MISSOURI S&T

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Formerly University of Missouri-Rolla

June 1, 2017

Dear Sir:

Please find enclosed the Annual Progress Report 2016-2017 for the Missouri Science and Technology Reactor (License R-79, Docket No. 50-123). This report is being filed under the reporting requirements of our Technical Specifications. A copy of this report is also being sent to our NRC Project Manager, Mr. Spyros Traiforos.

Sincerely,

William Bonzer

William Bonzer
Reactor Manager

mh

Enclosure

cc: Mr. Spyros Traiforos (NRC)
Document Control Desk (NRC) ✓
American Nuclear Insurers, c/o Librarian
University of Missouri-Columbia Research Reactor (MURR)
Interim Chancellor Dr. Christopher Maples (MST)
Michelle Bresnahan, Radiation Safety Officer (MST)
Dr. Hyoung Lee, Chair of Nuclear Engineering Dept. (MST)
Dr. Mark Fitch, Chairman, Radiation Safety Committee (MST)
Dr. Braden Lutz, Chair Mining and Nuclear Engineering Dept. (MST)

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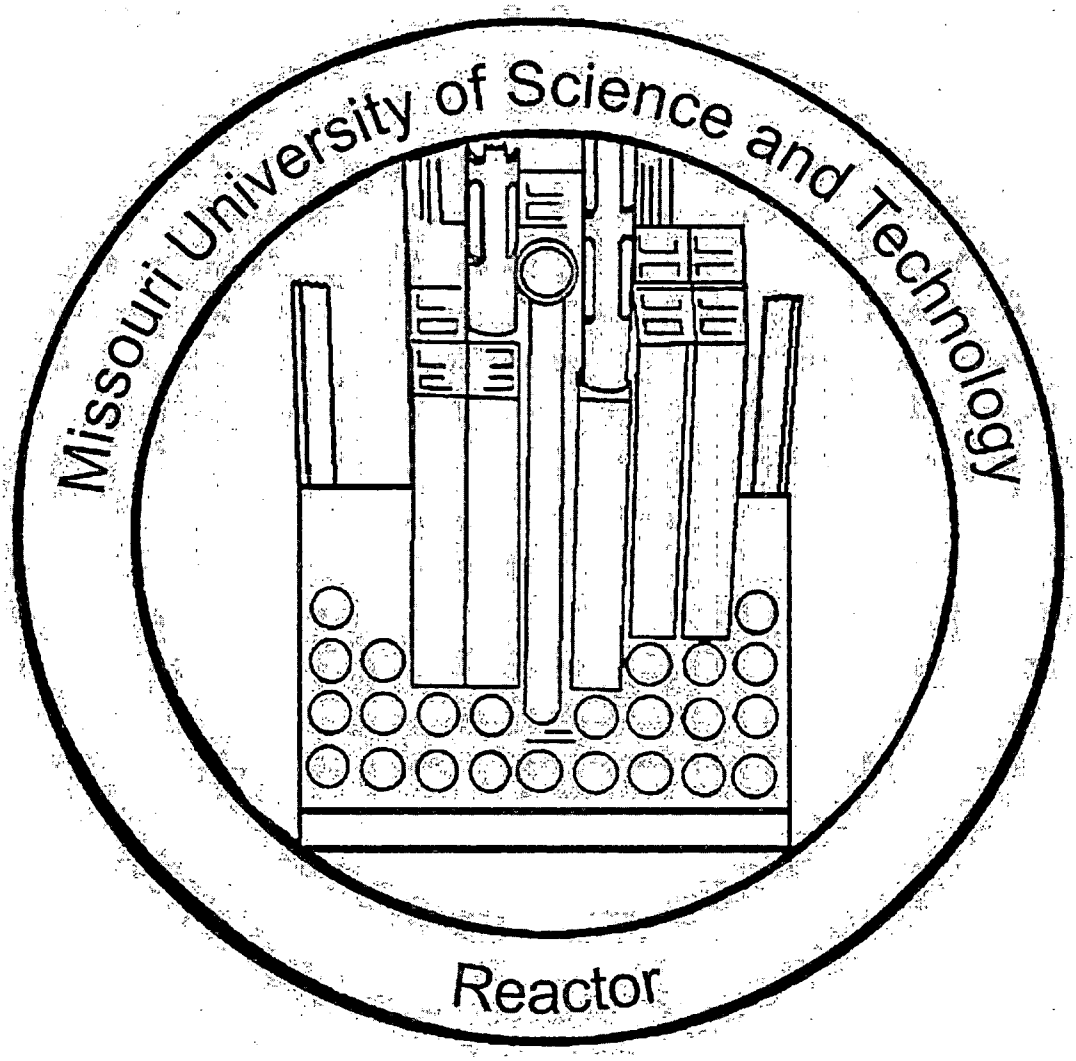
NRR

