

February 19, 2020

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: Submittal of annual operating report for the University of Missouri-Columbia
Research Reactor as required by MURR Technical Specification 6.6.e

Enclosed is a copy of the 2019 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.

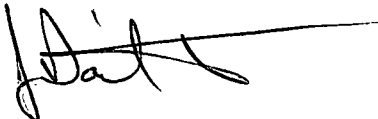
Sincerely,



Bruce A. Meffert
Reactor Manager

ENDORSEMENT:

Reviewed and Approved,



J. David Robertson
Reactor Facility Director

BAM/jlm

Enclosure

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

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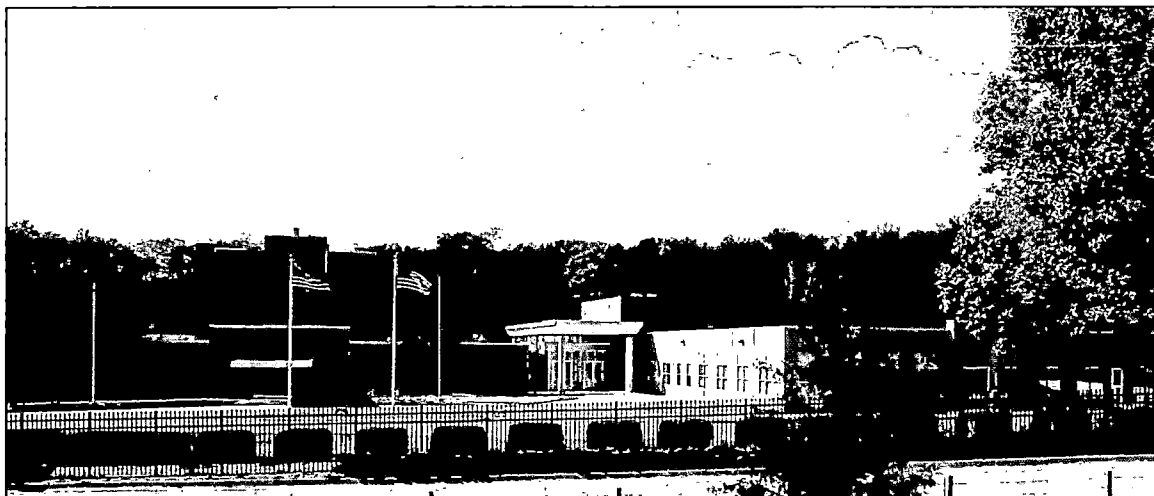


MURR[®]

**UNIVERSITY OF MISSOURI-COLUMBIA
RESEARCH REACTOR**

**REACTOR OPERATIONS
ANNUAL REPORT**

January 1, 2019 through December 31, 2019



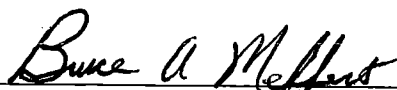
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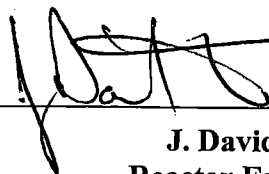
Compiled by the Staff of MURR

Submitted by:



**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, 2019 through December 31, 2019

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, materials science, plant science, nuclear medicine, radiation effects, radioisotope studies, targeted radiotherapy, and nuclear engineering; as well as research techniques including neutron activation analysis, neutron scattering, and gamma-ray imaging. 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 2019. Included within this report are changes to MURR Reactor Operations and Reactor 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), the National Nuclear Security Administration (NNSA), the National Science Foundation (NSF), and the NRC; 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 pneumatic actuator for anti-siphon system isolation valve V543A; (2) replacement of the pneumatic actuator for in-pool heat exchanger isolation valve V546A; (3) replacement of the drive gear assemblies for personnel airlock doors 277 and 276; (4) implementation of small flux trap sample holder enhancements; (5) replacement of the cabling and switches on the Flux-trap Irradiations Reactivity Safety Trip (FIRST) device; (6) replacement of the demineralizer tanks for the primary and pool coolant systems; (7) replacement of the diaphragms for primary coolant system heat exchangers outlet valves V540A and V540B; (8) installation of an improved control rod operate switch 1S4; (9) replacement of the drain collection system pump; (10) replacement of 2PS1 and 2PS2

power supplies; (11) refurbishment of the main air system with new compressors and dryers; (12) replacement of DPS-930 transmitter and indication; (13) replacement of TE-901D temperature channel transmitter; and (14) replacement of the servomotor for the regulating blade drive mechanism.

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, the compatibility of LEU fuel stored in HEU fuel locations – both in- and ex-pool, and the effects of the proposed LEU core on the lifetime of the beryllium reflector.

Reactor Operations management also wishes to commend the four individuals who received their Reactor Operator certifications and one individual who received his Senior Reactor Operator certification 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 licensed staff during normal and abnormal situations.

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SECTION I

REACTOR OPERATIONS SUMMARY

January 1, 2019 through December 31, 2019

The following table and discussion summarizes reactor operations during calendar year 2019.

Month	Full Power Hours	Megawatt Days	Full Power (% of total time)	Full Power (% of scheduled*)
January	665.20	277.25	89.4	100.1
February	610.09	254.27	90.8	101.7
March	680.35	283.53	91.4	102.4
April	629.45	262.38	87.4	98.0
May	660.89	275.49	88.8	99.5
June	649.95	270.91	90.3	101.2
July	656.18	273.52	88.2	98.7
August	684.25	285.20	92.0	103.0
September	649.18	270.59	90.2	101.1
October	657.76	274.16	88.4	99.0
November	654.27	272.69	90.9	101.9
December	648.18	270.21	87.1	97.5
Total for the Year	7,845.75	3,270.20	89.57	100.35

* 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 or year listed.

JANUARY 2019

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

On January 21, with all four shim control rods fully inserted into the reactor core, a deviation from MURR Technical Specification (TS) 3.3.a(1) occurred during performance of a reactor pre-startup checklist due to test jumpers being installed while electrical power was available to all four shim control rod drive mechanism (CRDM) electromagnets. For approximately 10 seconds, the anti-siphon system was considered inoperable while the reactor was, by definition, operating even though all four shim control rods were fully inserted and a reactor startup had not commenced. Inoperability of the anti-siphon system during reactor operation resulted in a deviation from TS 3.3.a(1), and Licensee Event Report No. 19-01 was submitted to the U.S. Nuclear Regulatory Commission (NRC) on January 31, 2019.

On January 27, with the reactor operating at 10 MW in the automatic control mode, the Lead Senior Reactor Operator (LSRO) observed no inward movement of control blade 'A' while completing a routine shimming evolution. A manual reactor scram was immediately initiated by the LSRO due to the inability to manually operate the shim control blades. The LSRO completed all immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," and verified all control blades were fully inserted. Subsequent investigation 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 Reactor Facility Director, in accordance with TS 6.6.c, 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. 19-02 was submitted to the NRC on February 1, 2019.

Major maintenance items for the month included: replacing the pneumatic actuator for anti-siphon system isolation valve V543A; replacing the pneumatic actuator for in-pool heat exchanger isolation valve V546A; replacing control rod operate switch 1S4; loading new de-ionizing bed 'O' and placing it on pool coolant system service; 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-202, "Measurement of Reactivity Worth of Movable Samples, RTP-6."

FEBRUARY 2019

The reactor operated continuously in February 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 pool coolant demineralizer system inlet filters; refurbishing the rod run-in monitoring system; completing Modification Record 18-04, "Reactor Pressure Vessel Cover Gasket;" replacing the drive gear assembly on personnel airlock door 277; replacing the air isolation valves to the sealing gaskets on personnel airlock doors 277/276 and motorized ventilation isolation doors 504/505; 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)."

MARCH 2019

The reactor operated continuously in March with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and one shutdown for physics measurement. 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 thermal column door limit switch; replacing the drive gear assembly on personnel airlock door 276; 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);" 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-202, "Measurement of Reactivity Worth of Movable Samples, RTP-6."

APRIL 2019

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

On April 28, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated upon discovery that shim control blade 'D' would not move in the inward direction while conducting the control blade operability TS 4.2.a surveillance. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Troubleshooting revealed a broken wire on the control rod 'D' drive mechanism inward relay. The wire was replaced and control rod 'D' drive mechanism was retested satisfactorily. Permission to restart the reactor was obtained from the Reactor Facility Director, in accordance with TS 6.6.c, and the reactor was subsequently returned to 10 MW operation. Inoperability of control blade 'D' during reactor operation resulted in a deviation from TS 3.2.a, and Licensee Event Report No. 19-03 was submitted to the NRC on May 10, 2019.

Major maintenance items for the month included: replacing the pool coolant demineralizer system inlet filters; loading new de-ionizing bed 'V' and placing it on pool coolant system service; replacing the reactor mechanical equipment room (Room 114) exhaust ventilation charcoal filters; replacing the 3-position control switch for cooling tower fan number 2; completing the biennial change-out of control blade 'A' offset mechanism; completing Modification Record 99-02, Addendum 1, "Small Flux Trap Sample Holder Enhancement;" 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)."

