UNIVERSITY OF MISSOURI-COLUMBIA
RESEARCH REACTOR

REACTOR OPERATIONS
ANNUAL REPORT

January 1, 2021 through December 31, 2021

UNIVERSITY OF MISSOURI-COLUMBIA
RESEARCH REACTOR

REACTOR OPERATIONS
ANNUAL REPORT

January 1, 2021 through December 31, 2021

Compiled by the Staff of MURR

Submitted by:

Ronald M. Astrino
Reactor Manager

Reviewed and approved by:

J. David Robertson
Reactor Facility Director

UNIVERSITY OF MISSOURI-COLUMBIA
RESEARCH REACTOR

REACTOR OPERATIONS ANNUAL REPORT

January 1, 2021 through December 31, 2021

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, graphite and beryllium 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 2021. 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 (MU) administration; the governing officials of the State of Missouri; the Missouri State Highway Patrol (MSHP); the City of Columbia Police Department (CPD); the University of Missouri 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 MU Campus Facilities organization; the Nuclear Energy Institute (NEI); 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) installing an uninterruptible power supply alternate source to inverter maintenance disconnect; (2) installing reactor plant LED status indicators and pushbuttons on the reactor control console; (3) removing, rebuilding, and reinstalling anti-siphon system isolation valves V543A and V543B; (4) transferring electrical power supply for the facility evacuation and containment isolation systems from the emergency electrical power system to the uninterruptible power supply system; (5) replacing the cabinet and solenoid-operated valves for the 16-inch ventilation exhaust system; (6) upgrading the facility evacuation and containment isolation system relays; (7) installing a variable

frequency drive on reactor containment building ventilation supply fan SF-2; (8) adding an approximately 1,600 ft^2 expansion to the Shipping and Receiving Building; and (9) demolishing and renovating Rooms 231/231A to support a new radioisotope processing line.

The facility continues to actively collaborate with the NNSA Office of Material Management and Minimization (M^3) Reactor Conversion Program and five other U.S. high-performance research and test reactor facilities, including one critical facility, 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: (1) LEU fuel element fabrication drawings and specifications; (2) the Design Demonstration Elements (DDE), one without uranium and one with uranium, that will be flow tested at the Oregon State University Hydro-Mechanical Fuel Testing Facility and inserted into an experimental position at the INL Advanced Test Reactor to achieve prototypic MURR operating conditions; (3) fuel specification impact assessment analyses; and (4) a technical report on preliminary shipping and backend information, which includes activities for analysis, licensing, and planning of fresh and spent LEU fuel element shipments and backend operations for receipt and storage of the spent nuclear fuel at DOE facilities, which is currently Savannah River Site.

Reactor Operations management also wishes to commend one individual who received their Reactor Operator certification and one individual who received their 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.

TABLE OF CONTENTS

SECTION I

REACTOR OPERATIONS SUMMARY

January 1, 2021 through December 31, 2021

The following table and discussion summarize reactor operations during calendar year 2021.

Month	Full Power Hours	Megawatt Days	Full Power (% of total time)	Full Power (% of scheduled*)
January	681.34	283.94	91.6	102.5
February	602.71	251.23	89.7	100.5
March	653.48	272.36	87.8	98.3
April	563.24	234.77	78.2	87.7
May	662.00	275.93	89.0	99.6
June	655.80	273.33	91.1	102.1
July	682.55	284.45	91.7	102.7
August	656.29	273.56	88.2	98.8
September	655.59	274.06	91.1	102.1
October	669.15	278.87	89.9	100.7
November	614.26	256.11	85.3	95.7
December	622.35	259.40	83.6	93.7
Total for the Year	**7,718.76**	**3,218.01**	**88.11**	**98.71**

* 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 2021

The reactor operated continuously in January with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and one shutdown for a physics measurement. There were no unscheduled/unplanned power reductions.

Major maintenance items for the month included: completing Modification Record 88-11, Addendum 2: "Uninterruptible Power Supply Alternate Source to Inverter Maintenance Disconnect;" repairing control blade selector switch 1S3; and performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

FEBRUARY 2021

The reactor operated continuously in February with the following exceptions: four shutdowns for scheduled maintenance and/or refueling and two unscheduled/unplanned power reductions. The NRC conducted a routine scheduled inspection of facility security.

On February 2, with the reactor operating at 10 MW in the automatic control mode, a manual reactor shutdown was initiated in accordance with operating procedure OP-RO-220, "Reactor Shutdown or Power Reduction," to investigate a decrease in anti-siphon system pressure. Investigation revealed that the cause of the pressure drop was air leaking past anti-siphon system isolation valves V543A and V543B. Valves V543A and V543B were subsequently repositioned in accordance with Standing Order 21-01 to maintain system pressure. Permission to restart the reactor was obtained from the Lead Senior Reactor Operator (LSRO), and the reactor was returned to 10 MW operation.

On February 10, with the reactor operating at 10 MW in the automatic control mode, a manual reactor shutdown was initiated in accordance with operating procedure OP-RO-220, "Reactor Shutdown or Power Reduction," to investigate a decrease in anti-siphon system pressure. Investigation revealed that the cause of the pressure drop was air leaking past anti-siphon system isolation valve V543B. The pneumatic actuator for valve V543B and the anti-siphon system low pressure alarm set point were adjusted, and applicable portions of compliance procedure CP-11, "Anti-Siphon High Level Rod Run-In and Low Pressure Alarm," were completed satisfactorily. Valves V543A and V543B were closed in accordance with Standing Order 21-02, and the primary coolant system was restarted. Permission to restart the reactor was obtained from the LSRO, and the reactor was returned to 10 MW operation.

Major maintenance items for the month included: replacing control blade 'C' control rod drive mechanism (CRDM) with a rebuilt spare; and performing two reactivity worth measurements in accordance with reactor physics procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D)."

MARCH 2021

The reactor operated continuously in March with the following exceptions: five shutdowns for scheduled maintenance and/or refueling and three shutdowns for physics measurements. There were no unscheduled/unplanned power reductions. The NRC conducted a routine scheduled inspection of the Radiation Protection and Shipping Programs.

Major maintenance items for the month included: completing Modification Record 21-01, "Reactor Control Console LED Status Indicators;" repairing a leak on the secondary coolant system in mechanical equipment Room 114; performing a chemical cleaning and backflush of the secondary coolant side of pool coolant heat exchanger HX-521; replacing the inlet filter cartridges on the primary coolant demineralizer system; and performing five reactivity worth measurements in accordance with reactor physics procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

APRIL 2021

The reactor operated continuously in April with the following exceptions: four shutdowns for scheduled maintenance and/or refueling, one shutdown for a physics measurement, and two unscheduled/unplanned power reductions.

On April 18, with the reactor operating at 10 MW in the automatic control mode, an automatic reactor scram and containment building isolation were initiated by Area Radiation Monitor System (ARMS) Air Plenum 1 Module. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed.

Investigation revealed that the module appeared to be operating erratically and was subsequently replaced with a spare. Applicable portions of compliance procedure CP-30, "ARMs and Associated Horns and Lights," were completed satisfactorily. Permission to restart the reactor was obtained from the LSRO, and the reactor was subsequently returned to 10 MW operation.

On April 21, with the reactor operating at 10 MW in the automatic control mode, a manual reactor shutdown was initiated in accordance with operating procedure OP-RO-220, "Reactor Shutdown or Power Reduction," to investigate a decrease in anti-siphon system pressure. Investigation revealed that the cause of the pressure drop was air leaking past anti-siphon system isolation valves V543A and V453B. Valves V543A and V543B were subsequently removed, rebuilt, and reinstalled. Compliance procedures CP-11, "Anti-Siphon High Level Rod Run-In and Low Pressure Alarm," and CP-24, "Anti-Siphon System Valves 543A/B," were satisfactorily completed, and the anti-siphon system was channel tested per operating procedure OP-RO-410, "Primary Coolant System." 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: removing, rebuilding, and reinstalling anti-siphon system isolation valves V543A and V543B; performing a chemical cleaning of the secondary coolant side of primary coolant heat exchanger HX-503A; loading new de-ionizing bed 'K' and placing it on pool coolant system service; and performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

MAY 2021

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

Major maintenance items for the month included: completing the biennial change-out of control blade 'A' offset mechanism; completing compliance procedure CP-26, "Containment Building Compliance Test;" performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-200, "Measurement of Differential Worth of a Shim Blade, RTP-11(D);" and performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

JUNE 2021

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

Major maintenance items for the month included: completing Modification Record 72-04, Addendum 1: "Transfer Evacuation and Isolation Electrical Circuit Supply from Emergency Power to the Uninterruptible Power Supply (UPS);" replacing relay 2K26; and performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D)."