PROGRESS REPORT

2016-2017

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

REACTOR



PROGRESS REPORT

FOR THE

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

(FORMALLY THE UNIVERSITY OF MISSOURI-ROLLA)

NUCLEAR REACTOR FACILITY

April 1, 2016 to March 31, 2017

Submitted to

The United States Nuclear Regulatory Commission

And

Missouri University of Science and Technology

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APPENDIX A: STANDARD OPERATING PROCEDURES CHANGED DURING THE 2016-2017 REPORTING YEAR

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SUMMARY

During the 2016-2017 reporting period, the Missouri University of Science and Technology Reactor (MSTR) was in use for 285.42 hours. The major part of this time, about 90%, was used for class instruction, research, and training purposes.

The MSTR operated safely and efficiently over the past year. No significant safety-related incidents or personnel exposures occurred.

The reactor facility supported several Missouri University of Science and Technology (Missouri S&T) courses and operator training over the year for more than 5,800 student-hours. More than 2,600 visitors visited the reactor during the past year. More than 535 participants, mostly high school students, were in the U.S. Department of Energy Reactor Sharing Program.

The reactor produced 8,791.63 kilowatt-hours of thermal energy using approximately 0.556 grams of uranium. A total of 214 samples were neutron irradiated in the reactor with the majority being analyzed in the reactor counting laboratory.

1.0 INTRODUCTION

This progress report covers activities at the Missouri University of Science and Technology Reactor (MSTR) Facility for the period April 1, 2016 to March 31, 2017.

The reactor operates as a University facility. It is available to the faculty and students from various departments of the University for their educational and research programs. Several other college and pre-college institutions also make use of the facility. The reactor is also available for the training of personnel from commercial concerns with legitimate interest in our facility use.

1.1 Background Information

The Missouri University of Science and Technology Reactor (MSTR) (formally University of Missouri-Rolla Reactor) attained initial criticality on December 9, 1961. The MSTR was the first operating nuclear reactor in the State of Missouri. The Bulk Shielding Reactor at Oak Ridge National Laboratory is the basis for the reactor's design. The reactor is a light water, open pool reactor cooled by natural convective flow. The fuel is MTR plate-type fuel. The initial licensed power was 10 kW. The licensed power was up-graded to 200 kW in 1966. During the summer of 1992, the reactor fuel was converted from high-enriched uranium fuel to low-enriched uranium fuel.

The facility is equipped with several experimental facilities including a beam port, thermal column, three pneumatic rabbit systems, and several manual sample irradiation containers and systems. The facility also contains a counting laboratory that has both gamma and alpha spectroscopy capabilities. The gamma spectroscopy system includes germanium and sodium-iodide detectors, associated electronics, state-of-the-art data acquisition, and spectrum analysis software. The alpha spectroscopy system consists of a surface barrier detector and data acquisition equipment. Additionally, there is a liquid scintillation counter, thermos-luminance dosimeter reader, digital neutron radiography imager, and x-ray imager for student and faculty usage.

1.2 General Facility Status

The MSTR operated safely and efficiently over the past year. No significant safety-related incidents or personnel exposures occurred.

An independent auditor from the University of Missouri Research Reactor (MURR) audited the reactor facility on November 30, 2016. There were no significant areas of concern. There is an agreement between MSTR and MURR to audit each other. This has been a very beneficial arrangement for both facilities involved.

