μCi)	TS Limit Multiplier	% TS
Ar-41	2.28E-06	1.07E+09	350	65.1667
I-131	1.93E-12	9.00E+02	1	0.9628
H-3	1.34E-08	6.29E+06	350	0.0384
Xe-131m	7.67E-08	3.58E+07	350	0.0110
Co-60	8.26E-16	3.86E-01	1	0.0017
Os-191	1.29E-14	6.01E+00	1	0.0006
C-14*	2.06E-11	9.36E+03	1	0.0001
I-133	2.20E-13	1.03E+02	350	0.0001

* C-14 activity is calculated based on the ratio of argon to nitrogen in the air and the (n, p) reaction cross sections for the activation of N-14 to C-14.

Isotopes observed at < 0.0001% Technical Specification (TS) limit are not listed.

Stack Flow Rate = ~30,000 cfm

Stack effluent releases are in compliance with University of Missouri-Columbia Research Reactor, Renewed Facility Operating License No. R-103 TS.

SECTION VIII

ENVIRONMENTAL MONITORING AND HEALTH PHYSICS SURVEYS

January 1, 2018 through December 31, 2018

Environmental samples are collected two times per year at eight locations and analyzed for radioactivity. Soil and vegetation samples are also taken at each location. Water samples are taken at three locations while subsurface soil samples are taken at six locations each period. Analytical results are shown in Tables 1 and 2.

Table 3 lists the radiation doses recorded by the environmental monitors deployed around MURR in 2018. All doses fluctuate around background except monitor numbers 8, 9, and 45. These monitors are located at or near loading dock areas where packages containing radioactive material are loaded or traverse prior to being placed on transport vehicles. The doses recorded by these monitors are considered to be the result of exposure to packages in transit. The environmental monitoring program confirms that minimal environmental impact exists from the operation of the MURR facility.

The number of radiation and contamination surveys performed each month is provided in Table 4.

TABLE 1
SUMMARY OF ENVIRONMENTAL SET 93 - SPRING 2018

Detection Limits*

Matrix	Alpha	Beta	Gamma	Tritium
Vegetation	1.45 pCi/g	8.86 pCi/g	1.65 pCi/g	6.25 pCi/mL
Soil	0.00 pCi/g	4.66 pCi/g	0.66 pCi/g	N/A
Water	0.62 pCi/L	4.90 pCi/L	190.5 pCi/L	7.98 pCi/mL
Subsurface Soil	0.72 pCi/g	5.53 pCi/g	0.61 pCi/g	N/A

Activity Levels - Vegetation

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
1V93	<MDA	33.11	<MDA	<MDA
2V93	<MDA	20.52	<MDA	<MDA
3V93	<MDA	12.96	<MDA	<MDA
4V93	<MDA	30.95	2.19	<MDA
5V93	<MDA	40.67	<MDA	<MDA
6V93	<MDA	31.67	<MDA	<MDA
7V93	<MDA	29.15	<MDA	<MDA
10V93	<MDA	30.95	<MDA	<MDA

TABLE 1 (Cont'd)
SUMMARY OF ENVIRONMENTAL SET 93 - SPRING 2018

Activity Levels - Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
1S93	1.87	22.86	3.36
2S93	0.93	16.74	2.60
3S93	1.25	16.56	2.66
4S93	0.62	11.40	2.43
5S93	0.78	22.50	3.50
6S93	0.78	7.74	1.79
7S93	1.25	19.80	3.44
10S93	1.09	21.96	3.92

Activity Levels - Water

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
4W93	<MDA	<MDA	<MDA	<MDA
6W93	0.66	<MDA	<MDA	<MDA
10W93	<MDA	8.86	<MDA	<MDA

Activity Levels - Subsurface Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
E93	1.23	12.95	4.31
S93	<MDA	16.14	4.54
SW93	0.93	19.86	4.58
W93	<MDA	19.86	4.00
N93	0.77	18.80	3.60
NE93	0.77	17.20	4.20

* Gamma and tritium analyses are based on wet weights while alpha and beta are based on dry weights. HPGe spectral analyses were performed on any sample with a gamma activity greater than minimum detectable activity (MDA).