JULY 2021

The reactor operated continuously in July with the following exceptions: four shutdowns for scheduled maintenance and/or refueling, one shutdown for a physics measurement, and two unscheduled/unplanned power reductions.

On July 5, during a normal reactor startup at a transient power level of 2 MW in the manual control mode, a manual reactor scram was initiated due to sporadic height indication for shim control blade 'D' on the rod position indication (RPI) panel. All immediate and subsequent actions of reactor emergency procedures REP-2, "Reactor Scram," and REP-7, "Rod Position Indication System Failure," were completed. Control blade 'D' CRDM was removed and taken to the Instrumentation Support Shop for troubleshooting. It was determined that control blade 'D' RPI encoder was failing. Control blade 'C' CRDM was subsequently moved to the 'D' position, and a spare CRDM was placed in the 'C' position. Permission to restart the reactor was obtained from the LSRO, and the reactor was subsequently returned to 10 MW operation.

On July 26, during a normal reactor startup with the reactor operating in a subcritical condition in the manual control mode, the 'Blade Full In' light illuminated for shim control blade 'B.' Although RPI for CRDM 'B' indicated a control blade height of approximately 10.30 inches, inspection revealed that the ball screw for CRDM 'B' had detached from the top of the drive mechanism allowing the ball screw, electromagnet, and shim control blade 'B' to fall to the fully inserted position. The LSRO directed another operator to shut down the reactor by initiating a manual scram by placing Master Control Switch 1S1 to the 'TEST' position. All immediate and applicable subsequent actions of reactor emergency procedure REP-8, "Control Rod Drive Mechanism Failure or Stuck Rod," were completed. After the reactor was secured, CRDM 'B' was removed for further investigation and a spare CRDM was installed in the 'B' position. Compliance procedure CP-10, "Rod Drop Times," for shim control blade 'B' was completed satisfactorily. Performing CP-10 operated the CRDM and its associated offset mechanism with the control blade through its entire range of motion while staff members could observe the CRDM and offset mechanism for binding or any other abnormalities. In accordance with Technical Specification (TS) 6.6.c(4), authorization from the Reactor Facility Director was obtained prior to reactor operation to perform CP-10. During CP-10, two staff members performed a careful visual and audible inspection of the entire assembly as it moved through its full range of travel. No abnormalities were noted during the inspection, and the Reactor Manager deemed the spare CRDM operable. A normal reactor startup was performed, and the reactor returned to 10 MW operation. With the ball screw detached from the top of CRDM 'B,' CRDM 'B' was considered inoperable, which resulted in a deviation from TS 3.2.a, and Licensee Event Report No. 21-01 was submitted to the NRC on August 9, 2021.

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

AUGUST 2021

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

On August 20, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated after a 'Rod Not In Contact' rod run-in was received due to shim control blade 'C' anvil disengaging from its electromagnet during a routine sample handling evolution. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. The reactor was refueled and 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: completing Modification Record 90-03, Addendum 1: "16-inch Ventilation Exhaust Isolation Valves Solenoid Cabinet Replacement;" loading new de-ionizing bed 'B' and placing it on pool coolant system service; replacing the inlet filter cartridges on the pool coolant demineralizer system; and performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

SEPTEMBER 2021

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

Major maintenance items for the month included: completing Modification Record 72-04, Addendum 2: "Replace Evacuation and Isolation Relays;" and performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-200, "Measurement of Differential Worth of a Shim Control Blade, RTP-11(D)."

OCTOBER 2021

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

On October 11, while the reactor was shut down for scheduled routine maintenance and TS surveillance testing, surveillance testing on reactor core outlet pressure instrument channel 944B (pressure transmitter PT 944B instrument channel) revealed that the PT 944B instrument channel did not initiate a reactor scram at the appropriate TS set point. Troubleshooting revealed the component in the PT 944B instrument channel that caused the set point deviation to be dual alarm unit 920F. Dual alarm unit 920F was replaced with an exact spare and successfully retested. In accordance with TS 6.6.c(4), authorization from the Reactor Facility Director was obtained prior to returning the reactor to operation. Failure of the dual alarm unit to provide a reactor scram within the TS-required set point resulted in a deviation from TS 3.2.g.6, and Licensee Event Report No. 21-02 was submitted to the NRC on October 25, 2021.

Major maintenance items for the month included: completing Modification Record 21-04, "Security Upgrades;" replacing pressure transmitter PT 944B instrument channel dual alarm unit 920F; performing a zero and span on pressure transmitter PT 943; and performing special maintenance procedure SM-RO-625, "Measuring Control Blade Pull Weight and Blade Drop Time with the Test Magnet Assembly, RTP-21."

NOVEMBER 2021

The reactor operated continuously in November with the following exceptions: five shutdowns for scheduled maintenance and/or refueling, one planned shutdown for nuclear instrumentation adjustment, and one unscheduled/unplanned power reduction. The NRC conducted a routine scheduled inspection of Reactor Operations and Emergency Preparedness.

On November 4, with the reactor operating at 10 MW in the automatic control mode, an automatic reactor scram was initiated due to a sustained loss of normal electrical power. All immediate actions of reactor emergency procedure REP-10, "Sustained Loss of Normal Electrical Power," were completed. Investigation by University of Missouri Energy Management (EM) discovered a failed circuit card within the smart switch that feeds the facility's 1,500 and

2,000 kVA transformers. EM restored power and permission to restart the reactor was obtained from the LSRO. The reactor was subsequently returned to 10 MW operation.

On November 8, while the reactor was shut down for routine maintenance and TS surveillance testing, the anti-siphon system high water level rod run-in function did not activate within the required specification during the performance of compliance procedure CP-11, "Anti-Siphon High Level Rod Run-in and Low Pressure Alarm." Troubleshooting revealed that the stainless steel cable that connects level controller LC 965 instrument channel to the suspended displacer (float) had developed loops in it, effectively shortening the cable. The loops in the cable were removed, and level controller LC 965 instrument channel was retested and documented to be back in compliance. Engineering analysis subsequently concluded that prior to removing the loops from the level controller cable, the rod run-in was actuating at a level greater than the maximum of 6 inches above anti-siphon system isolation valves V543A and V543B as required by TS 3.2.f.6. In accordance with TS 6.6.c(4), authorization from the Reactor Facility Director was obtained prior to returning the reactor to operation later that day. Failure of level controller LC 965 to actuate before the maximum allowable 6 inches of water above the valves resulted in a deviation from TS 3.2.f.6, and Licensee Event Report No. 21-03 was submitted to the NRC on November 23, 2021.

On November 15, while the reactor was shut down for routine maintenance and TS surveillance testing, the control room operators determined that the 'Reflector Hi-Low Diff Pressure Scram' annunciation did not illuminate as pool coolant flow rate decreased to zero after shutting down the pool coolant system. Investigation and further testing revealed that the low reflector differential pressure reactor scram from pressure transmitter PT 917 instrument channel did not activate due to a failed alarm meter unit. The alarm meter unit was replaced with a new spare and subsequently calibrated after installation. In accordance with TS 6.6.c(4), authorization from the Reactor Facility Director was obtained prior to returning the reactor to operation later that day. Failure of pressure transmitter PT 917 instrument channel to initiate a reactor scram resulted in a deviation from TS 3.2.g.10, and Licensee Event Report No. 21-04 was submitted to the NRC on November 23, 2021.