The reactor staff has continued to review the operation of the reactor facility in an effort to improve the safety and efficiency of its operation and to provide conditions conducive to its utilization by students and faculty. An "outreach" program, implemented over the past few years, has been continued in order to let both students and faculty in a number of departments across campus know that the reactor could be used to enhance course work and research. As a result, additional classes have been using the reactor facility to augment their programs, including:

1. Chemistry 2, 'General Chemisty Laboratory'
2 Civil Engineering 310, 'Senior Design Class'
3. Engineering Management 386, 'Safety Engineering Management'
4. Mechanical Engineering 229, 'Energy Conversion'
5. Life Sciences 352, 'Biological Effects of Radiation'
6 Physics 107, 'Modern Physics'
7. Physics 207, 'Modern Physics II'
8. Physics 322, 'Advanced Physics'
9. Materials Science & Engineering 348, 'Energy Materials'
10. Materials Science & Engineering 448, 'Advanced Energy Materials'

SOPs were revised, over the past year in order to improve and keep current the operations and efficiency of the MSTR. The following is a list of SOPs revised during the reporting period:

1. SOP 112 Fuel Management
2. SOP 311 Receipt of Licensed Materials
3. SOP 501 Emergency Procedures for Reactor Building Evacuation
4. SOP 501 Emergency Procedures for Reactor Building Evacuation
5. SOP 702 Irradiation Request Forms

2.0 REACTOR STAFF AND PERSONNEL

2.1 Reactor Staff

Name	Title
Dr. Hyoung-Koo Lee	Reactor Director
Mr. William Bonzer	Reactor Manager & Senior Operator
Ms. Maureen Henry	Office Support Assistant III
Mr. Craig Reisner	Senior Reactor Operator
Mr. Anthony Alchin	Electronic Technician III & Senior Operator

2.2 Licensed Operators

Name	License
1. William Bonzer	Senior Operator
2. Craig Reisner	Senior Operator
3. Anthony Alchin	Senior Operator
4. Cody Stuchal[1]	Reactor Operator
5. Jonathan Scott	Reactor Operator
6. Andrew Bingham	Reactor Operator

7. Garrett Jones[1]	Reactor Operator
8. Steve Wagstaff	Reactor Operator
9. Wesley Tucker[1]	Reactor Operator
10. Matthew Caddell[1]	Reactor Operator
11. Jacob Stueck	Reactor Operator
12. Justen Vinyard[1]	Reactor Operator
13. Kelly Jacobs[2]	Reactor Operator
14. Philip Rexing[2]	Reactor Operator
15. Laura Pirrone[3]	Reactor Operator
16. Alexander Watson[3]	Reactor Operator
17. David Clark[3]	Reactor Operator

1 Termination Date May 18, 2016
2 Effective Date August 10, 2016
3 Effective Date February 23, 2017

2.3 Radiation Safety Committee

The Radiation Safety Committee meets quarterly. The committee met on 6/9/2016, 9/16/2016, 12/15/2016 and 3/23/2017 during the reporting period. The committee members are listed below.

Name	Department
1. Dr. Mark Fitch	Civil Engineering
2. Ms. Michelle Bresnahan	Environmental Health and Safety Services
3. Mr. William Bonzer	Nuclear Reactor
4. Mr. Randy Stoll[2]	Business Services
5. Dr. David Wronkiewicz	Geological Sciences & Geology
6. Dr. Shoaib Usman	Mining & Nuclear Engineering
7. Dr. Fadha Al Falahi	Environmental Health and Safety Services
8. Dr. Yue-wern Huang	Biological Sciences
9. Dr. Amitava Choudhury	Chemistry
10. Dr. Carlos Castano	Mining & Nuclear Engineering
11. Mr. Tony Hunt	Environmental Health and Safety Services

12. Dr. Muthanna Al Dahhan[1]	Chemical and Biological Engineering
13. Dr. Joseph Graham[1]	Mining & Nuclear Engineering
14. Mr. John Mollenkamp[3]	Business Services

1 Joined the committee on September 2016
2 Retired from the committee on December 2016
3 Joined the committee on January 2017

2.4 Health Physics

The Environmental Health and Safety (EHS) Department provides the health physics support for the Missouri S&T Reactor. The EHS Department is organizationally independent of the Reactor Facility operations group. Health Physics personnel are listed below