MAY 2019

The reactor operated continuously in May with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and one unscheduled/unplanned power reduction. NRC inspectors conducted a routine scheduled inspection of the Radiation Protection and Shipping Programs, a non-routine security inspection, and an inspection of activities under the MURR Type B Shipping Casks Quality Assurance Program.

On May 29, while attempting to load a movable experiment into the six-tube center test hole canister with the reactor operating at 10 MW in the automatic control mode, the experiment came into contact with the Flux-trap Irradiations Reactivity Safety Trip (FIRST) device and automatically initiated a FIRST reactor scram. Investigation revealed the FIRST device limit switches were set overly responsive. The switches were adjusted and retested satisfactorily using compliance procedure CP-36, "FIRST Scrams." Permission to restart the reactor was obtained from the LSRO, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: replacing the pool coolant demineralizer system inlet filters; loading new de-ionizing bed 'L' and placing it on primary coolant system service; loading new de-ionizing bed 'W' and placing it on pool coolant system service; completing Modification Record 08-04, Addendum 1, "Modify DI Supply to the Beamport Fill Lines;" replacing the cabling and switches on the Flux-trap Irradiations Reactivity Safety Trip (FIRST) device; and completing compliance procedure CP-26, "Containment Building Compliance Test."

JUNE 2019

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

On June 2, with the reactor operating at 10 MW in the automatic control mode, an automatic high power reactor scram was initiated and 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 nuclear instrument power range monitor channel 6 (PRM-6) chart recorder was off scale high with no spike noted on PRM-4 or PRM-5. Further investigation revealed that the AR15 DC amplifier in the PRM-6 processing drawer was faulty. The amplifier was replaced and retested satisfactorily using compliance procedure CP-34, "Nuclear Instrumentation Power Range - Channel 6," and nuclear instrumentation front panel trip and response checks. Permission to restart the reactor was obtained from the Reactor Manager, and the reactor was subsequently returned to 10 MW operation.

On June 24, with the reactor operating at 10 kW in the manual control mode, shim control blade 'B' dropped off its electromagnet during a shimming evolution. The reactor was subsequently shut down by manual scram. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Control rod drive mechanism (CRDM) 744 was replaced with CRDM 317. CRDM 317 was tested satisfactorily using compliance procedure CP-10, "Rod Drop Times," and pre-startup shim blade movement checks. Permission to restart the reactor was obtained from the Reactor Manager, and the reactor subsequently attained 10 MW operation.

Major maintenance items for the month included: replacing AR15 DC amplifier in the nuclear instrument PRM-6 processing drawer; completing Modification Record 19-01, "Replacement of Primary and Pool Coolant System Demineralizer Tanks;" and completing the annual facility emergency preparedness drill.

JULY 2019

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

On July 1, with the reactor shutdown for scheduled, routine maintenance, a deviation from TS 3.4.b occurred during performance of scheduled maintenance on two shim CRDMs and unscheduled electrical preventative maintenance on two breakers. For approximately 10 minutes, the reactor containment building ventilation system's automatically-closing doors were inoperable due to the doors' breakers being open while maintenance was being performed on the CRDMs, causing the condition of the reactor to be shutdown per TS 1.27 but not secured per TS 1.26. Inoperability of the automatically-closing doors while the reactor was not secured resulted in a deviation from TS 3.4.b, and Licensee Event Report No. 19-04 was submitted to the NRC on July 12, 2019.

On July 29, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated upon discovery that the regulating blade drive mechanism was not operating. All immediate and subsequent actions of reactor emergency procedures REP-2, "Reactor Scram," and REP-7, "Rod Position Indication System Failure," were completed. The drive chain for the rod position indication encoder on the regulating blade drive mechanism had disengaged from a sprocket and became bound in another sprocket. The drive chain was replaced, and its sprockets re-aligned. The "Regulating Blade Operation And Rod Run-In Function Test" portion of form FM-57, "Long Form Startup Checklist," was completed satisfactorily as a pre-startup final test of proper operation of the regulating blade drive mechanism and its rotary limit switch assembly. Permission to restart the reactor was obtained from the Reactor Facility Director, in accordance with TS 6.6.c, and the reactor was subsequently returned to 10 MW operation. Failure of the regulating blade and the regulating blade $\leq 10\%$ withdrawn rod run-in function during reactor operation resulted in deviations from TSs 3.2.a and 3.2.f.8, and Licensee Event Report No. 19-05 was submitted to the NRC on August 7, 2019.

On July 31, with the reactor operating at 10 MW in the automatic control mode, a low primary coolant pressure reactor scram was automatically initiated. Upon investigation of the reactor mechanical equipment room (Room 114), which

contains a large portion of the cooling equipment for the reactor, primary coolant was found leaking from primary coolant system heat exchanger HX-503A outlet valve V540A. Valve V540A was isolated, and the affected section of the primary coolant system was drained to allow for removal and inspection of the bonnet, which revealed that the valve diaphragm had ruptured. The diaphragm was replaced, and the system was refilled and leak tested satisfactorily. Permission to restart the reactor was obtained from the LSRO, and the reactor was subsequently returned to 10 MW operation following a reactor refuel.

Major maintenance items for the month included: replacing primary coolant system heat exchanger HX-503A outlet valve V540A diaphragm; replacing the pool coolant demineralizer system inlet filters; completing Modification Record 19-02, "Modification of the Laboratory Building Configuration;" replacing control rod operate switch 1S4; 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)."

AUGUST 2019

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: loading new de-ionizing bed 'S' and placing it on pool coolant system service; 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);" 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);" replacing the drain collection system pump; and completing Modification Record 19-03, "Replacement of 2PS1 and 2PS2 Power Supplies."

SEPTEMBER 2019

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

Major maintenance items for the month included: replacing primary coolant system heat exchanger HX-503B outlet valve V540B diaphragm; flooding beamport 'D' with super demineralized water; filling beamport 'D' with helium; 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 completing Modification Record 19-04, "Main Air System."

OCTOBER 2019

The reactor operated continuously in October with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and one unscheduled/unplanned power reduction.

On October 15, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated to investigate abnormal temperature indications in the primary and pool coolant systems. Compliance procedures CP-8A, "Primary Coolant System RTDs 901A/B," and CP-8C, "Pool Coolant System RTDs 901C/D," were performed satisfactorily to recalibrate three temperature channels. Permission to restart the reactor was obtained from the Reactor Manager, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: completing the biennial change-out of control blade 'C' 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 completing Modification Record 19-05, "Replacement of DPS-930 Transmitter and Indication."

NOVEMBER 2019

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

On November 18, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated to investigate an abnormal pool coolant system temperature indication. The transmitter for temperature element TE-901D channel was replaced, and compliance procedure CP-8C, "Pool Coolant System RTDs 901C/D," was performed satisfactorily as post-maintenance testing. Permission to restart the reactor was obtained from the Reactor Manager, and the reactor was subsequently returned to 10 MW operation.

Major maintenance items for the month included: replacing the transmitter for temperature element TE-901D channel.

DECEMBER 2019

The reactor operated continuously in December with the following exceptions: five shutdowns for scheduled maintenance and/or refueling and three unscheduled/unplanned power reductions.

On December 10, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated upon discovery that the regulating blade drive mechanism was not operating. All immediate and subsequent actions of reactor emergency procedures REP-2, "Reactor Scram," and REP-7, "Rod Position Indication System Failure," were completed. The drive chain for the rod position indication encoder on the regulating blade drive mechanism had disengaged from a sprocket and became bound in another sprocket. The drive chain was replaced, and its sprockets re-aligned. The "Regulating Blade Operation And Rod Run-In Function Test" portion of form FM-57, "Long Form Startup Checksheet," was completed satisfactorily as a pre-startup final test of proper operation of the regulating blade drive mechanism and its rotary limit switch assembly. Permission to restart the reactor was obtained from the Acting Reactor Facility Director, in accordance with TS 6.6.c, and the reactor was subsequently returned to 10 MW operation. Failure of the regulating blade and the regulating blade $\leq 10\%$ withdrawn rod run-in function during reactor operation resulted in deviations from TSs 3.2.a and 3.2.f.8, and Licensee Event Report No. 19-06 was submitted to the NRC on December 17, 2019.

On December 12, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated upon discovery that the regulating blade drive mechanism chain was rubbing on the drive housing. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Material was removed from the housing to allow increased clearance for the chain, and the entire drive assembly was

rotated several degrees. Permission to restart the reactor was obtained from the LSRO, and the reactor was subsequently returned to 10 MW operation following a reactor refuel.

On December 19, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated upon discovery that the regulating blade drive mechanism was not operating. All immediate and subsequent actions of reactor emergency procedures REP-2, "Reactor Scram," and REP-7, "Rod Position Indication System Failure," were completed. Troubleshooting revealed the regulating blade drive mechanism servomotor had seized. A new servomotor was installed, and the regulating blade drive mechanism was bench tested satisfactorily. The "Regulating Blade Operation And Rod Run-In Function Test" portion of form FM-57, "Long Form Startup Checksheet," was completed satisfactorily as a pre-startup final test of proper operation of the regulating blade drive mechanism and its rotary limit switch assembly. Permission to restart the reactor was obtained from the Reactor Facility Director, in accordance with TS 6.6.c, and the reactor was subsequently returned to 10 MW operation. Failure of the regulating blade and the regulating blade $\leq 10\%$ withdrawn rod run-in function during reactor operation resulted in deviations from TSs 3.2.a and 3.2.f.8, and Licensee Event Report No. 19-07 was submitted to the NRC on December 23, 2019.