Major maintenance items for the month included: completing Modification Record 21-05, "Supply Fan 2 Variable Frequency Drive;" replacing the inlet filter cartridges on the pool coolant demineralizer system; adjusting anti-siphon system LC 965 level controller displacer; replacing pressure transmitter PT 917 alarm meter unit; replacing the fission chamber and associated cabling for nuclear instrumentation signal processor no. 1; and completing compliance procedure CP-25, "Control Blade Inspection," for shim control blade 'C.'

DECEMBER 2021

The reactor operated continuously in December with the following exceptions: four shutdowns for scheduled maintenance and/or refueling, one shutdown for a physics measurement, and three unscheduled/unplanned power reductions. The NRC administered three senior reactor operator licensing examinations.

On December 14, with the reactor operating at 10 MW in the automatic control mode, a control room operator inadvertently placed the reactor in the manual control mode. While attempting to return the reactor to the automatic control mode, an automatic high power rod run-in occurred. After reactor power had reduced to below the trip set point, the LSRO reset the rod run-in, and the reactor was returned to 10 MW operation.

On December 24, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated due to incorrect regulating blade height indication on the RPI panel. All immediate and subsequent actions of reactor emergency procedure REP-7, "Rod Position Indication System Failure," were completed. Investigation revealed that a setscrew on the coupler attaching the drive motor to the RPI encoder on the regulating rod drive mechanism had backed out, allowing the coupler to slip. The regulating rod drive mechanism was removed and a

rebuilt spare was installed. Permission to restart the reactor was received from the LSRO, and the reactor was returned to 10 MW operation.

On December 30, with the reactor operating at 10 MW in the automatic control mode, a manual reactor scram was initiated due to a lowering of pressurizer liquid level. All immediate and subsequent actions of reactor emergency procedure REP-2, "Reactor Scram," were completed. Investigation revealed a leak on the diaphragm of primary coolant heat exchanger HX-503B outlet throttle valve. The reactor remained shutdown for the remainder of the year to perform repairs.

Major maintenance items for the month included: repairing a leak on the secondary coolant system in mechanical equipment Room 114; and performing a reactivity worth measurement in accordance with reactor physics procedure RP-RO-201, "Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)."

SECTION II

MURR PROCEDURES

January 1, 2021 through December 31, 2021

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 57 revisions issued to the Reactor Operations policies, procedures, and forms. The majority of these revisions were strictly format or editorial in nature. Additionally, one new procedure and one new policy were issued, while one procedure was obsoleted. The following is a list of the new, revised, and obsoleted policies, procedures, and forms:

Number	Name	Rev.	Rev. Date	Notes
AP-RO-105	MURR Operator Requalification Process	2	12/28/2021	Minor Editorial
AP-RO-110	Conduct of Operations	30	5/19/2021	Minor Editorial
AP-RO-135	Reactor Utilization Requests	5	12/28/2021	Minor Editorial
AP-RR-003	10 CFR 50.59 Evaluations	15	1/6/2021	Minor Editorial
AP-RR-010	Facility Access Criteria	24	3/4/2021	Minor Editorial
AP-RR-011	Facility Access Process	24	3/30/2021	Minor Editorial
AP-RR-024	Ombudsman Program	9	6/11/2021	Minor Editorial
EX-RO-110	Pneumatic Tube System	3	1/29/2021	Minor Editorial
EX-RO-120	Beamport 'A' Operation	17	1/29/2021	Minor Editorial
EX-RO-120	Beamport 'A' Operation	18	11/24/2021	Minor Editorial
EX-RO-125	Beamport 'F' Operation	19	1/29/2021	Minor Editorial
EX-RO-125	Beamport 'F' Operation	20	11/24/2021	Minor Editorial
FM-03	Sponsor List	31	1/6/2021	Minor Editorial
FM-03	Sponsor List	32	7/27/2021	Minor Editorial
FM-03	Sponsor List	33	10/27/2021	Minor Editorial
FM-04	Visitor/After-Hours Access Request Form	18	2/18/2021	Minor Editorial
FM-04	Visitor/After-Hours Access Request Form	19	12/28/2021	Minor Editorial
FM-11	Reactor Shutdown Checksheet	9	3/8/2021	Minor Editorial
FM-15	10 CFR 50.59 Qualified Reviewers List	26	6/11/2021	Minor Editorial
FM-56	Reactor Routine Patrol	28	1/29/2021	Minor Editorial
FM-57	Long Form Startup Checksheet	35	5/19/2021	Minor Editorial
FM-63	DI Water Makeup Log	13	10/27/2021	Minor Editorial

Number	Name	Rev.	Rev. Date	Notes
FM-66	Customer Sample Pre-Encapsulation Evaluation Worksheet	11	4/5/2021	Minor Editorial
FM-97	Routing Form for Facility Drawing Revisions	12	11/24/2021	Minor Editorial
FM-140	MURR Access Inactivation Form	8	6/11/2021	Minor Editorial
FM-140	MURR Access Inactivation Form	9	9/2/2021	Minor Editorial
FM-200	Authorization to Conduct Background Investigation for Unescorted Access to MURR	6	2/3/2021	Minor Editorial
GS-RA-100	MURR Equipment Tag Out	18	12/28/2021	Full Review
IRR-PSO-104	Receipt of Non-Radioactive Material for Irradiation	11	10/28/2021	Minor Editorial
OP-RO-101	Instrument Air System	14	1/29/2021	Minor Editorial
OP-RO-250	In-Pool Fuel Handling	24	1/12/2021	Minor Editorial
OP-RO-410	Primary Coolant System	19	1/12/2021	Minor Editorial
OP-RO-461	Pool Coolant System - One Pump Operation	20	7/6/2021	Minor Editorial
OP-RO-465	Pool Level Control - Skimmer System	12	2/11/2021	Minor Editorial
OP-RO-466	Pool Level Control - Pool Coolant System	15	4/6/2021	Minor Editorial
OP-RO-480	Secondary Coolant System	26	6/22/2021	Minor Editorial
OP-RO-532	Drain Collection System	12	2/11/2021	Minor Editorial
OP-RO-532	Drain Collection System	13	7/6/2021	Minor Editorial
OP-RO-533	Skimmer System	11	11/24/2021	Minor Editorial
OP-RO-555	Fire Protection System	18	6/22/2021	Obsoleted
OP-RO-741	Waste Tank System Operation	26	5/19/2021	Minor Editorial
POL-20	Special Nuclear Materials Manual	6	4/6/2021	Minor Editorial
POL-20	Special Nuclear Materials Manual	7	7/16/2021	Minor Editorial
POL-30	MURR Filter Management Program	0	9/22/2021	New Policy
RM-RO-400	Waste Tank System Filter Replacement	12	5/19/2021	Minor Editorial
RM-RO-405	Reactor Demineralizer System	20	5/19/2021	Minor Editorial
RM-RO-405	Reactor Demineralizer System	21	12/28/2021	Minor Editorial
RP-RO-100	Fuel Movement	16	10/27/2021	Minor Editorial
RP-RO-200	Measurement of Differential Worth of a Shim Blade, RTP-11 (D)	10	9/2/2021	Minor Editorial
RP-RO-201	Measurement of Reactivity Worth of Flux Trap Loadings or Individual Samples, RTP-17(B)	6	9/2/2021	Minor Editorial
RP-RO-203	Measurement of Primary Coolant/Moderator Temperature Coefficient of Reactivity, RTP-19	2	10/27/2021	Minor Editorial
RP-RO-300	Receipt, Inspection, Accounting, and Shipping of Unirradiated Fuel	8	1/21/2021	Full Review
SM-RO-011	Beryllium Reflector Replacement	9	4/6/2021	Minor Editorial
SM-RO-025	Removal, Transfer or Installation of an Offset Mechanism	4	4/6/2021	Minor Editorial
SM-RO-025	Removal, Transfer or Installation of an Offset Mechanism	5	11/23/2021	Minor Editorial
SM-RO-555	Fire Protection System	0	6/22/2021	New Procedure
SM-RO-636	Retracting and Reinserting Beamport 'B' Liner	7	2/17/2021	Minor Editorial
SM-RO-637	Retracting and Reinserting Beamport 'C' Liner	7	2/17/2021	Minor Editorial
SM-RO-638	Retracting and Reinserting Beamport 'D' Liner	8	2/17/2021	Minor Editorial
SM-RO-639	Retracting and Reinserting Beamport 'E' Liner	7	2/17/2021	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 11 revisions issued to the Emergency Plan implementing procedures, forms, and operator aids. All of these revisions were strictly format or editorial in nature. Additionally, one form was obsoleted. The following is a list of the revised and obsoleted procedures, forms, and operator aids:

Number	Name	Rev.	Rev. Date	Notes
EP-RO-002	Emergency Responsibilities	10	2/9/2021	Minor Editorial
EP-RO-004	Fire	10	6/16/2021	Minor Editorial
EP-RO-006	Radiological Emergency	12	6/16/2021	Minor Editorial
EP-RO-013	Facility Evacuation	13	6/16/2021	Minor Editorial
FM-104	Emergency Call List	43	2/10/2021	Minor Editorial
FM-104	Emergency Call List	44	4/1/2021	Obsoleted
OA-9	Combined Emergency Flowcharts	8	2/9/2021	Minor Editorial
OA-10	Fire Extinguisher Locations and Types	17	2/9/2021	Minor Editorial
OA-20	Emergency Equipment	28	2/9/2021	Minor Editorial
OA-20	Emergency Equipment	29	6/16/2021	Minor Editorial
REP-RO-100	Reactor Emergency Procedures	26	4/6/2021	Minor Editorial
REP-RO-100	Reactor Emergency Procedures	27	6/14/2021	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 54 revisions issued to the radiological control, byproduct materials shipping, and preparation for shipping byproduct material policies, procedures, forms, and operator aids. The majority of these revisions were strictly format or editorial in nature. Additionally, three new procedures and one new form were issued, while two procedures were obsoleted. The following is a list of the new, revised, and obsoleted policies, procedures, forms, and operator aids:

Number	Name	Rev.	Rev. Date	Notes
AP-HP-115	Iodine 131 Bioassay	6	12/28/2021	Minor Editorial
AP-HP-119	High Radiation Area Access	12	2/3/2021	Minor Editorial
AP-HP-125	Review of Unplanned Radiation Exposure	8	1/14/2021	Minor Editorial
AP-HP-129	Hot Cell HC-01 Control	20	4/5/2021	Minor Editorial
AP-HP-130	Reactor License Projects Annual Review	9	10/27/2021	Minor Editorial
AP-RR-013	Access Authorization Program for Category 1 and/or Category 2 Quantities of Radioactive Material	7	1/15/2021	Minor Editorial
AP-RR-017	Physical Security Program for Category 1 and/or Category 2 Quantities of Radioactive Materials	0	3/8/2021	New Procedure
AP-RR-017	Physical Security Program for Category 1 and/or Category 2 Quantities of Radioactive Materials	1	9/2/2021	Minor Editorial
AP-SH-001	Administrative Procedure - Radioactive Material Shipping	14	1/19/2021	Minor Editorial
AP-SH-004	Notification for Category 2 Material Per Export License PXB143.01	3	3/22/2021	Minor Editorial
BPB-SH-020	Receipt Inspection Of Type B Shipping Package	10	4/6/2021	Minor Editorial
BPB-SH-031	Bubble Testing Acceptance for Croft SAFKEG-HS Insert Model No. 3987	1	3/8/2021	Minor Editorial
BPB-SH-031	Bubble Testing Acceptance for Croft SAFKEG-HS Insert Model No. 3987	2	8/26/2021	Minor Editorial
BPB-SH-032	Type B USA/0820/B(U)-96 (F-522 Series) Packaging of Type B Radioactive Material	0	8/26/2021	New Procedure
FB-SH-110	Type B Shipment of Spent Fuel Using the BEA Research Reactor Package	9	2/11/2021	Minor Editorial
FM-17	Radiation Work Permit	16	4/5/2021	Minor Editorial
FM-29	Dosimetry Request Packet	13	1/15/2021	Minor Editorial
FM-50	Control Checksheet for Type B USA/0820/B(U)-96 (F-522 Series) Radioactive Material Shipment	0	8/26/2021	New Form
FM-50	Control Checksheet for Type B USA/0820/B(U)-96 (F-522 Series) Radioactive Material Shipment	1	10/28/2021	Minor Editorial
FM-137	Type B Qualified Shipper List	33	4/6/2021	Minor Editorial
FM-137	Type B Qualified Shipper List	34	10/28/2021	Minor Editorial
FM-137	Type B Qualified Shipper List	35	11/19/2021	Minor Editorial
FM-147	Control Checksheet for Packaging of Type A Radioactive Material Using Tracerco LS-15	8	1/19/2021	Minor Editorial
FM-159	Control Checksheet for Health Physics Review of Radioactive Material Shipment Documentation	14	9/23/2021	Minor Editorial
FM-165	Radiation Protection Data Sheet 'A' for cMo-99 Process in Hot Cell HC-02A/B	6	3/11/2021	Minor Editorial

Number	Name	Rev.	Rev. Date	Notes
FM-173	Control Checksheet for Health Physics Review of Excepted (Limited) Quantity Radioactive Material Shipment	4	3/8/2021	Minor Editorial
FM-201	Control Checksheet for Documentation and Labeling of NorthStar Radioactive Material Shipment	2	8/26/2021	Minor Editorial
HC-PSO-002	Hot Cell Preparation of Radioactive Material for Shipment	21	4/5/2021	Minor Editorial
HC-PSO-005	Hot Cell-01 Loading of Host Cans	18	11/18/2021	Minor Editorial
IC-HP-300	Calibration - Radiation Survey Instruments	11	5/12/2021	Minor Editorial
IC-HP-306	Mirion PING209L Stack Monitor - Flow Calibration	1	7/27/2021	Minor Editorial
IC-HP-308	Calibration - Mirion PING209L Stack Monitor - Iodine Channel	1	7/27/2021	Minor Editorial
IC-HP-309	Calibration - Mirion PING209L Stack Monitor - Particulate Channel	1	7/27/2021	Minor Editorial
IC-HP-310	Calibration - Eberline Model PING 1A Stack Monitor - Particulate Channel	10	3/8/2021	Minor Editorial
IC-HP-310	Calibration - Eberline Model PING 1A Stack Monitor - Particulate Channel	11	7/14/2021	Minor Editorial
IC-HP-311	Calibration - Eberline Model PING 1A Stack Monitor - Iodine Channel	11	2/3/2021	Minor Editorial
IC-HP-312	Calibration - Eberline Model PING 1A Stack Monitor - Gas Channel	10	2/3/2021	Minor Editorial
IC-HP-312	Calibration - Eberline Model PING 1A Stack Monitor - Gas Channel	11	3/21/2021	Minor Editorial
IC-HP-345	Calibration - Canberra S5 XLB Swipe Counter	0	6/15/2021	New Procedure
IC-HP-348	Calibration - Canberra S5XLB-G	8	5/12/2021	Obsoleted
IC-HP-351	Calibration - Lab Impex Stack Monitor - Gas Channel	7	1/11/2021	Minor Editorial
IC-HP-351	Calibration - Lab Impex Stack Monitor - Gas Channel	8	9/22/2021	Minor Editorial
IC-HP-354	Calibration - NOA Lab Impex Stack Monitor - Particulate Channel	2	9/27/2021	Minor Editorial
IC-HP-356	Calibration - NOA Lab Impex Stack Monitor - Flow Calibration	5	9/27/2021	Minor Editorial
OA-99	Packaging of Type A Radioactive Material Using USA DOT 7A MURR Model 1500	3	9/23/2021	Minor Editorial
OP-HP-222	Air Sampling - Containment Building Ar-41	12	2/3/2021	Minor Editorial
OP-HP-228	Performing Iodine 131 Bioassay Measurements	9	9/22/2021	Minor Editorial
OP-HP-300	Receipt of Radioactive Material	14	12/28/2021	Minor Editorial
OP-HP-353	Waste Tank Sample - Analysis	11	6/15/2021	Minor Editorial
OP-HP-365	Iodine 131 Processing Hot Cells Radiation Monitor (ALMO-6)	4	9/22/2021	Minor Editorial
OP-HP-400	Gemstone Shipping Barrel Analysis	12	1/14/2021	Obsoleted
POL-03	Radiation Protection Program	21	2/9/2021	Minor Editorial
POL-03	Radiation Protection Program	22	11/12/2021	Minor Editorial
QAB-SH-005	Type B QA Personnel Training	7	2/11/2021	Minor Editorial
QAB-SH-006	Type B Shipping Program Quality Audits	4	3/22/2021	Minor Editorial
QAB-SH-008	Training for Type B Shipment Leak Test Performers	6	2/11/2021	Minor Editorial
RP-HP-105	Transfer of Radioactive Material Within the Facility	15	2/9/2021	Minor Editorial
RP-HP-120	Personnel Radioactive Contamination	16	12/28/2021	Minor Editorial
RP-HP-135	Room 114 Entry - Self Monitored	12	12/28/2021	Minor Editorial
WM-SH-116	Removal of Waste from Hot Cell HC-11A Using Shielded Container	1	4/6/2021	Minor Editorial