Name	Title
1. Ms. Michelle Bresnahan	Director of Environmental Health and Safety
2. Tony Hunt	Assistant Director of Environmental Health and Safety
3. Dr. Fadha Al Falahi	Health Physicist
4. Mr. Alex Swearingen	Health Physics Technician (part time)
5. Mr. Brandon Ochterbeck	Health Physics Technician (part time)

3.0 REACTOR OPERATIONS

Core Confirmation 122W is presently in use. The "W" mode core is completely water reflected and used for normal reactor operations. The "T" mode (core positioned near graphite thermal column) may be used for various experiments, including beam port and thermal column experiments.

Table 3-1 presents pertinent core data and Figure 3-1 shows the core configuration of core 122W. The excess reactivity, shutdown margin, and rod worth's were measured in cold, clean conditions.

Table 3-1. Core 122W Technical Data

Parameter	Value
Rod 1	3.958% Δk/k
Rod 2	3.239% Δk/k
Rod 3	1.778% Δk/k
Reg Rod	0.232% Δk/k
Excess Reactivity	0.640% Δk/k
Shutdown Margin*	4.377% Δk/k

*Assumes Rod 1 (highest worth rod) and Reg Rod are fully withdrawn.

A									
B						S			
C					C-4	F-5	F-11	F-17	
D				F-4	F-8	F-14	C-1	F-10	F-1
E				F-9	C-3	F-12	C-2	F-7	F-3
F				CR	F-15	HC	F-13	BR	F-6

Figure 3-1. MSTR Core 122W Configuration

KEY TO PREFIXES

F - Standard Elements
C - Control Elements
HF - Half Element
BR - Bare Rabbit
CR - Cadmium Rabbit
HC - Hot Cell Rabbit
S - Source Holder

Table 3-2: Unscheduled Shutdowns

Date	Type of Rundown/Cause and Corrective Action Taken
	RUNDOWNS
04/20/2016	Action: 120% Demand Rundown Cause: Operator downscaled too early. Corrective Action Taken: No corrective action taken. SRO on Duty granted permission to continue decrease in power.
11/08/2016	Action: 120% Demand Rundown Cause: Student did not upscale at the proper time. Corrective Action Taken: Student informed to pay attention to all instrumentation. SRO on Duty granted permission to restart reactor.
01/17/2017	Action: Reg Rod on Insert Limit Rundown Cause: Trainee went into auto without raising the Reg Rod to 15 inches. Corrective Action Taken: No corrective action needed other than to remind trainee to follow SOPs. SRO on Duty granted permission to restart reactor.
	UNPLANNED SHUTDOWNS
Date	**Type of Unplanned Shutdown, Cause and Corrective Action Taken**
	Unplanned Shutdowns
11/18/2016	Action: Power Outage Corrective Action Taken: None. Power Restored.

SRO granted permission to restart reactor.

12/01/2016 Action: SCRAM after Fire Alarm

Corrective Action: None. Reactor secured for rest of day following cessation of fire alarm incident.

12/08/2016 Action: Power to half of campus cut during response to a fire in Electrical Engineering Building.

Corrective Action: None. Reactor secured for rest of day.

Table 3-3: Maintenance

Date	Type of Maintenance
08/09/2016	Issue: Log N Drawer Linear output stuck at 9.8%. Corrective Action: Troubleshooting narrowed it down to the Log Ampl, CIC card PCA 100500-103. Op Amps U8 was found to be malfunctioned. Replacing U8 created a new problem due to the very sensitive nature of the board that could not be fixed. New board was ordered. Upon arrival the boards were swapped and the Log N drawer worked as expected. Calibration was done to ensure proper operation and the reactor was returned to operation on 10/26/2016.
12/01/2016	Thermocouple 2 (Outlet Temp) reinserted after being removed due to an issue with channel 2 of the Recorder reading abnormally high. Corrective Action: Recorder Channel 2 was found to be faulty. Temp recorder and CAM recorder were swapped. Programs reinstalled. Weekly check was performed to ensure trips operated as expected.