Major maintenance items for the month included: replacing the regulating blade drive mechanism servomotor; 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)."

SECTION II

MURR PROCEDURES

January 1, 2019 through December 31, 2019

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 73 revisions issued to the Reactor Operations procedures, forms, operator aids, policies, and charters. One new operator aid and one new procedure 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, policies, and charters:

Number	Name	Rev	Rev Date	Notes
AP-RO-105	MURR Operator Requalification Process	1	10/04/19	Minor Editorial
AP-RO-110	Conduct of Operations	27	10/04/19	Minor Editorial
AP-RO-115	Modification Records	13	05/02/19	Minor Editorial
AP-RR-001	Corrective Action Program	14	08/15/19	Minor Editorial
AP-RR-003	10 CFR 50.59 Evaluations	13	05/30/19	Minor Editorial
AP-RR-005	Security of "For Official Use Only" Information	13	10/17/19	Minor Editorial
AP-RR-008	Fingerprint-Based Criminal History Records Checks Program for Granting Unescorted Access and Access to Safeguards Information	4	11/12/19	Minor Editorial
AP-RR-011	Facility Access Process	22	10/04/19	Minor Editorial
AP-RR-033	Access Authorization Program for Irradiated Reactor Fuel in Transit	3	10/28/19	Minor Editorial
EX-RO-105	Reactor Irradiation Experiments	25	10/17/19	Minor Editorial
EX-RO-110	Pneumatic Tube System	2	06/26/19	Minor Editorial
EX-RO-120	Beamport 'A' Operation	16	10/22/19	Minor Editorial
EX-RO-121	Beamport 'B' Operation	16	10/22/19	Minor Editorial
EX-RO-122	Beamport 'C' Operation	17	10/22/19	Minor Editorial
EX-RO-123	Beamport 'D' Operation	16	10/22/19	Minor Editorial
EX-RO-124	Beamport 'E' Operation	17	10/22/19	Minor Editorial
EX-RO-125	Beamport 'F' Operation	18	10/22/19	Minor Editorial
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	8	02/11/19	Minor Editorial
FM-02	MURR Access Request Form	28	10/17/19	Minor Editorial

Number	Name	Rev	Rev Date	Notes
FM-03	Sponsor List	29	05/01/19	Minor Editorial
FM-03	Sponsor List	30	07/24/19	Minor Editorial
FM-04	Visitor/After-Hours Access Request Form	17	05/01/19	Minor Editorial
FM-11	Reactor Shutdown Checksheet	8	02/05/19	Minor Editorial
FM-15	10 CFR 50.59 Qualified Reviewers List	24	06/20/19	Minor Editorial
FM-19	Unscheduled/Unplanned Power Reduction Report	8	05/02/19	Minor Editorial
FM-43	Nuclear and Process Data Sheet	28	02/05/19	Minor Editorial
FM-56	Reactor Routine Patrol	25	03/08/19	Minor Editorial
FM-56	Reactor Routine Patrol	26	10/22/19	Minor Editorial
FM-57	Long Form Startup Checksheet	31	02/05/19	Minor Editorial
FM-57	Long Form Startup Checksheet	32	10/22/19	Minor Editorial
FM-58	Short Form Startup Checksheet	16	10/22/19	Minor Editorial
FM-127	MURR Irradiations Encapsulation Evaluation Worksheet	5	09/11/19	Minor Editorial
FM-136	MURR Aluminum Sample Welding Qualification Record	1	01/09/19	Cover Page
FM-136	MURR Aluminum Sample Welding Qualification Record	2	07/24/19	Minor Editorial
FM-140	MURR Access Inactivation Form	6	02/11/19	Minor Editorial
FM-143	1/M Graph	4	10/04/19	Minor Editorial
FM-152	Fuel Element Inspection	5	11/12/19	Minor Editorial
FM-200	Authorization to Conduct Background Investigation for Unescorted Access to MURR	3	02/28/19	Minor Editorial
FM-200	Authorization to Conduct Background Investigation for Unescorted Access to MURR	4	10/04/19	Minor Editorial
IRR-PSO-100	Scheduling Flux Trap Tubes	10	10/28/19	Minor Editorial
IRR-PSO-110	Target Encapsulation	14	05/02/19	Minor Editorial
LCC-001	Reactor Advisory Committee Charter	2	03/22/19	Minor Editorial
LCC-002	Reactor Safety Subcommittee Charter	2	02/28/19	Minor Editorial
LCC-003	Isotope Use Subcommittee Charter	2	03/22/19	Minor Editorial
LCC-004	Reactor Safety Procedure Review Subcommittee Charter	2	02/28/19	Minor Editorial
LCC-005	Isotope Use Procedure Review Subcommittee Charter	2	02/28/19	Minor Editorial
LCC-006	Reactor Action Subcommittee Charter	1	02/28/19	Minor Editorial
OA-3	Beamport and Pool Overflow Loop Seals	11	08/08/19	Full Review
OA-28	Pressure Vessel Cover Installation	0	02/05/19	New Operator Aid
OP-RO-210	Reactor Startup - Normal	22	01/09/19	Minor Editorial
OP-RO-211	Reactor Startup - Hot	17	01/09/19	Minor Editorial
OP-RO-211	Reactor Startup - Hot	18	08/08/19	Minor Editorial
OP-RO-212	Reactor Startup - Recovery from Temporary Power Reduction	16	01/09/19	Minor Editorial
OP-RO-220	Reactor Shutdown or Power Reduction	12	01/09/19	Minor Editorial
OP-RO-220	Reactor Shutdown or Power Reduction	13	08/08/19	Minor Editorial
OP-RO-250	In-Pool Fuel Handling	21	06/26/19	Minor Editorial
OP-RO-250	In-Pool Fuel Handling	22	10/17/19	Minor Editorial
OP-RO-310	Nuclear Instrumentation - Signal Processor #1	14	01/09/19	Minor Editorial
OP-RO-311	Nuclear Instrumentation - Signal Processor #2	15	01/09/19	Minor Editorial
OP-RO-330	Nuclear Instrumentation - Wide Range Monitor	13	08/08/19	Minor Editorial

Number	Name	Rev	Rev Date	Notes
OP-RO-340	Nuclear Instrumentation Adjustment	13	01/09/19	Minor Editorial
OP-RO-410	Primary Coolant System	17	10/04/19	Minor Editorial
OP-RO-480	Secondary Coolant System	24	05/02/19	Minor Editorial
OP-RO-530	Demineralized Water Supply System	20	08/08/19	Minor Editorial
OP-RO-741	Waste Tank System Operation	25	05/02/19	Minor Editorial
POL-20	Special Nuclear Materials Manual	5	01/28/19	Minor Editorial
RM-RO-400	Waste Tank System Filter Replacement	10	03/22/19	Cover Page
RP-RO-100	Fuel Movement	14	10/04/19	Minor Editorial
RP-RO-200	Measurement of Differential Worth of a Shim Blade, RTP-11 (D)	9	10/04/19	Minor Editorial
RP-RO-300	Receipt, Inspection and Accounting of Unirradiated Fuel	7	06/17/19	Minor Editorial
SM-RO-011	Beryllium Reflector Replacement	7	09/10/19	Minor Editorial
SM-RO-110	Venting Primary, Pool, and Secondary Coolant System Transmitters	0	10/31/19	New Procedure
SM-RO-200	Manual Operation of Airlock Doors 276 and 277	7	06/20/19	Minor Editorial
SM-RO-500	Replacement of Flux Trap Irradiations Reactivity Safety Trip Support Rig	3	10/28/19	Minor Editorial
SM-RO-660	Replacement of Inner and Outer Pressure Vessels	7	01/28/19	Minor Editorial

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 15 revisions issued to the Emergency Plan implementing procedures, forms, and operator aids. All 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-002	Emergency Responsibilities	7	07/12/19	Minor Editorial
EP-RO-004	Fire	8	07/12/19	Minor Editorial
EP-RO-006	Radiological Emergency	10	07/12/19	Cover Page
EP-RO-008	Threat To Security	4	07/12/19	Minor Editorial
EP-RO-008	Threat To Security	5	10/02/19	Minor Editorial
EP-RO-013	Facility Evacuation	11	07/12/19	Minor Editorial
EP-RO-015	Emergency Notifications	19	07/12/19	Minor Editorial
EP-RO-017	Emergency Air Sampling	10	07/12/19	Cover Page
EP-RO-018	Emergency Radiation Exposure	9	07/12/19	Cover Page
EP-RO-019	Emergency Dosimeters	5	07/12/19	Cover Page
FM-104	Emergency Call List	38	07/12/19	Minor Editorial
FM-104	Emergency Call List	39	10/02/19	Minor Editorial
FM-104	Emergency Call List	40	10/18/19	Minor Editorial
OA-20	Emergency Equipment	26	07/12/19	Minor Editorial
REP-RO-100	Reactor Emergency Procedures	25	10/28/19	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 161 revisions issued to the radiological control, byproduct materials shipping, and preparation for shipping byproduct material procedures, forms, operator aids, policies, and plans. Two new forms and five new procedures were issued, while one form was 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, operator aids, policies, and plans:

Number	Name	Rev	Rev Date	Notes
ACG-NAA-218	Cleaning Options for High Purity Materials Processing	9	05/01/19	Cover Page
ACG-NAA-221	High Purity Materials Analysis Flux Monitor Measurement	11	05/01/19	Cover Page
ACG-NAA-222	Neutralization and Disposal of Waste Acids From High Purity Materials Processing	5	05/29/19	Cover Page
AP-HP-115	Iodine 131 Bioassay	5	08/15/19	Minor Editorial
AP-HP-117	MURR Initial Radiation Worker Training Program	16	10/04/19	Minor Editorial
AP-HP-119	High Radiation Area Access	11	05/01/19	Minor Editorial
AP-HP-122	Material License Projects Quarterly Review	12	07/24/19	Minor Editorial
AP-HP-123	Visitor Dosimetry - Reception Desk	14	05/01/19	Cover Page
AP-HP-123	Visitor Dosimetry - Reception Desk	15	12/09/19	Minor Editorial
AP-HP-124	Ordering and Assigning Dosimetry	2	07/26/19	Minor Editorial
AP-HP-129	Hot Cell HC-01 Control	18	05/01/19	Minor Editorial
AP-HP-135	Project Authorization Requests	2	05/31/19	Cover Page
AP-RR-013	Access Authorization Program for Category 1 and/or Category 2 Quantities of Radioactive Material	4	02/11/19	Minor Editorial
AP-SH-004	Notification for Category 2 Material per Export License PXB143.01	2	05/29/19	Minor Editorial
BPB-SH-020	Receipt Inspection Of Type B Shipping Package	9	05/29/19	Minor Editorial
BPB-SH-023	Type B Equipment Calibration	8	05/29/19	Cover Page
BPB-SH-024	Type B USA/0697/B(U)-96 (F-458 Series) Packaging of Type B Radioactive Material	10	05/10/19	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)	8	05/01/19	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)	9	05/07/19	Minor Editorial
BPB-SH-030	Receipt Inspection of New SAFKEG LS/HS Type B Byproduct Material Shipping Packages	4	05/01/19	Minor Editorial
BPB-SH-031	Bubble Testing Acceptance for Croft SAFKEG-HS Insert Model No. 3987	0	06/07/19	New Procedure
BP-SH-005	Packaging of Type A Radioactive Material Using SAFKEG-LS and SAFKEG-HS	3	07/24/19	Cover Page
BP-SH-012	DOT-7A Package Certification	9	05/29/19	Cover Page

Number	Name	Rev	Rev Date	Notes
BP-SH-013	Packaging of Type A Radioactive Material Using USA DOT 7A 5- to 30-Gallon Resuable Drum	12	05/01/19	Cover Page
BP-SH-014	Packaging Type A Radioactive Material in an Overpack	9	05/01/19	Minor Editorial
BP-SH-018	Packaging of Type A Radioactive Material Using USA DOT 7A NorthStar Medical Radioisotopes Package	8	05/29/19	Cover Page
BP-SH-018	Packaging of Type A Radioactive Material Using USA DOT 7A NorthStar Medical Radioisotopes Package	9	11/12/19	Minor Editorial
BP-SH-052	Radioactive Material Shipment Package Documentation and Labeling	19	05/29/19	Minor Editorial
FM-26	MURR Radiation Worker Training Quiz	16	05/01/19	Cover Page
FM-27	In-House Radioactive Shipping Request Form	20	05/01/19	Cover Page
FM-29	Dosimetry Request Packet	11	05/01/19	Cover Page
FM-54	Report of Personnel Contamination	11	05/01/19	Cover Page
FM-69	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A 5- to 30-Gallon Resuable Drum	15	05/01/19	Cover Page
FM-91	Declaration of Pregnancy	9	03/07/19	Cover Page
FM-94	Exclusive Use Shipment Controls	11	05/01/19	Cover Page
FM-107	Control Checksheet for Packaging Type A Radioactive Material in an Overpack	12	05/01/19	Cover Page
FM-109	Dy/Ho-166 Separation Data Sheet	4	05/01/19	Cover Page
FM-119	Health & Safety Standing Order Form	3	05/31/19	Cover Page
FM-125	Lutetium Chloride Process Notification	6	05/02/19	Cover Page
FM-126	Documentation of Compliance for DOT-7A Shipping Package	7	03/22/19	Cover Page
FM-137	Type B Qualified Shipper List	26	03/07/19	Minor Editorial
FM-137	Type B Qualified Shipper List	27	05/10/19	Minor Editorial
FM-137	Type B Qualified Shipper List	28	06/20/19	Minor Editorial
FM-137	Type B Qualified Shipper List	29	12/06/19	Minor Editorial
FM-139	Lutetium Chloride Radiation Protection Data Sheet C	8	05/02/19	Minor Editorial
FM-141	Control Checksheet for Packaging of Type A Radioactive Material Using SAFKEG-LS and SAFKEG-HS	6	07/24/19	Cover Page
FM-150	Statement of Training and Experience	7	01/09/19	Cover Page
FM-150	Statement of Training and Experience	8	05/30/19	Cover Page
FM-156	Required Documentation for Non-MURR Owned Type B Shipping Packages	7	08/13/19	Cover Page
FM-159	Control Checksheet for Health Physics Review of Radioactive Material Shipment Documentation	11	03/07/19	Minor Editorial
FM-159	Control Checksheet for Health Physics Review of Radioactive Material Shipment Documentation	12	10/17/19	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)	12	05/01/19	Minor Editorial
FM-164	Authorization for Use of North Office Addition West Passageway (C2001)	6	05/01/19	Minor Editorial

Number	Name	Rev	Rev Date	Notes
FM-164	Authorization for Use of North Office Addition West Passageway (C2001)	6	12/09/19	Obsoleted
FM-165	Mo-99 Radiation Protection Data Sheet A	4	08/15/19	Minor Editorial
FM-170	Control Checksheet for Packaging of Type A Radioactive Material Using USA DOT 7A Northstar Medical Radioisotopes Package	6	05/29/19	Cover Page
FM-173	Control Checksheet for Health Physics Review of Excepted (Limited) Quantity Radioactive Material Shipment	3	05/01/19	Cover Page
FM-179	Control Checksheet for Documentation and Labeling of Excepted (Limited) Quantity Radioactive Material Shipment	3	05/29/19	Cover Page
FM-201	Control Checksheet for Documentation and Labeling of NorthStar Radioactive Material Shipment	0	07/24/19	New Form
FM-201	Control Checksheet for Documentation and Labeling of NorthStar Radioactive Material Shipment	1	10/03/19	Minor Editorial
FM-202	Control Checksheet for Receipt Inspection of SAFKEG HS Model No. 3987 Type B Inserts	0	08/13/19	New Form
GMP-BR-216	Lu-177 Chloride Process Rework	3	10/02/19	Minor Editorial
GMP-BR-217	Lutetium Chloride Batch Record for Variable Concentration	11	05/21/19	Minor Editorial
GMP-BR-217	Lutetium Chloride Batch Record for Variable Concentration	12	10/02/19	Minor Editorial
GMP-BR-218	Terminal Sterilization of Lutetium Chloride	8	03/27/19	Cover Page
GMP-BR-218	Terminal Sterilization of Lutetium Chloride	9	10/02/19	Minor Editorial
GMP-BR-405	Mo-99 Production Apparatus Assembly	5	01/11/19	Minor Editorial
GMP-BR-501	Tellurium Dioxide Target Preparation Batch Record	6	01/28/19	Minor Editorial
GMP-BR-502	Sodium Iodide I-131 Solution Batch Record	6	04/15/19	Minor Editorial
GMP-MCE-124	Cleaning, Maintenance and Operation of HC-08 A/B	10	12/20/19	Minor Editorial
GMP-MCE-129	Operation and Maintenance for a Tuttnauer 3870 EA-B/L Electronic Tabletop Autoclave	6	01/02/19	Minor Editorial
GMP-MCE-129	Operation and Maintenance for a Tuttnauer 3870 EA-B/L Electronic Tabletop Autoclave	7	05/22/19	Minor Editorial
GMP-PRC-501	I-131 Pre- and Post-Process Checks	6	10/02/19	Minor Editorial
GMP-PRC-503	Transfer of Sodium Iodide I-131 Product to Shipping	3	06/21/19	Minor Editorial
GMP-PRC-508	I-131 Pre-Process System Dry Out	0	04/15/19	New Procedure
GMP-QC-254	Activity Concentration Verification of Lu-177 Chloride Solution	3	01/09/19	Minor Editorial
GMP-QU-011	Dose Calibrator Linearity Check - Decay Method	8	10/17/19	Minor Editorial
GS-RA-014	Use and Operation of the I-131 Production Facility Lifting Crane	3	05/01/19	Cover Page
GXP-APRT-208	Stability Study for Implementation of 8 Ci IN 4.0 mL Orders for Lu-177	0	06/11/19	New Procedure
GXP-EPRT-051	New and/or Retrospective Installation, Operation, and Performance Qualification or Requalification of the ALMO-1 Activity Meter	5	11/07/19	Minor Editorial
GXP-MCE-050	Operation of I-131 Can Opener	4	09/24/19	Minor Editorial