SECTION III

REVISIONS TO THE SAFETY ANALYSIS REPORT

January 1, 2021 through December 31, 2021

On August 31, 2006, MURR submitted a request to the 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 2021, 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 2021, 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 1.2.1, Figure 1.1 (page 1-5)

Update with Print No. 1145, Sheet 1 of 5, "Placement of Emergency Equipment – Basement Level," Rev. 19, dated 09/21/21

Section 1.2.1, Figure 1.2 (page 1-6) (as revised by the 2019 Reactor Operations Annual Report)

Update with Print No. 1145, Sheet 2 of 5, "Placement of Emergency Equipment – Grade Level," Rev. 42, dated 09/30/21

CHAPTER 7 – INSTRUMENTATION AND CONTROL

Section 7.6.2.1, second paragraph (page 7-37) (as revised by the 2018 Reactor Operations Annual Report)

Insert new sentences at end of paragraph to read: "The chart recorder will display an additional trend line on a loss of electrical power to the primary coolant circulation pumps. A pair of relays are connected to the control circuits for primary coolant circulation pumps P501A and P501B that will provide a real time indication of electrical power to the pumps. This feature assists in data collection for a primary coolant system flow coast down."

Section 7.8.2.1, first paragraph (page 7-58)

Delete: "2. Parallel relays R2A and R2B and relay 2K2 in the CAS will de-energize;"

Replace with: "2. Parallel R2 series relays (R2A-R2F) and relay 2K2 in the CAS will de-energize;"

Section 7.8.2.1, second paragraph (page 7-58)

Delete: "De-energizing either relay R2A or R2B (see No. 2 above) of the CAS will cause the following actions to occur:"

Replace with: "De-energizing the R2 series relays (see No. 2 above) of the CAS will cause the following actions to occur:"

Section 7.8.2.2, first paragraph (page 7-59)

Delete: "2. All actions caused by relays R2A and R2B de-energizing."

Replace with: "2. All actions caused by the R2 series relays de-energizing."

Section 7.8.2.2, second paragraph (page 7-59)

Delete: "1. Parallel relays R3A and R3B will de-energize and open contacts in the CAS thereby de-energizing relays 2K2, R2A, and R2B; and"

Replace with: "1. Parallel relays R3A and R3B will de-energize and open contacts in the CAS thereby de-energizing relay 2K2 and the R2 series relays; and"

Section 7.9.2.1, Figure 7.11 (pages 7-63/64)

Update with Print No. 203, Sheet 1 of 1, "Area Monitoring System," Rev. 16, dated 07/22/21

CHAPTER 8 – ELECTRICAL POWER SYSTEMS

Section 8.1.3, Figure 8.1 (page 8-4)

Update with Print No. 2294, Sheet 1 of 1, "Uninterruptible Power Supply Interconnect Diagram," Rev. 4, dated 01/22/21

Section 8.1.3, Figure 8.2 (pages 8-5/6)

Update with Print No. 522, Sheet 1 of 8, "Electrical Distribution Reactor/Laboratory," Rev. 53, dated 09/07/21, and Print No. 522, Sheet 4 of 8, "Electrical Distribution Emergency Electrical Power System," Rev. 3, dated 01/22/21

CHAPTER 9 – AUXILIIARY SYSTEMS

Section 9.12.2, third and fourth paragraphs (pages 9-20 and 9-21)

Delete: "In addition to the water treatment system discussed above, an ion exchange demineralizer system (DI-300) serves as a backup. This system consists of a 300-gallon (1,136-l) rubber-lined carbon steel tank sized to hold 24 cubic feet (0.68 m3) of mixed bed resin, filters before and after the demineralizer tank, and associated piping and valves.

Demineralized water from either system may then be directed to the water storage systems for the facility or the reactor plant."

Replace with: "Demineralized water from the RO unit may be directed to the water storage systems for the facility or reactor plant."

SECTION IV

PLANT AND SYSTEM MODIFICATIONS

January 1, 2021 through December 31, 2021

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 72-04, ADDENDUM 1

Transfer Evacuation and Isolation Electrical Circuit Supply from Emergency Power to Uninterruptable Power Supply (UPS)

This addendum to Modification Record 72-04, "Evacuation and Isolation," documents the transfer of electrical supply power to the facility evacuation and reactor containment isolation systems from the emergency electrical power system to the uninterruptible power supply (UPS) system. Historically, there have been momentary losses of normal electrical power that have been long enough in duration to cause a reactor scram from either the facility evacuation or the reactor containment isolation system; however, not long enough to cause a reactor scram due to decreased primary coolant or pool coolant system flow rate. This change should decrease the probability that the facility evacuation and reactor containment isolation systems will actuate during a momentary loss of normal electrical power, thus increasing operational reliability.

MODIFICATION RECORD 72-04, ADDENDUM 2

Replace Evacuation and Isolation Relays

This addendum to Modification Record 72-04, "Evacuation and Isolation," documents the replacement of relays (R1A, R1B, R2A, R2B, R3A, and R3B) in the facility evacuation and reactor containment isolation systems. The new Schneider relays replace obsolete Square D relays; however, the functionality of the relays remain the same.

MODIFICATION RECORD 88-11, ADDENDUM 2

Uninterruptible Power Supply Alternate Source to Inverter Maintenance Disconnect

This addendum to Modification Record 88-11, "Reactor Control Power Upgrade (Replacing Line Conditioner with Uninterruptible Power Supply)," documents the maintenance required to replace a malfunctioning transformer on the UPS system inverter. To assist in this maintenance, an additional 70-amp fused disconnect was added to the output of the alternate source to allow isolation of the inverter without securing power to all UPS panels. This disconnect was installed to the output of the alternate source and the corresponding contacts on the inverter. This line is a sensing line that supplies the inverter and provides an input to the inverter for detection of the phase for the alternate source.

MODIFICATION RECORD 90-03, ADDENDUM 1

16-inch Ventilation Exhaust Isolation Valves Solenoid Cabinet Replacement

This addendum to Modification Record 90-03, "16" Valve Solenoid Cabinet," documents the replacement of the 16-inch ventilation exhaust solenoid-operated isolation valves cabinet. Replacement of the cabinet also included replacement of all of the solenoid-operated valves, which were upgraded to more robust and reliable continuous duty Parker N3554104853 3-way valves, and associated piping inside the cabinet. Additionally, all security features installed under Modification Record 90-03 were removed following a change in license requirements authorized by the MURR Physical Security Plan.