Table 3-4. Reactor Utilization

1.	Reactor use	258.42 hrs.
2.	Time at power	186.07 hrs.
3.	Energy generated	8,791.63 kW/hrs.
4.	Total number of samples, neutron irradiated	214
5.	U-235 Burned	0.385 g
6.	U-235 Burned and Converted	0.454

Table 3-5. Experimental Facility Usage

Facility	Hours
Bare Rabbit Tube	39.81 hrs.
Cadmium Rabbit Tube	0.00 hrs.
Beam Port	0.0 hrs.
Thermal Column	0.0 hrs.
Other Core Positions	12.58 hrs.
Hot Cell	0.0 hrs.
Gamma Exposures	0.0 hrs.
Total	52.39 hrs.

4.0 EDUCATIONAL UTILIZATION

The reactor facility supported several Missouri S&T courses in the past year for a total of 2,824 student-hours. The number of Missouri S&T students utilizing the facility was 533. Additional usage of the reactor facility included operator licensure training adding a minimum of 3,000 student-hours of activity. This usage is a direct result of an aggressive and continuing campus wide "outreach" program. The reactor facility provided financial support for two students with hourly wages. Additionally, students from several universities, colleges and high schools have used the facility.

Table 4-1 lists Missouri S&T classes taught at the facility along with associated reactor usage for this reporting period.

Table 4-1 Missouri S&T Classes at Reactor Facility

Semester	CLASS NUMBER/TITLE	# OF STUDENTS	Time at the Reactor (hrs.)	Students Hours
SP 2016	NE 4438	12	42	504
SP 2016	NE 2406	30	12	360
SP 2016	NE 1105	35	1	35
SP 2016	NE 4312	50	2	100
SP 2016	Chem Labs	218	2	436
FS 2016	NE 1105	33	1	33
FS 2016	NE 2406	24	18	432
FS 2016	NE 4428	32	7	224
SP 2017	NE 1105	25	2	50
SP 2017	NE 4312	34	5	170
SP 2017	NE 4438	20	15	300
SP 2017	NE 2406	20	9	180

The Reactor Sharing Program, previously funded by the U.S. Department of Energy, was established for colleges, universities, and high schools that do not have a nuclear reactor. This past year, more than 540 students and instructors from at least 100 institutions participated in the program. Table 4-2 lists those schools and groups that were involved in this year's Reactor Sharing Program. The majority of participants were high school students. MSTR coordinates with the Missouri S&T Admissions Office to schedule high school students to see other items of interest at Missouri S&T after they have visited the reactor facility. The students visited the Missouri S&T Chapter of American Nuclear Society, the

Computer Integrated Manufacturing Lab, the Foundry, Ceramics Engineering, Mineral Museum, Computer Center, Experimental Mine, Solar Car, Electron Microscope, and Stonehenge. The Reactor Sharing Program serves as a strong campus-wide recruiting tool by attracting high school students to the university and hopefully sparking some interest in nuclear engineering, science, and technology.

Table 4-2 Reactor Sharing Program

DATE	EVENT	VISITORS	TIME (hrs.)
4/2016	Visitor Tours	10	5.5
	Lebanon High School	24	1
5/2016	Visitor Tour	8	3.5
	Rolla Police Department	9	1
6/2016	Visitor Tours	9	1
	Jackling Camp	92	3.5
	Nuclear Engineering Camp	33	5
7/2016	Visitor Tours	28	5
	Police Safety Meeting	5	1
	Jackling Camp	67	3.5
	Fort Leonard Wood	20	3
8/2016	Visitors Tours	8	1.5
	Ozark Groups	15	1
9/2016	Visitor Tours	9	3.5
	St. Charles Community College	8	1
10/2016	Visitor Tours	2	0.5
	Open House	27	1
	Boy Scouts	33	1.5
11/2016	Elton High School	23	1.5
	East Central College	13	2
12/2016	University of Illinois	6	4.5
1/2017	Visitor Tours	3	0.5
2/2017	Visitor Tours	8	1
	Boy Scouts	38	1.5
	Marketing Commission Tour	18	1.5
	Out of State Counselors	22	2
3/2017	Visitor Tours	7	14

The reactor staff continues to educate the public about applications of nuclear science. Over 2,600 persons visited the facility during this reporting period. Tour groups are typically given a brief orientation and/or demonstration by a member of the reactor staff.