TABLE 2
SUMMARY OF ENVIRONMENTAL SET 94 - FALL 2018

Detection Limits*

Matrix	Alpha	Beta	Gamma	Tritium
Vegetation	0.00 pCi/g	6.90 pCi/g	1.60 pCi/g	4.90 pCi/ml
Soil	0.72 pCi/g	3.55 pCi/g	0.60 pCi/g	N/A
Water	0.62 pCi/L	4.47 pCi/L	186.0 pCi/L	5.64 pCi/ml
Subsurface Soil	0.72 pCi/g	3.95 pCi/g	0.53 pCi/g	N/A

Activity Levels - Vegetation

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
1V94	0.31	31.31	<MDA	<MDA
2V94	0.31	37.79	<MDA	<MDA
3V94	<MDA	80.26	<MDA	<MDA
4V94	<MDA	27.35	<MDA	<MDA
5V94	0.31	62.27	<MDA	<MDA
6V94	<MDA	27.71	<MDA	<MDA
7V94	<MDA	44.99	<MDA	<MDA
10V94	0.62	29.51	<MDA	<MDA

Activity Levels - Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
1S94	1.25	19.98	3.52
2S94	0.78	19.62	2.95
3S94	<MDA	25.02	2.24
4S94	0.93	21.06	2.06
5S94	0.93	21.06	2.81
6S94	0.78	16.74	2.36
7S94	1.09	21.96	2.00
10S94	1.25	32.39	3.43

TABLE 2 (Cont'd)
SUMMARY OF ENVIRONMENTAL SET 94 - FALL 2018

Activity Levels - Water

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
4W94	0.66	37.26	<MDA	<MDA
6W94	2.00	37.79	<MDA	<MDA
10W94	<MDA	21.11	<MDA	<MDA

Activity Levels - Subsurface Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
E94	0.77	17.73	4.11
S94	1.08	19.33	4.09
SW94	<MDA	21.10	4.52
W94	1.08	19.51	5.11
N94	1.54	23.76	4.57
NE94	<MDA	22.88	4.07

* Gamma and tritium analyses are based on wet weights while alpha and beta are based on dry weights. HPGe spectral analyses were performed on any sample with a gamma activity greater than MDA.

TABLE 3
ENVIRONMENTAL TLD SUMMARY

Badge Number	Direction from MURR	Meters from MURR Stack	1st Quarter (net mrem)	2nd Quarter (net mrem)	3rd Quarter (net mrem)	4th Quarter (net mrem)	Total (net mrem)
0*	Control	N/A	34	26	23	27	110
1*	Schnieders	N/A	-2	-1	3	2	2
2*	Schnieders	N/A	-2	-1	0	2	-1
3	W	34	-9	-4	-5	-3	-21
4	SW	55	-11	-2	-3	2	-14
5	ENE	118	-6	-7	-1	-2	-16
6	NNE	88	-3	2	2	6	7
7	ENE	57	-8	-2	2	-2	-10
8	SW	30	0	8	9	16	33
9	SSE	24	19	18	17	21	75
10	NE	143	-4	-5	-2	-1	-12
11	NNW	140	-2	-1	2	2	1
12	NE	289	-2	3	2	2	5
13	NNE	316	-7	-4	0	-1	-12
14	SSW	165	-2	-4	1	1	-4
15	S	73	-4	-4	0	0	-8
16	SE	104	-10	-3	0	-1	-14
17	E	299	-5	-3	-2	0	-10
18	NE	456	-8	-4	-2	-1	-15
19	NE	674	-13	-8	-8	-7	-36
20	NE	895	-6	-7	-7	-6	-26
21	SSE	252	-4	-2	-1	1	-6
22	SE	157	-11	-7	-5	-4	-27
23	NW	96	-6	0	1	3	-2
24	SSW	392	-7	-1	-2	2	-8
25	SW	442	-6	-5	-1	0	-12
26	SW	323	-9	-4	-1	-1	-15
27	SW	198	-9	-7	-3	-6	-25
28	WNW	255	0	0	2	1	3
29	NW	262	-6	-4	-3	-2	-15
30	N	339	-7	-5	-3	-4	-19
31	NNE	679	-3	-2	0	-1	-6
32	NNE	607	-6	-2	1	2	-5
33	ESE	585	-9	-6	-4	-4	-23
34	NE	619	-13	-3	-7	-7	-30
35	SSE	473	0	0	1	9	10
36	SE	443	-6	-3	-1	-2	-12
37	NE	736	-10	-8	-7	-4	-29
38	WNW	516	-3	2	1	1	1
39	W	534	-5	-4	0	-1	-10
40	N	532	-10	-6	-4	-2	-22
41	NE	158	-7	-5	-2	-3	-17
42	In Building	N/A	-5	-1	5	8	7
43	Spare	N/A	-4	1	1	2	0
44	SW	100	-5	-3	-3	1	-10
45	SE	94	3	3	9	4	19
46	SE	105	1	-2	0	0	-1

* The control monitors are approximately 50 miles SE of MURR, and gross values are shown.