MODIFICATION RECORD 19-02

Modification to the Laboratory Building Configuration

This modification record was generated for the purpose of providing a means for documenting structural changes to the laboratory building. It is intended to capture changes such as the addition or removal of walls, combining or separating laboratory building spaces, etc. It can also be used to capture service changes to laboratory building spaces. Individual changes under this modification record will be evaluated under 10 CFR 50.59, as needed.

MODIFICATION RECORD 20-03

Substation B, MCC-5 Micro-Versa-Plus Trip Unit

This modification record documents replacement of Substation 'B' motor control center MCC-5 breaker with a refurbished General Electric Type AK 2A-25-1 unit retrofitted with a solid state MicroVersaTrip+ (MVT+) unit.

MODIFICATION RECORD 21-01

Reactor Control Console LED Status Indicators

This modification record documents the replacement of the original-style lamps and pushbuttons utilized for various reactor plant indicators and controls on the reactor control console. The original lamps and pushbuttons, which are General Electric (GE) CR103 incandescent bulbs and GE-style pushbuttons, respectively, were upgraded to confront obsolescence. The packages used in this modification are IDEC AL6 LED Pilot Lights and IDEC AL6 Illuminated Pushbutton switches. These changes were analyzed from an electrical perspective in Tech Note 20-005.00 and found to be suitable replacements for the existing GE lamps and pushbuttons. The listed mechanical life of the proposed pushbuttons is a minimum of 100,000 operations for the selected style of operation. Using a conservative estimation of 6 operations per week, the proposed pushbuttons have a rated operational lifetime of over 300 years.

MODIFICATION RECORD 21-02

Reactor Containment Building Sealing Gasket Solenoid Valve Replacement

This modification record documents the replacement of the sealing gasket solenoid-operated valves for the reactor containment building truck entry door (Door 101), ventilation supply and exhaust plenums (Doors 504 and 505), and

the personnel airlock (Doors 276 and 277) with a newer model (ASCO 8344 Dual Action Piston/Poppet Solenoid Valves) due to obsolescence of the previously-installed solenoid-operated valves.

MODIFICATION RECORD 21-04

Security Upgrades

This modification record was created as a means of documenting changes to various MURR security features and storing them in one common location. The intent of this modification record is to host various letters to file that describe necessary changes to MURR security that do not warrant a modification record on their own. Individual changes under this modification record will be evaluated under 10 CFR 50.59, as needed. Typical information in each letter to file will include a description of the change, procedural changes, and print changes. This Modification Record is handled as Safeguards Information and is controlled as such.

MODIFICATION RECORD 21-05

Supply Fan 2 Variable Frequency Drive

This modification record documents the replacement of the undersized motor contactor on motor control center MCC-4 that supplies electrical power to reactor containment building supply fan SF-2.

MODIFICATION REDORD 19-02 – LETTER TO FILE (December 2, 2020)

Addition of Exhaust Ventilation to Room 241 Oven

This letter to Modification Record 19-02, "Modification to the Laboratory Building Configuration," documents adding additional exhaust ventilation for Room 241 for an oven which will support potentially radioactive work.

MODIFICATION RECORD 19-02 – LETTER TO FILE (December 22, 2020)

Room 236 Exhaust Ventilation Renovation

This letter to Modification Record 19-02, "Modification to the Laboratory Building Configuration," documents the addition of a larger exhaust ventilation trunk to support a welding snorkel in Room 236, in addition to the existing room exhaust ventilation.

MODIFICATION RECORD 15-01 – LETTER TO FILE (February 11, 2021)

Anti-Siphon Actuator Flow Throttling

This letter to Modification Record 15-01, "Additional Coupling Joint for Anti-Siphon System Isolation Valves V543A and V543B," documents a procedural change to throttle the air supply valve for the pneumatic actuators that this modification record describes. The intent of this change was to reduce wear and tear on the actuators, linkages, and valves.

MODIFICATION RECORD 88-07, ADDENDUM 3 – LETTER TO FILE (February 24, 2021)

HC-11 Solenoid Cabinet Pneumatic Exhaust Addition

This letter to Modification Record 88-07, Addendum 3, "Exhaust Ventilation in MIB Eastward Expansion," documents the relocation of hot cell HC-11 solenoid cabinet pneumatic exhaust from HC-11B to the exhaust line just before the charcoal filters in Room 299V. Previously, the pneumatic exhaust was routed back to HC-11B creating a potential release path into the surrounding room. This change routes all the pneumatic exhaust to the facility exhaust ventilation system and installs a block-off plate on the abandoned HC-11B penetration.

MODIFICATION RECORD 86-01, ADDENDUM 5 – LETTER TO FILE (February 25, 2021)

Thermal Neutron Flux Changes Due to Replacement of Graphite Reflector Elements 5A and 5B in Year 2020

This letter to Modification Record 86-01, Addendum 5, "Replacement of Graphite Reflector Elements in Reflector Tank Positions 5A and 5B," documents the effects of changing graphite reflector elements '5A' and '5B' in calendar year 2020. After installation of element '5B' in February of 2020, MURR Reactor Health Physics noted that Argon-41 levels were approximately 10% higher than previous levels. Replacement of element '5A' was postponed until further modifications and procedural changes could be implemented to reduce Argon-41 production. Following the changes that are outlined in their applicable modification records, total annual Argon-41 activity released has been maintained at or slightly below pre-2020 levels.

MODIFICATION RECORD 19-02 – LETTER TO FILE (March 26, 2021)

Lab 215A Ventilation Control

This letter to Modification Record 19-02, "Modification to the Laboratory Building Configuration," documents the modification to the exhaust ventilation system for Room 215A. The previously-installed ventilation system for Room 215A was non-functional. The original configuration for this laboratory utilized control air to manipulate dampers and an exhaust fan. This change will replace the exhaust fan control with an on-off switch and fully open the dampers for maximum flow.

MODIFICATION RECORD 13-02, ADDENDUM 1 – LETTER TO FILE (July 21, 2021)

Secondary Chemistry Modifications

This letter to Modification Record 13-02, Addendum 1, "Secondary Coolant Chemistry Control," documents, at the request of NALCO Water, the relocation the injection point of the liquid biocide agent. This move is intended reduce chemical usage through increased efficiency.

MODIFICATION RECORD 99-01, Addendum 1 – LETTER TO FILE (August 6, 2021)

Primary Coolant System Coast Down Data Collection

This letter to Modification Record 99-01, Addendum 1, "Replace Process Instrumentation Recorders - 2018," documents the utilization of the functions of the digital paperless chart recorders to generate a signal when the primary

coolant pumps are de-energized. This change allows MURR to more accurately evaluate the coast down times for the primary coolant system when the pumps are secured.

MODIFICATION RECORD 03-03, ADDENDUM 4 – LETTER TO FILE (August 8, 2021)

SaRB Fire Protection Expansion

This letter to Modification Record 03-03, Addendum 4, "Fire Protection System in the Shipping and Receiving Building," documents the expansion of the fire protection system in the Shipping and Receiving Building (SaRB) in support of an approximately 1,600 ft^2 building expansion.

MODIFICATION RECORD 93-01 – LETTER TO FILE (September 22, 2021)

Removal of DI-300 AND Associated Piping

This letter to Modification Record 93-01, "The Installation of Three New DI Tanks in the North Tower," documents the removal of the ion exchange column (DI-300) that was originally used to supply demineralized water to the facility and reactor plant.

MODIFICATION RECORD 21-02 – LETTER TO FILE (November 5, 2021)

Solenoid Cabinet Isolation Valve

This letter to Modification Record 21-01, "Reactor Containment Building Sealing Gasket Solenoid Valve Replacement," documents the addition of an additional isolation valve for the containment building airlock.