5.0 REACTOR HEALTH PHYSICS ACTIVITIES

The health physics activities at the Missouri S&T Reactor facility consist primarily of radiation and contamination surveys, monitoring of personnel exposures, airborne activity, pool water activity, and waste disposal. Releases of all by-product material to authorized, licensed recipients are surveyed and recorded. In addition, health physics activities include calibrations of portable and stationary radiation detection instruments, personnel training, special surveys and monitoring of non-routine procedures.

5.1. Routine Surveys

Monthly radiation exposure surveys of the facility consist of direct gamma and neutron measurements. No unusual exposure rates were identified. Monthly surface contamination surveys consist of 20 to 40 swipes counted separately for alpha and beta/gamma activity. No significant contamination outside of contained work areas was found.

5.2. By-Product Material Release Surveys

There were no shipments of by-product material released off-campus. There were no by-product releases on campus.

5.3. Routine Monitoring

Thirty-six reactor facility personnel and students involved with the operations in the reactor facility are currently assigned Mirion Technologies, Thermo-Luminescent dosimeters (TLDs). Three of the Reactor Staff have beta, gamma, neutron dosimeters and a three TLD rings which are read twice monthly. There are five area beta, gamma, neutron dosimeters which are also read twice monthly. There are three environmental TLDs outside the reactor building which are read quarterly. There are also five other beta, gamma, neutron dosimeters used by the health physics personnel and four other area beta, gamma, neutron dosimeters that are read monthly. The remaining dosimeters detect beta and gamma radiation only and are read monthly. In addition, seven digital, direct-reading dosimeters are used for visitors and high radiation work. There have been no significant personnel exposures during this reporting period. Visitors are monitored with direct reading dosimeters. No visitors received any reportable or significant exposure.

Airborne activity in the reactor bay is monitored by a fixed filter; particulate continuous air monitors (CAM). Low levels of Argon-41 are routinely produced during operations.

Pool water activity is monitored monthly to ensure that no gross pool contamination or fuel cladding rupture has occurred. Gross counts and spectra of long-lived gamma activity are compared to previous monthly counts. From April 2016 through March 2017 sample concentrations averaged 4.38×10^{-6} μCi/ml.

Release of gaseous Ar-41 activity through the building exhausts is determined by relating the operating times of the exhaust fans and reactor power during fan operation to previously measured air activity at maximum reactor power. During this period, an estimated 26,890.67 μCi of Ar-41 was released into the air.

5.4. Waste Disposal

Solid waste, including used water filters, used resins, and contaminated paper/gloves is stored and/or transferred to the campus waste storage area for later shipment to a commercial burial site. Water is analyzed for radioactive contamination and approval is required before the water is released. During this period there are only one waste picked up from the reactor facility.

5.5. Instrument Calibrations

During this period, portable instruments and area monitors were calibrated annually.

6.0 PLANS

The reactor staff will be involved in several major projects during the next reporting period; 1) creating a restricted area outside the reactor building, 2), replacing control room equipment and 3) continuation of the reactor operator training program.

6.1 Restricted Area Created Outside Reactor Building

The reactor building's east wall on the exterior side has levels of radiation approaching the 10 CFR 20.1301(a) (1) limit of 0.1 rem in a year for an unrestricted area. Options for reducing these levels of radiation within the reactor building have been very limited. The Radiation Safety Officer for the Missouri University of Science and Technology is requiring a restricted area created at the reactor building's exterior east side to eliminate this issue. The restricted area will be fifteen by thirty feet, adjacent to the east wall and enclosed by a tall chain link fence. The public will not have access within the fenced area.

6.2 Replacing Control Room Equipment

A process of replacing individual control room instrumentation is starting in 2017. Equipment to be replace will be selected on a priority basis of what needs replaced sooner than later. Control room equipment replacement will have a thorough analysis of a 10 CFR 50.59 review process. The reactor staff will present the completed 10 CFR 50.59 review to the Radiation Safety Committee as required by MSTR Technical Specifications.