Number	Name	Rev	Rev Date	Notes
GXP-MCE-134	Cleaning, Maintenance and Operation of HC-02 A/B	5	11/19/19	Minor Editorial
HC-PSO-002	Hot Cell Preparation of Radioactive Material for Shipment	20	09/20/19	Minor Editorial
HC-PSO-003	Glove Box Preparation of Radioactive Material for Shipment	13	09/20/19	Minor Editorial
IC-HP-343	Calibration - Sodium Iodide Detector	7	03/07/19	Minor Editorial
IC-HP-346	Calibration - Lab Impex Smart MCA Continuous Air Monitor	6	05/31/19	Minor Editorial
IC-HP-346	Calibration - Lab Impex Smart MCA Continuous Air Monitor	7	11/12/19	Minor Editorial
IC-HP-349	Calibration - Lab Impex Stack Monitor - Particulate Channel	10	05/02/19	Cover Page
IC-HP-350	Calibration - Lab Impex Stack Monitor - Iodine Channel	7	05/02/19	Cover Page
IC-HP-352	Calibration - Lab Impex Stack Monitor - Flow Calibration	8	07/15/19	Minor Editorial
IC-HP-353	Calibration - Lab Impex Monitor - DP2001	4	03/07/19	Minor Editorial
IC-HP-356	Calibration - NOA Lab Impex Stack Monitor - Flow Calibration	4	10/17/19	Minor Editorial
IC-HP-357	Calibration - NOA Lab Impex Monitor - DP2001	3	05/02/19	Cover Page
IC-HP-367	Calibration - I-131 Bioassay Detection System	4	05/02/19	Cover Page
IC-HP-368	Calibration - ALMO-6 Radiation Monitoring Instrument	2	11/12/19	Minor Editorial
IC-HP-368	Calibration - ALMO-6 Radiation Monitoring Instrument	3	12/06/19	Minor Editorial
IC-HP-371	Calibration - Protean ASC-950 Swipe Counter	0	07/15/19	New Procedure
OA-8	Importing Authority Notification for the Netherlands	2	05/01/19	Minor Editorial
OA-26	NRC 749 Manual License Verification Report for Category 2 Materials	2	07/24/19	Minor Editorial
OP-HP-221	Environmental Sample - Analysis	9	03/07/19	Minor Editorial
OP-HP-222	Air Sampling - Containment Building Ar-41	10	05/02/19	Cover Page
OP-HP-222	Air Sampling - Containment Building Ar-41	11	12/06/19	Cover Page
OP-HP-228	Performing Iodine 131 Bioassay Measurements	7	08/15/19	Minor Editorial
OP-HP-231	Respirator Cleaning and Care	2	05/02/19	Minor Editorial
OP-HP-232	Respirator Storage, Maintenance and Inspection	2	07/24/19	Minor Editorial
OP-HP-233	Respirator Fit Test	2	07/15/19	Minor Editorial
OP-HP-233	Respirator Fit Test	3	11/12/19	Minor Editorial
OP-HP-234	Physical Exam for Respirator Program	2	05/02/19	Minor Editorial
OP-HP-234	Physical Exam for Respirator Program	3	07/24/19	Minor Editorial
OP-HP-235	Annual Respirator Training	2	05/02/19	Minor Editorial
OP-HP-236	Respirator Selection, Issuance, and Wearing	3	05/31/19	Minor Editorial
OP-HP-300	Receipt of Radioactive Material	12	05/10/19	Minor Editorial
OP-HP-305	Ordering or Transfer of Radioactive Materials	8	07/26/19	Cover Page
OP-HP-306	Health Physics Daily Facility Checks	11	10/17/19	Minor Editorial
OP-HP-350	Eberline Model PING 1A - Filter Change	9	05/02/19	Cover Page
OP-HP-353	Waste Tank Sample - Analysis	10	03/07/19	Minor Editorial
OP-HP-355	North Office Addition Waste Tank System Operation	6	03/22/19	Minor Editorial

Number	Name	Rev	Rev Date	Notes
OP-HP-358	Operation - Lab Impex Smart MCA Continuous Air Monitor Filter Change and Source Check	3	08/15/19	Minor Editorial
OP-HP-359	Bag-In Bag-Out for Changing Bank Exhaust Filters	1	07/26/19	Minor Editorial
OP-HP-365	Iodine 131 Processing Hot Cells Radiation Monitor (ALMO-6)	3	08/15/19	Minor Editorial
OP-HP-400	Gemstone Shipping Barrel Analysis	12	05/01/19	Cover Page
PLAN-130	10 CFR 37 Security Plan for the University of Missouri Research Reactor	2	01/17/19	Minor Editorial
POL-03	MURR Radiation Protection Program, February 2019	18	05/01/19	Minor Editorial
POL-03	MURR Radiation Protection Program, June 2019	19	10/16/19	Minor Editorial
POL-14	MURR Type B Shipping QA Program, University of Missouri-Columbia Research Reactor Facility, Shipping Quality Assurance Program for Type B Shipping Casks	7	07/24/19	Cover Page
POL-24	Iodine Bioassay Program	2	02/28/19	Cover Page
POL-25	MURR Respiratory Protection Program	4	06/20/19	Minor Editorial
POL-25	MURR Respiratory Protection Program	5	08/14/19	Minor Editorial
PRC-RRD-001	Preparing and Submitting a Radioactive Sample for Packaging	7	05/01/19	Cover Page
PRC-RRD-103	Remote Quartz Vial Washing	6	02/28/19	Cover Page
PRC-RRD-104	Miscellaneous Radiopharmaceutical Isotopes	6	05/01/19	Minor Editorial
PRC-RRD-108	Dissolving Ho-166 Nitrate	4	11/12/19	Minor Editorial
PRC-RRD-217	Dissolving Lu-177	4	05/01/19	Cover Page
PRC-RRD-218	Lu-177 Distribution	10	10/01/19	Cover Page
PRC-RRD-312	Gum Arabic Formation of Au Nanoparticles	2	06/10/19	Minor Editorial
PRC-RRD-313	Au Dissolution	7	07/24/19	Minor Editorial
PRC-RRD-319	Cd-115/In-115m Processing	2	07/24/19	Cover Page
PRC-RRD-420	Rh-105 Processing	9	08/15/19	Minor Editorial
PRC-RRD-424	Dissolving Platinum Powder	4	08/15/19	Minor Editorial
PRC-RRD-424	Dissolving Platinum Powder	5	12/06/19	Minor Editorial
QAB-SH-002	Procurement of Type B Packages	7	03/07/19	Cover Page
QAB-SH-003	Material Control for Type B Shipping Program	9	05/01/19	Cover Page
QAB-SH-004	Type B Program Vendor Qualification	9	03/07/19	Cover Page
QAB-SH-005	Type B QA Personnel Training	6	08/13/19	Cover Page
QAB-SH-008	Training for Type B Shipment Leak Test Performers	4	05/01/19	Cover Page
RCP-PSO-035	Material and Document Control Program for Carbon Adsorbers Used in Association with Radioiodine (I-131) Production	2	09/20/19	Minor Editorial
RCP-PSO-040	Preparation of I-131 Liquid Spill Kits	0	07/24/19	New Procedure
RM-HP-101	Stack Monitor Preventive Maintenance - Eberline Ping 1A	7	07/24/19	Minor Editorial
RM-HP-102	Stack Monitor Preventative Maintenance - Lab Impex	5	07/24/19	Minor Editorial
RP-HP-105	Transfer of Radioactive Material Within the Facility	14	12/09/19	Minor Editorial
RP-HP-120	Personnel Radioactive Contamination	15	07/26/19	Minor Editorial
RP-HP-130	Receipt of Unirradiated Fuel	10	05/01/19	Cover Page

Number	Name	Rev	Rev Date	Notes
RP-HP-135	Room 114 Entry - Self Monitored	9	10/17/19	Minor Editorial
RP-HP-135	Room 114 Entry - Self Monitored	10	12/09/19	Minor Editorial
SI-PSO-009	Operation of the Can Press	5	05/02/19	Minor Editorial
SV-HP-100	Reactor Chemistry Isotope Counter Trending and Investigative Level Determination	10	03/22/19	Minor Editorial
SV-HP-110	Environmental Sampling	10	05/02/19	Cover Page
SV-HP-115	Building Exhaust Stack Effluent - Tritium Monitoring	8	03/01/19	Cover Page
SV-HP-117	Secondary Coolant and Sump Water Analysis	8	05/02/19	Cover Page
SV-HP-119	Property Release	13	05/01/19	Cover Page
SV-HP-121	Building Exhaust Stack Effluent - Ar-41 Monitoring	9	05/02/19	Cover Page
TPZ-PSO-001	Receiving Gemstone Irradiation Shipping Drums	9	05/02/19	Cover Page
TPZ-PSO-002	Irradiation of Gemstone Irradiation Containers	10	05/02/19	Minor Editorial
TPZ-PSO-003	Loading Gemstone Shipping Drums	8	05/02/19	Cover Page
TSP-02	Transportation Security Plan	10	02/28/19	Cover Page
WM-SH-100	Radioactive Waste - Preparation and Storage	12	05/01/19	Minor Editorial
WM-SH-115	Iodine I-131 Waste Handling	4	05/01/19	Minor Editorial
WM-SH-115	Iodine I-131 Waste Handling	5	11/12/19	Minor Editorial
WM-SH-300	Exclusive Use Shipment of LSA or SCO Radioactive Waste	18	05/01/19	Cover Page

SECTION III

REVISIONS TO THE SAFETY ANALYSIS REPORT

January 1, 2019 through December 31, 2019

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.