MODIFICATION RECORD 91-01 – LETTER TO FILE (November 23, 2021)

Rod Drop Timer

This letter to Modification Record 91-01, "Replacement of Mechanical Rod Drop Timers and Photoelectric Cells with Digital Rod Drop Timers and Wavelength Sensitive Photoelectric Cells," documents the addition of a fuse on the power supply to the rod drop timer circuitry. This fuse helps reduce the cycling of Breaker No. 9 located in UPS Panel No. 2.

SECTION V

NEW TESTS AND EXPERIMENTS

January 1, 2021 through December 31, 2021

The following amended tests or experiments were approved during calendar year 2021 under a Reactor Utilization Request (RUR):

RUR 406, AS AMENDED

Irradiation of Enriched Ytterbium Oxide

This RUR amendment authorizes the irradiation of up to 3.5 grams of enriched ytterbium oxide in the flux trap position of the reactor.

RUR 440, AS AMENDED

Irradiation of Tellurium Oxide

This RUR amendment authorizes the irradiation of tellurium oxide at a maximum thermal neutron flux of 1.3 E+14 $n/cm^2/s$. This change was necessitated due to an increase in the achievable thermal flux in certain graphite reflector irradiation positions due to a planned graphite reflector reconfiguration.

RUR 458, AS AMENDED

Molybdenum Metal Irradiation

This RUR amendment authorizes the irradiation of molybdenum metal at a maximum thermal neutron flux of 1.3 E+14 $n/cm^2/s$ and a maximum fluence of 3.5 E+20 n/cm^2. These changes were partly necessitated due to an increase in the achievable thermal flux in certain graphite reflector irradiation positions and partly due to an increase in end-of-irradiation activity needs.

RUR 459, AS AMENDED

Irradiation of Enriched Uranium Oxide

This RUR amendment authorizes the long-term irradiation of small quantities (approximately 36 mg) of 3.44% enriched uranium oxide pellets to support research and development efforts of Texas A&M University researchers.

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, 2021 through December 31, 2021

INSPECTIONS

The U.S. Nuclear Regulatory Commission (NRC) conducted one routine inspection reviewing special nuclear material (SNM) activities during calendar year 2021. All records and activities were found to be in compliance with NRC rules and regulations. No violations were noted.

REACTOR CHARACTERISTICS MEASUREMENTS

Fifty-seven refueling evolutions were completed in 2021. Reactor core excess reactivity verifications were performed for each refueling. The largest measured excess reactivity was 3.77%. MURR Technical Specification (TS) 3.1.a requires reactor core excess reactivity above reference core condition to be less than 9.8%.

REACTIVITY MEASUREMENTS

Five differential blade-worth measurements of the shim control blades were performed either following a planned replacement of a control blade or to ensure compliance with TS 4.2.g.

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.

Four reactivity measurements were performed to estimate the worth of various samples that are irradiated in the center test hole region of the reactor and another one to estimate the worth of the center test hole removable experiment sample canister.

SECTION VII

RADIOACTIVE EFFLUENT

January 1, 2021 through December 31, 2021

TABLE 1
SANITARY SEWER EFFLUENT

Descending Order of Activity Released for Nuclide Totals > 1.000E-02 mCi

Nuclide	Activity (mCi)
H-3	1.51E+02
Co-60	6.27E+00
S-35	3.24E+00
Te-125m	1.22E+00
Zn-65	7.81E-01
Lu-177	4.64E-01
P-32	1.88E-01
Ca-45	1.66E-01
Be-7	7.26E-02
Sc-46	5.34E-02
Mo-99	4.88E-02
In-115m	2.62E-02
Cd-115	2.31E-02
Na-24	2.09E-02
Tc-99m	2.03E-02
Fe-59	1.69E-02
Ag-110m	1.65E-02
Total H-3	**1.51E+02**
Total Other	**1.28E+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	2.25E-06	1.04E+09	350	64.1836
I-131	1.07E-12	4.98E+02	1	0.5360
H-3	2.45E-08	1.14E+07	350	0.0701
Kr-79	9.38E-09	4.35E+06	350	0.0383
Xe-131m	1.10E-07	5.13E+07	350	0.0158
C-14*	2.04E-11	9.14E-03	1	0.0068
Re-186	1.03E-11	4.76E+03	350	0.0015
Bi-214	4.74E-12	2.20E+03	350	0.0014
Sc-46	2.81E-15	1.31E+00	1	0.0009
Br-82	1.82E-12	8.46E+02	350	0.0001
Hg-203	7.85E-16	3.65E-01	1	0.0001
Os-191	1.16E-15	5.36E-01	1	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, 2021 through December 31, 2021

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 2021. All doses fluctuate around background with the exception of monitor numbers 4, 8, 9, and 45. These monitors are located near a loading dock area where packages containing radioactive material are loaded or traversed 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. Data from the fourth quarter is unavailable at this time due to changes in dosimetry provider and logistical issues related to the COVID-19 pandemic. This data will be provided in a follow-up report to the NRC once it is available.

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

TABLE 1
SUMMARY OF ENVIRONMENTAL SET 99 - SPRING 2021

Detection Limits*

Matrix	Alpha	Beta	Gamma	Tritium
Vegetation	0.99 pCi/g	9.47 pCi/g	1.20 pCi/g	7.51 pCi/mL
Soil	0.00 pCi/g	4.52 pCi/g	0.58 pCi/g	N/A
Water	0.40 pCi/g	3.58 pCi/g	186.60 pCi/L	7.04 pCi/mL
Subsurface Soil	0.00 pCi/g	4.91 pCi/g	0.44 pCi/g	N/A

Activity Levels - Vegetation

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
1V99	<MDA	17.44	<MDA	<MDA
2V99	<MDA	19.37	<MDA	<MDA
3V99	<MDA	13.80	<MDA	<MDA
4V99	<MDA	14.23	<MDA	<MDA
5V99	<MDA	13.80	<MDA	<MDA
6V99	<MDA	14.02	<MDA	<MDA
7V99	<MDA	22.79	<MDA	<MDA
10V99	<MDA	9.74	<MDA	<MDA

TABLE 1 (Cont'd)
SUMMARY OF ENVIRONMENTAL SET 99 - SPRING 2021

Activity Levels - Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
1S99	1.05	13.21	2.24
2S99	0.45	8.72	2.62
3S99	0.60	13.11	2.40
4S99	0.90	12.36	3.49
5S99	0.30	13.00	3.00
6S99	1.05	12.14	2.89
7S99	0.75	13.11	2.65
10S99	1.05	15.14	4.58

Activity Levels - Water

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/L)	Tritium (pCi/mL)
4W99	<MDA	<MDA	<MDA	<MDA
6W99	<MDA	<MDA	<MDA	<MDA
10W99	<MDA	4.79	<MDA	<MDA

Activity Levels - Subsurface Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
E99	<MDA	12.57	3.73
S99	1.05	10.97	3.79
SW99	1.05	11.82	3.43
W99	1.35	10.00	3.12
N99	1.50	11.72	3.52
NE99	1.05	10.65	4.05

* 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 100 - FALL 2021

Detection Limits*

Matrix	Alpha	Beta	Gamma	Tritium
Vegetation	1.40 pCi/g	4.16 pCi/g	1.59 pCi/g	2.85 pCi/mL
Soil	0.00 pCi/g	2.02 pCi/g	0.57 pCi/g	N/A
Water	0.00 pCi/g	2.09 pCi/g	188.47 pCi/L	3.33 pCi/mL
Subsurface Soil	0.99 pCi/g	2.08 pCi/g	0.51 pCi/g	N/A

Activity Levels - Vegetation

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)	Tritium (pCi/mL)
1V100	2.10	14.88	<MDA	<MDA
2V100	<MDA	11.96	<MDA	<MDA
3V100	<MDA	11.34	<MDA	<MDA
4V100	<MDA	13.21	<MDA	<MDA
5V100	<MDA	14.25	<MDA	<MDA
6V100	<MDA	15.08	<MDA	<MDA
7V100	<MDA	11.55	<MDA	<MDA
10V100	<MDA	19.25	<MDA	<MDA