6.3 Reactor Operator Training

The MSTR had five students obtain their license of Reactor Operator. The reactor staff is limiting operator training to only ten students with a very strong desire to obtain the license and assist reactor staff with reactor operations. The new training program has proven to be effective in keeping the students that want the license and work with reactor staff. At the end of the reporting period, six students were training for an operator's license to take in the fall of 2017.

APPENDIX A.

STANDARD OPERATING PROCEDURES

CHANGED DURING THE 2016-2017

REPORTING YEAR

1. An individual will be designated in writing as the fuel custodian. He will be responsible for the reactor fuel and special nuclear materials. His duties will be to take physical inventory as required by the NRC (annually) and to report production and consumption of special nuclear material as required by DOE (annually). Rev

2. A physical inventory will be made at intervals prescribed by the NRC (at present, yearly). The custodian or his designee shall satisfy himself (preferably by direct examination) that the report contains all elements on previous inventory plus items received less items shipped. Rev

3. Records of the reactor power history will be maintained in such a manner that the total kilowatt-hours for the reactor core can be calculated, using the Excel spread that was created to calculate Fuel Burn-up. Rev

4. Burn-up and production of special nuclear material will be reported at intervals as prescribed by the DOE (annually). Rev

Revised By: Craig Reisner

Approved By: William Bonzer

A. PURPOSE

To assure compliance with Licensed Material quantity limits at the Reactor Facility.

B. PRECAUTIONS, PREREQUISITES, AND LIMITATIONS

1. This procedure is not intended to serve as sole guidance for receipt of licensed materials. The scope of this procedure is limited to assuring compliance with inventory limits specified in the license.

2. This procedure should be performed prior to the receipt of any licensed material. Licensed materials include enriched uranium (e.g. fuel, fission chamber, flux foils) and sealed PuBe sources.

C. PROCEDURE

1. Complete the Receipt of Licensed Material Approval Form as follows:

   a. Determine the amount of licensed material onsite by examining the latest DOE/NRC 742, 742C and 741C forms. Record this information in the "Present Onsite Inventory" column of the approval form.

   b. Specify the amount of licensed material to be received in an incoming shipment in the "Inventory of Proposed Shipment" column of the approval form.

   c. Project the total amount of licensed material that will be present after the incoming shipment is received by summing values in the "Present Onsite Inventory" and "Inventory of Proposed Shipment" columns.

Rev

d. Compare the projected total amount of licensed material calculated in Step 1.c. with current license limits to assure that the projected total will comply with license limits.

e. Record the anticipated date of the shipment.

2. Have the Reactor Director or Reactor Manager review and approve the form prior to receipt of any licensed material shipment.

Revised By: William Bonzer

William Bonzer

Approved By: William Bonzer

William Bonzer

RECEIPT OF LICENSED MATERIAL APPROVAL FORM

Material Description	License Limit	Present Onsite Inventory	Inventory of Proposed Shipment	Projected Inventory After Shipment
1. U-235 (< 20% Enrichment)	5.50 kg	_____	_____	_____
2. Sealed Sources (Pu-239)	0.200 kg	_____	_____	_____
3. Fission Chambers and Flux Foils (U-235)	0.050 kg	_____	_____	_____

Rev

4. Does Projected Material Inventory Meet License Limits? _____ Yes _____ No

5. Approximate Anticipated Date of Shipment _____

Performed by: Title _____ Date: _____

Signature _____

Approved by: Signature _____ Date: _____
(Reactor Director or Reactor Manager)

Revised By: William Bonzer

Approved By: William Bonzer

MISSOURI S&T EMERGENCY PHONE LIST

Reactor Staff	CELL	HOME	WORK
William Bonzer, Manager, SRO	578-9463	368-0318	341-4384
Craig Reisner, Senior Reactor Operator	573-247-7557	573-729-7277	341-4291
Anthony Alchin, Electronics Technician III	816-274-1771		341-6617
Maureen Henry, Office Support Ast. III	201-7275		341-6016