From 2017 through 2019, a significant amount of effort was 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.

During calendar year 2019, 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 1 – THE FACILITY

Section 1.2.2, Figure 1.2 (page 1-6)

Update with Print No. 1145, Sheet 2 of 5, "Placement of Emergency Equipment – Grade Level," Rev. 39 dated 12/17/19

CHAPTER 5 – REACTOR COOLANT SYSTEMS

Section 5.5.2, first paragraph, first sentence (page 5-10)

Revise to read: "The water purification system consists of three stainless steel demineralizer tanks sized to hold up to 25.6 cubic feet (0.72 m³) of mixed bed resin."

CHAPTER 6 – ENGINEERED SAFETY FEATURES

Section 6.2.3.1, last paragraph (page 6-7)

Delete "k. 3/8-inch cooling water discharge line (from the experimental facilities);" and re-alphabetize the remainder of the list of services and lines through the seal trench

Section 6.2.3.3, Figure 6.2 (page 6-8)

Update with Print No. 1145, Sheet 2 of 5, "Placement of Emergency Equipment – Grade Level," Rev. 39 dated 12/17/19

CHAPTER 7 – INSTRUMENTATION AND CONTROL

Section 7.3.1, Table 7-3 (pages 7-12 to 7-14)

Revise No. 20 to read: “+24 Vdc Regulated Power Supply Drawer (2PS1)”

Revise No. 21 to read: “-24 Vdc Regulated Power Supply Drawer (2PS2)”

Delete “95 Pressurizer Water Level Indication Meter”

Section 7.6.5, seventh paragraph, first sentence (page 7-51)

Delete

Section 7.6.5, seventh paragraph, third sentence (page 7-51)

Revise to read: “This signal is sent to a paperless chart recorder on the instrument panel which provides the reactor operator with a continuous indication of pressurizer liquid level.”

CHAPTER 9 – AUXILIARY SYSTEMS

Section 9.4, Table 9-1 (page 9-11)

Add a line to read: “Room 299T HC-11”

Section 9.14.2 (page 9-23)

Revise, in its entirety, to read: “The main air system utilizes two compressors, designated the North and South Main Air Compressors, which supply the majority of the compressed air needs of the reactor facility. Both compressors have a discharge capacity of around 100 cfm. The two compressors automatically alternate roles between lead and lag unit each time the lead compressor cycles in order to equalize wear. When in the lead role, the compressor will automatically start when main air pressure reduces to a pre-established low setpoint and secure when main air pressure reaches a pre-established upper setpoint. If main air system pressure cannot be kept within this band and continues to lower, the lag compressor will start at a pre-established lower setpoint to aid the lead compressor. This condition also initiates the lag alarm circuit, which generates a local alarm and illuminates a local warning lamp. The lag compressor will receive a signal to stop at a lower setpoint than the lead as pressure rises. The control system also allows for a manual mode of control for either compressor. When in manual control, the selected compressor will cycle within a pre-established pressure band.”

CHAPTER 11 – RADIATION PROTECTION PROGRAM AND WASTE MANAGEMENT

Section 11.1.1.3, Table 11-9, last row, fourth column (page 11-11)

Revise to read: “18-25 ft³ of mixed bed resin stored in 4 steel tanks

Typically:

In Primary Service (1);

In Pool Service (1);

Depleted (2);”

SECTION IV

PLANT AND SYSTEM MODIFICATIONS

January 1, 2019 through December 31, 2019

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 18-04

Reactor Pressure Vessel Cover Gasket

This modification record documents replacement of the reactor pressure vessel cover gasket with a different material. The previous gasket material contained asbestos with a stainless steel ring surrounding it. The gasket material was utilized at MURR in this application for many years. However, due to significant issues related to the adverse health risks associated with asbestos, the material had become challenging to procure. The replacement gasket material is made of Ethylene Propylene Diene Monomer (EPDM). It has very good flexibility, superior resistance to water and steam, excellent resistance to heat, is inexpensive, and is readily available. This material was tested over a period of several weeks prior to being placed in service. The new material has performed as well or better than the previous asbestos material.

MODIFICATION RECORD 19-01

Replacement of Primary and Pool Coolant System Demineralizer Tanks

This modification record documents changes to the primary and pool coolant demineralizer (DI) system. The scope of this work included full replacement of the DI tanks (DI-200, DI-201, and DI-202), the resin storage tank, and necessary piping to connect the new tanks to the existing system. The original resin tanks were carbon steel, cylindrical tanks that had an internal rubber lining for corrosion resistance. They were sized to hold 12 cubic feet of mixed bed resin with each bed capable of removing 1,500 grains of hardness per day from water at a design flow rate of 50 gpm and a temperature not to exceed 140°F. The primary motive for implementing this modification was significant degradation of the existing resin tank rubber liners. Initial indications of this degradation were increased fouling of the primary and pool coolant inlet filters with abnormally dark residue and a reduction in DI system flow rate. Tank inspections confirmed that the inner rubber liner within the tanks was degraded and being introduced into the system. The tanks were replaced with a stainless steel design that do not require a liner. The new tanks are stainless steel pressure vessels with a design pressure of 100 psig and a nominal flow rate of 50 gpm. These tanks were designed to utilize the same or similar type of mixed bed resin that was previously in use at MURR. However, the new tanks are a larger diameter and therefore require a larger volume of resin to maintain the same depth and ion exchange capability. Although this resulted in a larger volume of resin, it should also result in a greater length of time between resin bed replacements. This should keep the volume of radioactive waste from the spent resin relatively constant over time. All tank internals are constructed of stainless steel with the exception of the gasket material. The piping that connects the tanks to the primary and pool coolant DI systems are constructed of aluminum or stainless steel.

MODIFICATION RECORD 19-03

Replacement of 2PS1 and 2PS2 Power Supplies

This modification record documents the replacement of low voltage power supplies 2PS1 and 2PS2. 2PS1 supplies +24-volt direct current (DC) power to both process instrumentation reactor safety system strings (green and yellow legs), the process instrumentation rod rod-in string (blue leg), both non-coincidence logic units (NCLUs) for the reactor safety system, both NCLUs for the rod run-in system, the wide range monitor nuclear instrument drawer, and the power range monitor channel 6 nuclear instrument drawer. 2PS2 provides -24-volt power to the wide range monitor nuclear instrument drawer and the power range monitor channel 6 nuclear instrument drawer. Failure of either the 2PS1 or the 2PS2 power supply will cause a reactor scram. In addition, both the 2PS1 and 2PS2 racks house a potentiometer and ammeter for adjusting shim control blade electromagnet current. However, 2PS1 and 2PS2 do not provide power to the electromagnets. Electromagnet power is provided by separate power supplies inside the associated reactor safety system trip actuator amplifiers. 2PS1 and 2PS2 are identical power supplies, and the analog power supply used was the General Electric Model 104B2731, which was capable of supplying up to 10 DC amperes in a range of 10-35 volts. The polarity of voltage is determined by the connection to the power supply output. MURR replaced the original power supplies due to obsolescence and potential equipment degradation. The replacement analog power supplies are the Acopian Model 24PT10 which are capable of supplying up to 10 DC amperes at 24+/- 0.5 volts. Again, MURR has designed both the new power supply racks to house a potentiometer and ammeter for adjusting shim control blade electromagnet current. No new failure modes are associated with the replacement Acopian Model 24PT10. One new improvement to the new racks is a protective shroud around the power supply input AC toggle switch which will reduce the potential for inadvertent actuation of the toggle switch that would cause a reactor scram.

MODIFICATION RECORD 19-04

Main Air System

This modification record documents significant enhancements to the main air system, which includes a change to the air compressor control system; as well as removal of the current air dryer, cyclone separator, Deltech filters, and associated piping and valves. These changes were made in order to increase the reliability and flexibility of the system. The air dryer and cyclone separator were replaced with two non-cycling refrigerated compressed air dryers, each with a capacity of 100 cfm. The air dryers are configured in parallel, which provides flexibility for dual operation or isolation of one dryer from the system. This portion of the modification has significance as it directly relates to prevention of recurrence of the condition that resulted in Licensee Event Report (LER) No. 17-06. Excessive moisture in the main air system caused the containment backup door air supply to freeze, allowing the door to close, which then reduced containment differential pressure and resulted in a violation of MURR Technical Specifications 3.4.b and 3.4.a(6). The air dryers are designed to provide reliable, dry air at an ISO 8573.1 quality class 4-5, which is more than suitable for the air systems at MURR. The lines that supply air to the backup door cylinders are exposed to potentially freezing conditions. The new design air dryers provides a higher quality of air providing greater assurance that a freezing condition will not recur in those lines. The existing Deltech filter was replaced by a set of two enhanced filters, designed to remove water, oil, and other particulate from the air. The filters are located immediately upstream and downstream of the air dryers. The first filter is designed to remove bulk particulate, oil, and water from the air prior to entering the dryers. The second filter is designed for coalescing fine water and oil aerosols and removing solid particulate to 0.01 microns. Both filters have a differential pressure gauge for easy identification of optimum filter cartridge replacement. Another significant change to the main air system is the control system of the main air compressors. The compressors will now automatically alternate roles as being the lead and lag unit. Under normal conditions, the compressor in the lead role will start at an established low pressure setpoint and then secure at a higher pre-determined setpoint. The compressor roles will then reverse such that the other compressor is in the lead position.