Activity Levels - Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
1S100	0.30	9.52	3.09
2S100	1.05	6.29	3.46
3S100	1.35	7.23	3.27
4S100	0.45	7.54	3.14
5S100	0.60	6.81	2.62
6S100	0.15	4.63	2.36
7S100	0.45	3.69	2.04
10S100	0.45	8.06	4.18

TABLE 2 (Cont'd)
SUMMARY OF ENVIRONMENTAL SET 100 - FALL 2021

Activity Levels - Water

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/L)	Tritium (pCi/mL)
4W100	<MDA	4.51	<MDA	<MDA
6W100	0.30	5.01	<MDA	<MDA
10W100	0.36	12.94	1492	<MDA

Activity Levels - Subsurface Soil

Sample	Alpha (pCi/g)	Beta (pCi/g)	Gamma (pCi/g)
E100	1.05	13.89	3.64
S100	1.20	14.51	4.08
SW100	<MDA	13.47	3.17
W100	<MDA	14.10	4.11
N100	<MDA	14.82	3.59
NE100	1.20	13.99	4.13

* 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	24	25	25	N/A	74
1*	Control	N/A	23	23	26	N/A	72
2*	Control	N/A	22	24	24	N/A	70
3	W	30	0	<MDA	<MDA	N/A	0
4	SW	59	19	9	3	N/A	31
5	ENE	110	<MDA	<MDA	<MDA	N/A	0
6	NNE	84	4	2	3	N/A	9
7	ENE	55	0	<MDA	<MDA	N/A	0
8	SW	32	21	20	6	N/A	47
9	SSE	27	11	26	13	N/A	50
10	NE	139	<MDA	<MDA	<MDA	N/A	0
11	N	135	<MDA	<MDA	<MDA	N/A	0
12	NE	284	2	1	0	N/A	3
13	NNE	305	<MDA	<MDA	<MDA	N/A	0
14	S	168	<MDA	0	<MDA	N/A	0
15	SSE	74	<MDA	<MDA	<MDA	N/A	0
16	SE	113	<MDA	<MDA	<MDA	N/A	0
17	E	299	<MDA	<MDA	<MDA	N/A	0
18	NE	453	<MDA	<MDA	<MDA	N/A	0
19	NE	673	<MDA	<MDA	<MDA	N/A	0
20	NE	893	<MDA	<MDA	<MDA	N/A	0
21	SSE	239	2	<MDA	0	N/A	2
22	SE	158	<MDA	<MDA	<MDA	N/A	0
23	NW	89	2	1	1	N/A	4
24	SSW	308	<MDA	<MDA	<MDA	N/A	0
25	SSW	435	<MDA	<MDA	<MDA	N/A	0
26	SSW	365	<MDA	<MDA	<MDA	N/A	0
27	SW	170	<MDA	<MDA	<MDA	N/A	0
28	NW	229	0	0	1	N/A	1
29	NW	260	<MDA	0	<MDA	N/A	0
30	N	335	<MDA	<MDA	<MDA	N/A	0
31	NNE	677	0	<MDA	<MDA	N/A	0
32	NW	760	0	<MDA	1	N/A	1
33	ESE	578	<MDA	<MDA	<MDA	N/A	0
34	ENE	596	<MDA	<MDA	<MDA	N/A	0
35	SSE	477	2	4	2	N/A	8
36	SE	446	<MDA	<MDA	<MDA	N/A	0
37	NE	732	<MDA	<MDA	<MDA	N/A	0
38	NW	487	2	3	2	N/A	7
39	W	528	<MDA	<MDA	<MDA	N/A	0
40	N	503	<MDA	<MDA	<MDA	N/A	0
41	NE	161	<MDA	<MDA	<MDA	N/A	0
42	In Building	N/A	8	9	8	N/A	25
43	In Building	N/A	3	3	1	N/A	7
44	SW	102	0	0	<MDA	N/A	0
45	SE	94	6	9	0	N/A	15
46	SE	105	4	2	<MDA	N/A	6

* The control monitors are approximately 10 miles NW of MURR, and gross values are shown.

** These totals exclude 4th Quarter data, which will be provided to the NRC in a follow-up report once it is available.

TABLE 4
NUMBER OF FACILITY RADIATION AND CONTAMINATION SURVEYS

Month	Radiation	Surface Contamination*	Air Samples**	Radiation Work Permits	Receipt of Radioactive Materials
January	125	125	42	20	3
February	84	84	36	13	7
March	111	111	45	17	8
April	117	117	43	20	12
May	93	93	44	10	13
June	108	108	48	9	20
July	126	126	50	10	17
August	102	102	47	18	11
September	119	119	47	10	16
October	130	130	48	11	6
November	101	101	43	16	8
December	94	94	46	19	3
TOTAL	**1,310**	**1,310**	**539**	**173**	**124**

* 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.

Miscellaneous Note
During calendar year 2021, MURR shipped 1,525 cubic feet of low-level radioactive waste containing 20,249 mCi of activity.

SECTION IX

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

January 1, 2021 through December 31, 2021

Total Personnel Dose (mrem) by Dosimetry Group

	BCS	DO	FOE	HC	HP	IRR	NA	NS	NSP	OPS	PRD	QA	RES	RP	SH	TEE	Total
January	8	32	54	170	302	0	5	71	99	771	186	36	14	17	52	12	1,829
February	9	1	34	141	160	12	92	7	109	706	155	41	12	33	39	33	1,584
March	10	9	68	140	295	0	13	7	641	887	333	67	3	11	38	15	2,537
April	13	9	76	86	261	6	13	7	44	1,752	194	53	15	25	81	8	2,643
May	13	0	30	136	200	57	1	45	76	808	202	74	14	38	41	13	1,748
June	28	13	165	117	397	79	23	17	50	939	179	56	6	27	30	1	2,127
July	33	19	157	TR	193	145	32	66	114	848	248	30	4	39	55	27	2,010
August	10	41	275	TR	200	246	83	29	297	1,316	257	84	21	32	51	6	2,948
September	6	26	33	TR	226	147	15	136	161	855	178	55	6	14	28	6	1,892
October	18	17	150	TR	327	139	29	34	123	886	203	96	25	31	44	14	2,136
November	10	1	244	TR	702	416	32	35	342	2,325	456	245	33	40	193	24	5,098
December																	
Total for Year	**158**	**168**	**1,286**	**790**	**3,263**	**1,247**	**338**	**454**	**2,056**	**12,093**	**2,591**	**837**	**153**	**307**	**652**	**159**	**26,552**
Monthly Average	**13**	**14**	**107**	**66**	**272**	**104**	**28**	**38**	**171**	**1,008**	**216**	**70**	**13**	**26**	**54**	**13**	**2,213**
Highest WB (annual)	**25**	**22**	**573**	**TR**	**586**	**535**	**27**	**139**	**504**	**737**	**254**	**214**	**25**	**61**	**122**	**24**	
High Extremity (annual)	**111**	**NM**	**2,799**	**TR**	**643**	**1,326**	**1,261**	**65**	**6,581**	**2,510**	**9,140**	**1,517**	**100**	**462**	**631**	**84**	

BCS-Business & Central Services
DO-Director's Office
FOE-Facilities Operations & Engineering
HC-Hot Cell
HP-Health Physics
IRR-Irradiations
NA-Neutron Activation
NS-Neutron Scattering
NSP-NorthStar Partners
OPS-Operations
PRD-Production
QA-Quality Assurance
RES-Research
RP-Radiopharmaceutical
SH-Shipping
TEE-Trace Elemental Epidemiology
WB-Whole Body
NM-Not Monitored
OB-Obsolete
TR-Transfer to New Group

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).

Due to COVID-19 and supply issues, dosimetry services scheduling experienced interruptions from October through December, 2021. This caused dosimetry-wear periods to be uneven from month-to-month. December 2021 dosimeters were only issued to personnel with 11 days remaining in December, making November badges almost two months worth of data. This report excludes data for the remaining 11 days of December 2021 and will be provided to the NRC in a follow-up report once it is available.