TABLE 4
NUMBER OF FACILITY RADIATION AND CONTAMINATION SURVEYS

Month	Radiation	Surface Contamination*	Air Samples**	Radiation Work Permits	Receipt of Radioactive Materials
January	102	102	64	18	7
February	91	91	58	7	7
March	90	90	63	8	5
April	78	78	58	16	9
May	104	104	66	19	12
June	81	81	62	7	8
July	97	97	65	16	7
August	96	96	66	14	7
September	79	79	56	12	7
October	104	104	69	13	5
November	84	84	57	14	7
December	80	80	49	11	4
TOTAL	**1,086**	**1,086**	**733**	**155**	**85**

* In addition, general building contamination surveys are conducted each normal working day.
** Air samples include stack Ar-41, containment Ar-41, special I-131 monitoring, and hot cell entries.

Miscellaneous Note
During calendar year 2018, MURR shipped 180 cubic feet of low-level radioactive waste containing 12,900 mCi of activity.

SECTION IX

SUMMARY OF RADIATION EXPOSURE TO FACILITY STAFF, EXPERIMENTERS, AND VISITORS

January 1, 2018 through December 31, 2018

Total Personnel Dose (mrem) by Dosimetry Group

	AC/PRD	BCS	DO	FOE	HC	HP	IRR	NA	NS	NSP	OPS	PRO	QA	RES	RP	SH	SIL	TEE	WC	Total
January	64	0	0	0	237	203	1	13	1	50	1,759	18	47	0	0	89	147	0	29	2,658
February	75	0	0	0	206	170	0	5	0	16	1,685	13	43	0	1	90	154	1	24	2,483
March	53	0	0	2	161	239	8	0	2	33	2,015	23	31	7	27	84	182	14	8	2,889
April	58	0	0	19	160	156	0	3	18	24	2,387	22	66	0	19	107	312	2	168	3,521
May	51	0	0	0	196	185	0	3	28	7	1,861	10	37	0	1	121	242	2	5	2,749
June	46	0	0	8	233	153	0	0	16	80	2,005	9	52	0	3	137	279	10	46	3,077
July	73	7	3	24	178	342	0	5	38	16	2,133	30	60	14	2	143	366	3	15	3,452
August	101	10	2	16	263	263	0	29	32	28	2,098	6	70	7	11	91	254	15	3	3,299
September	127	0	4	8	175	214	0	0	10	99	1,584	23	84	7	9	48	249	8	0	2,649
October	139	0	1	231	195	165	0	1	0	19	1,671	31	74	0	0	81	227	2	0	2,837
November	68	0	0	57	194	203	0	1	4	51	3,081	41	80	4	6	86	200	0	0	4,076
December	64	0	0	70	206	115	0	1	3	64	1,916	16	70	0	1	55	143	0	3	2,727
Total for Year	**919**	**17**	**10**	**435**	**2,404**	**2,408**	**9**	**61**	**152**	**487**	**24,195**	**242**	**714**	**39**	**80**	**1,132**	**2,755**	**57**	**301**	**36,417**
Monthly Average	**77**	**1**	**1**	**36**	**200**	**201**	**1**	**5**	**13**	**41**	**2,016**	**20**	**60**	**3**	**7**	**94**	**230**	**5**	**25**	**3,035**
Highest WB (annual)	**239**	**7**	**5**	**134**	**973**	**683**	**4**	**12**	**36**	**82**	**1,340**	**103**	**158**	**9**	**30**	**285**	**1,564**	**29**	**20**	
High Extremity (annual)	**887**	**97**	**NM**	**622**	**2,649**	**1,034**	**25**	**747**	**36**	**421**	**2,590**	**488**	**1,465**	**71**	**714**	**1,259**	**2,421**	**126**	**25**	

AC/PRD-Analytical Chemistry/Production
BCS-Business & Central Services
DO-Director's Office
FOE-Shops & Support
HC-Hot Cell
HP-Health Physics
IRR-Irradiations
NA-Nuclear Analysis
NS-Neutron Scattering
NSP-NorthStar Partners
OPS-Operations
PRO-Isotope Processing
QA-Quality Assurance
RES-Research
RP-Radiopharmaceutical
SH-Shipping
SIL-Silicon
TEE-Trace Elemental Epidemiology
WC-Work Control

WB-Whole Body **NM**-Not Monitored

Analysis of personnel exposure levels indicates that exposures are significantly below the limits of 10 CFR 20.1201 and are generally maintained ALARA.
No significant personnel exposures occurred during this monitoring year.
Dosimetry services are provided by Mirion Technologies (except self reading dosimetry).