This cycle will repeat as long as the system is in automatic control in order to keep main air system pressure within that established band. A second lower pressure band has been established so that if main air system pressure reduces below a pre-determined low-low setpoint, the lag compressor will start along with the lead compressor. Once pressure reaches a pre-determined setpoint, the lag compressor will stop. When the lag alarm circuit is initiated, a local lag alarm will sound and a local lag lamp will illuminate. The alarm can be silenced with a local push button switch and the entire circuit reset once pressure rises above a pre-determined setpoint. In addition to these automatic features, the new air compressor control system has provisions to operate either compressor in manual mode without the control panel in service. When in manual mode, whichever compressor is selected will cycle in a pre-determined range of pressures.

MODIFICATION RECORD 19-05

Replacement of DPS-930 Transmitter and Indication

This modification record documents the replacement of the pressurizer level transmitter (DPS-930) and meter due to failing upscale. The transmitter is mounted next to the pressurizer and produces a DC milliamper signal proportional to the differential pressure created by a dry reference leg and a wet variable leg. The output signal is directed to a pressurizer liquid level indication in the instrument cabinet of the control room. The original equipment, a 0-60" H₂O GE transmitter (SN BK045001-001), sent a signal to a +20" to -30" analog meter and was replaced with a 0-150" H₂O Rosemount 1151DP differential pressure transmitter. Additionally, the pressurizer liquid level indication was transferred from the analog level meter in the instrument cabinet to the demineralizer flow paperless recorder as a third input and display to that recorder. This indication is normally buffered to provide a single digit inch liquid level indication but can be unbuffered when desired to provide an indication of one tenth of an inch. In order to facilitate this change, minor transmitter piping and mounting modifications were implemented but did not affect transmitter functionality. The former pressurizer liquid level indication meter has been temporarily covered pending future instrument cabinet modifications.

MODIFICATION RECORD 99-02, ADDENDUM 1

Small Flux Trap Sample Holder Enhancement

This addendum to Modification Record 99-02, "Six Barrel Flux Trap," documents enhancements to the small flux trap sample holder and sample canister. The previous configuration required extensive underwater manipulation to remove the sample canister from the aluminum rod and to remove the aluminum rod from the upper stainless steel section of the holder. This was a cumbersome process that resulted in additional time and dose to Reactor Operations and Reactor Health Physics (HP) personnel. Additionally, the aluminum rods were removed each week, which generated a substantial volume of radioactive waste and also consumed storage space within the reactor pool. The new design of the small flux trap sample holder consists of a single assembly, which is attached to the sample canister via a spring-loaded dovetail connection. A mating dovetail connection on the sample canister provides a secure attachment to the holder. The top end of the sample holder is spring-loaded to the inner connecting rod such that when the top is forced down against the spring, the dovetail end of the rod is exposed to mate with the canister connection. When the top is released, the force of the spring pushes the inner rod upward and retracts the dovetail connection into the outer tube. The top is then pinned in place, which prevents inadvertent actuation of the holder with the sample canister attached. A rope or wire is connected to the top of each holder and extends to the pool surface. This enhanced design provides the following key benefits: (1) it will significantly reduce the amount of radioactive waste generated from the weekly replacements of the aluminum connecting rods; (2) it will reduce the amount of temporary storage in the reactor pool; (3) it will reduce the disposal costs; and (4) it will reduce operator and HP dose since sample canister replacements will generally be performed under water.

MODIFICATION RECORD 08-04, ADDENDUM 1

Modify DI Supply to the Beamport Fill Lines

This modification record documents the reconfiguration of demineralized (DI) water piping in Room 101 (beamport floor) to supply DI water to both the beamport manifolds from existing DI supply lines coming through the utility entry water seal (seal trench). This modification also disconnected, capped, and abandoned the DI supply piping from the Room 114 pipe tunnel to Room 101 which had deteriorated and was leaking water into Room 101 when pressurized.

SECTION V

NEW TESTS AND EXPERIMENTS

January 1, 2019 through December 31, 2019

The following new and amended tests or experiments were approved during this period under a Reactor Utilization Request (RUR):

RUR 456

Holmium Complexed PLA Microspheres

This RUR authorizes the irradiation of up to 2.0 g of holmium-doped, synthetic polymer microspheres in the bulk pool region of the reactor for use in therapeutic applications.

RUR 456, AS AMENDED

Holmium Complexed PLA Microspheres

This RUR amendment authorizes the use of sealed aluminum as the primary outer encapsulation for this therapeutic application irradiation in either the bulk pool or graphite reflector regions of the reactor.

RUR 456, AS AMENDED

Holmium Complexed PLA Microspheres

This RUR amendment authorizes the use of high density polyethylene as the primary outer encapsulation for this therapeutic application irradiation in either the bulk pool or graphite reflector regions of the reactor.

RUR 219/234, AS AMENDED

Irradiation of Tellurium Metal

This RUR amendment authorizes an increase in the target mass of tellurium-122 (metal) from 20 mg to 30 mg for irradiation in the center test hole region of the reactor in support of product development activities.

RUR 209/219, AS AMENDED

Irradiation of Holmium Oxide

This RUR amendment authorizes an increase in the mass of holmium oxide from 200 mg to 1.0 g for irradiation in the center test hole 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 MURR 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, 2019 through December 31, 2019

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

One shipment containing 16.4 grams of low-enriched uranium (LEU) UO_2 was sent to Oregon State University on behalf of Northwest Medical Isotopes, LLC, for molybdenum-99 research.

REACTOR CHARACTERISTICS MEASUREMENTS

Fifty-eight refueling evolutions were completed in 2019. Reactor core excess reactivity verifications were performed for each refueling. The largest measured excess reactivity was 4.16%. 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 six shim control blades were performed either following a planned replacement of a control blade or to ensure compliance with TS 4.2.g.

One reactivity measurement was performed to determine the reactivity worth of a newly fabricated center test hole removable experiment sample canister.

Two reactivity measurements were performed to determine the reactivity worth of the small flux trap tubes of the center test hole removable experiment sample canister loaded with the maximum number of samples in order to confirm that their reactivity worth is less than the movable experiment limit of TS 3.8.c.

Five reactivity measurements were performed to estimate the total reactivity worth of the center test hole removable experiment sample canister, in addition to all samples loaded in the center test hole region of the reactor.

Two reactivity measurements were performed to investigate the reactivity worth of irradiation cans containing enriched molybdenum targets irradiated in the center test hole region of the reactor.

SECTION VII

RADIOACTIVE EFFLUENT

January 1, 2019 through December 31, 2019

TABLE 1
SANITARY SEWER EFFLUENT

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

Nuclide	Activity (mCi)
H-3	1.18E+02
Co-60	1.16E+01
S-35	1.14E+01
Zn-65	4.07E+00
Cd-109	2.72E+00
P-32	1.24E+00
Ca-45	1.22E+00
Fe-59	4.52E-01
Pd-109	4.01E-01
Sb-124	3.84E-01
Mn-54	3.48E-01
Cr-51	3.27E-01
Lu-177	2.04E-01
Sc-46	1.92E-01
W-181	1.46E-01
Tc-99m	1.12E-01
Mo-99	2.97E-02
Co-58	2.34E-02
Rh-105	1.31E-02
Total H-3	1.18E+02
Total Other	3.49E+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 ($\mu\text{Ci/ml}$)	Total Release (μCi)	TS Limit Multiplier	% TS
Ar-41	2.60E-06	1.17E+09	350	74.2682
I-131	3.27E-12	1.47E+03	1	1.6329
C-14*	2.34E-11	1.06E+04	1	0.7800
H-3	2.02E-08	9.10E+06	350	0.0577
Xe-131m	2.39E-07	1.08E+08	350	0.0341
Co-60	2.12E-15	9.55E-01	1	0.0042
Os-191	4.76E-14	2.14E+01	1	0.0024
I-133	3.21E-13	1.45E+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, 2019 through December 31, 2019

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 2019. All doses fluctuate around background except monitor number 9. This monitor is located near a loading dock area where packages containing radioactive material are loaded or traverse prior to being placed on transport vehicles. The doses recorded by this monitor 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 95 - SPRING 2019

Detection Limits*

Matrix	Alpha	Beta	Gamma	Tritium
Vegetation	0.00 pCi/g	6.91 pCi/g	1.55 pCi/g	5.22 pCi/mL
Soil	0.72 pCi/g	3.55 pCi/g	0.62 pCi/g	N/A
Water	0.78 pCi/L	5.61 pCi/L	191.25 pCi/L	5.19 pCi/mL
Subsurface Soil	0.72 pCi/g	3.96 pCi/g	0.58 pCi/g	N/A

Activity Levels - Vegetation

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
1V95	0.61	45.93	<MDA	<MDA
2V95	<MDA	24.14	<MDA	<MDA
3V95	<MDA	24.14	<MDA	<MDA
4V95	0.62	32.07	<MDA	<MDA
5V95	<MDA	47.21	<MDA	<MDA
6V95	0.31	30.99	<MDA	<MDA
7V95	1.25	32.07	<MDA	<MDA
10V95	0.62	46.13	<MDA	<MDA

TABLE 1 (Cont'd)
SUMMARY OF ENVIRONMENTAL SET 95 - SPRING 2019

Activity Levels - Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
1S95	1.87	15.32	2.33
2S95	1.56	19.28	2.42
3S95	0.78	17.48	1.43
4S95	0.78	11.35	2.08
5S95	0.94	20.18	3.55
6S95	0.94	9.73	1.30
7S95	1.71	34.41	2.97
10S95	0.94	20.00	2.84

Activity Levels - Water

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
4W95	0.83	<MDA	<MDA	<MDA
6W95	<MDA	<MDA	<MDA	<MDA
10W95	<MDA	<MDA	<MDA	<MDA

Activity Levels - Subsurface Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
E95	<MDA	20.06	3.89
S95	1.08	20.04	4.00
SW95	1.08	23.23	3.97
W95	1.70	23.23	4.02
N95	1.54	20.22	3.31
NE95	1.23	24.12	4.45

* 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 96 - FALL 2019

Detection Limits*

Matrix	Alpha	Beta	Gamma	Tritium
Vegetation	0.00 pCi/g	7.50 pCi/g	1.75 pCi/g	5.63 pCi/ml
Soil	0.00 pCi/g	8.58 pCi/g	0.54 pCi/g	N/A
Water	0.86 pCi/L	3.66 pCi/L	199.25 pCi/L	5.78 pCi/ml
Subsurface Soil	0.00 pCi/g	3.93 pCi/g	0.52 pCi/g	N/A

Activity Levels - Vegetation

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
1V96	0.29	36.60	<MDA	6.75
2V96	<MDA	24.28	<MDA	<MDA
3V96	<MDA	10.21	<MDA	<MDA
4V96	<MDA	36.25	<MDA	<MDA
5V96	0.29	29.21	<MDA	<MDA
6V96	<MDA	12.32	<MDA	<MDA
7V96	0.29	28.51	<MDA	<MDA
10V96	<MDA	28.86	<MDA	<MDA

Activity Levels - Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
1S96	1.00	<MDA	3.18
2S96	0.57	<MDA	2.19
3S96	0.86	<MDA	2.45
4S96	0.86	<MDA	2.54
5S96	0.86	<MDA	2.81
6S96	0.72	<MDA	1.80
7S96	1.29	<MDA	1.94
10S96	1.14	<MDA	2.39

TABLE 2 (Cont'd)
SUMMARY OF ENVIRONMENTAL SET 96 - FALL 2019

Activity Levels - Water

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
4W96	<MDA	9.10	<MDA	<MDA
6W96	<MDA	14.92	<MDA	<MDA
10W96	<MDA	18.57	<MDA	<MDA

Activity Levels - Subsurface Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
E96	0.43	19.06	4.77
S96	1.39	22.08	4.48
SW96	0.84	23.18	4.91
W96	1.39	18.85	4.80
N96	1.29	18.19	4.21
NE96	1.13	19.05	3.94

* 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	1 st Quarter (net mrem)	2 nd Quarter (net mrem)	3 rd Quarter (net mrem)	4 th Quarter (net mrem)	Total (net mrem)
0*	Control	N/A	30	32	27	33	122
1*	Control	N/A	33	30	25	28	116
2*	Control	N/A	29	30	27	29	115
3	W	30	-2	-1	-6	-3	-12
4	SW	59	-1	3	-1	16	17
5	ENE	110	-4	-5	-4	-2	-15
6	NNE	84	5	5	4	6	20
7	ENE	55	-6	-3	-1	1	-9
8	SW	32	6	5	6	5	22
9	SSE	27	18	22	15	19	74
10	NE	139	-4	-1	-1	-1	-7
11	N	135	-1	1	0	2	2
12	NE	284	-1	1	-1	3	2
13	NNE	305	-7	-1	-6	-3	-17
14	S	168	-2	-1	-4	0	-7
15	SSE	74	-8	-2	-2	-1	-13
16	SE	113	-4	-1	-3	-3	-11
17	E	299	-2	-6	-4	-5	-17
18	NE	453	-5	-5	Missing	-6	-16
19	NE	673	-8	-10	-10	-6	-34
20	NE	893	-7	-4	-8	-5	-24
21	SSE	239	-3	-22	20	1	-4
22	SE	158	-8	-9	-9	-7	-33
23	NW	89	-2	-2	1	6	3
24	SSW	308	-4	0	-2	-5	-11
25	SSW	435	-6	-2	-5	1	-12
26	SSW	365	-4	-2	-4	-2	-12
27	SW	170	-10	-8	-8	-7	-33
28	NW	229	1	-1	-1	1	0
29	NW	260	-1	0	-2	0	-3
30	N	335	-5	-5	-6	-2	-18
31	NNE	677	-3	-1	-1	2	-3
32	NW	760	-3	-1	-1	-1	-6
33	ESE	578	-8	-9	-8	-7	-32
34	ENE	596	-7	-10	-7	-6	-30
35	SSE	477	6	-2	2	6	12
36	SE	446	-5	-1	-2	-8	-16
37	NE	732	-7	-7	-9	-5	-28
38	NW	487	-3	1	0	1	-1
39	W	528	-4	-22	18	1	-7
40	N	503	-9	-5	-5	-2	-21
41	NE	161	-2	-3	-7	-5	-17
42	In Building	N/A	5	6	7	5	23
43	In Building	N/A	0	0	0	4	4
44	SW	102	-1	-3	-5	0	-9
45	SE	94	9	1	1	16	27
46	SE	105	6	-4	1	9	12

* 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	103	103	67	16	3
February	85	85	52	11	5
March	91	91	58	14	8
April	106	106	66	25	9
May	86	86	68	22	5
June	97	97	62	18	6
July	100	100	63	16	7
August	103	103	66	8	13
September	85	85	51	11	6
October	104	104	52	15	8
November	84	84	42	13	4
December	105	105	32	3	7
TOTAL	1,149	1,149	679	172	81

* In addition, general building contamination surveys are conducted each normal working day.

** Air samples include stack Ar-41, containment Ar-41, sump entries, and hot cell entries. This number is lower for 2019, as sampling for Ar-41 is done on a continuous basis and not reported as discrete samples.

Miscellaneous Note

During calendar year 2019, MURR shipped 1,804 cubic feet of low-level radioactive waste containing 5,364 mCi of activity.

SECTION IX

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

January 1, 2019 through December 31, 2019

Total Personnel Dose (mrem) by Dosimetry Group

IX-1

	AC/PRD	BCS	DO	FOE	HC	HP	IRR	NA	NS	NSP	OPS	QA	RES	RP	SH	SIL	TEE	WC	Total
January	128	0	0	303	193	491	0	9	18	102	1,944	70	13	16	52	207	4	0	3,550
February	59	1	0	46	132	252	0	6	69	88	1,629	79	3	5	39	187	14	0	2,609
March	79	0	0	17	185	254	0	0	312	86	2,007	76	2	4	55	175	5	1	3,258
April	53	0	14	202	190	164	0	4	203	128	2,226	84	0	7	33	236	0	0	3,544
May	230	0	0	81	172	224	9	0	149	52	1,939	51	0	8	43	219	0	6	3,183
June	58	0	0	167	121	199	0	10	2	26	1,573	51	0	0	16	114	7	0	2,344
July	162	12	44	57	187	300	6	89	156	175	1,781	107	49	79	46	236	41	6	3,533
August	213	0	2	73	200	176	0	10	59	90	1,388	26	1	7	84	212	2	18	2,561
September	91	0	0	20	287	277	0	24	74	148	982	59	0	0	30	179	0	0	2,171
October	62	2	0	73	127	140	0	12	0	82	1,144	36	13	2	19	139	0	0	1,851
November	86	0	9	69	210	303	0	5	69	214	1,328	36	28	6	55	88	18	0	2,524
December	101	3	2	39	228	332	0	4	85	169	1,125	106	55	5	68	79	0	0	2,401
Total for Year	1,322	18	71	1,147	2,232	3,112	15	173	1,196	1,360	19,066	781	164	139	540	2,071	91	31	33,529
Monthly Average	110	2	6	96	186	259	1	14	100	113	1,589	65	14	12	45	173	8	3	2,794
Highest WB (annual)	308	6	13	229	884	757	4	28	128	308	1,069	159	58	36	235	1,288	15	19	
High Extremity (annual)	5,594	123	NM	5,608	2,309	1,150	20	1,204	50	1,498	1,750	1,520	150	843	432	1,404	112	0	

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-Neutron Activation

NS-Neutron Scattering

NSP-NorthStar Partners

OPS-Operations

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).