University Administrative Staff			
Michelle Bresnahan, EHS Director, Radiation Safety Officer	314-239-7751		341-4305
Doug Roberts Director Missouri S&T Police	202-3689		341-4300
Dr.Cheryl B. Schrader, Chancellor	201-7392	341-7141	341-4116
Walter Branson, VC Chancellor Finance & Adm.	260-402-0317		341-4122
James Packard, Director Physical Facilities		578-8167	341-4252
Dr. Goodman DO, Director Student Health Services			341-4284
Dr.Hyoung Lee,Chair of Nuclear Eng, Reactor Director	573-202-4665		341-4585
Dr.Ralph Flori Jr, Interim Chair of Mining and Nuclear	578 -3130		341-7583
Fadha Ahmed, Health Physicist EHS-Missouri S&T	314-960-9211	636-223-2054	341-7014

Local	
Missouri S&T Police	341-4300
Rolla City Police	911
Rolla Fire Department	911
Phelps County Hospital	911
Rolla Emergency Management Agency	911

State Agencies		
Missouri Highway Patrol		(573) 368-2345
Missouri State Emergency Mgt. (24 hr.)		(573) 751-2748
Missouri Dept. of Natural Resources (24 hr.)		(573) 634-2436
Missouri Bureau of Environmental Epidemiology	(573) 751-6160	(573) 751-4674 (24hrs)

Federal Agencies	
NRC, Operations Center	(301) 951-0550
NRC Duty Officer (24 hr.)	(301) 816-5100

Other		
American Nuclear Insurers		(860) 682-1301
Radiation Emergency Assistance Center	(865) 576-3131	(865) 576-1005 (24hrs)

Revised By: Maureen Henry Approved: William Bonzer

Maureen Henry William Bonzer

MISSOURI S&T EMERGENCY PHONE LIST

Reactor Staff	CELL	HOME	WORK
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James Packard, Director Physical Facilities		578-8167	341-4252
Dr. Goodman DO, Director Student Health Services			341-4284
Dr.Hyoung Lee, Chair of Nuclear Eng, Reactor Director	573-202-4665		341-4585
Dr. Braden Lusk, Chair of Mining and Nuclear	620-960-1645		341-4174
Fadha Al Falahi, Health Physicist EHS-MS&T	314-960-9211	636-223-2054	341-7014

Local	
Missouri S&T Police	341-4300
Rolla City Police	911
Rolla Fire Department	911
Phelps County Hospital	911
Rolla Emergency Management Agency	911

State Agencies		
Missouri Highway Patrol		(573) 368-2345
Missouri State Emergency Mgt. (24 hr.)		(573) 751-2748
Missouri Dept. of Natural Resources (24 hr.)		(573) 634-2436
Missouri Bureau of Environmental Epidemiology	(573) 751-6160	(573) 751-4674 (24hrs)

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Radiation Emergency Assistance Center	(865) 576-3131	(865) 576-1005 (24hrs)

Revised By: Maureen Henry Approved: William Bonzer

Maureen Henry William Bonzer

A. PURPOSE

To provide for the thorough Reactor Staff review of all experiments to be irradiated by neutrons from the MSTR. The review evaluates potential 1) reactivity effects, 2) dose hazards to the experimenter, and 3) hazards to the reactor.

B. PRECAUTIONS, PREREQUISITES OR LIMITATIONS

1. All sample irradiations must be performed under an approved Irradiation Request Form (IRF) with two approval signatures.

2. All materials to be irradiated are to either be corrosion resistant or encapsulated in corrosion resistant containers.

3. Approved IRFs remain valid for future irradiations.

4. IRFs will be numbered sequentially following the last two digits of the current year (e.g. 95-1, 95-2, etc.).

5. Radiation Safety Committee approval is required for

   a. experiments worth more than 0.4% Δk/k,
   b. explosive materials,
   c. fueled experiments, or
   d. untried experiments.

6. The total of the absolute values of all experiments is limited to 1.2% Δk/k. | Rev

7. Experiments having moving parts shall not have an insertion rate greater than 0.05% Δk/k per second.

8. Cooling is to be provided as needed to prevent the surface temperature of an experiment being irradiated from exceeding the boiling point of the pool.

C. PROCEDURE - IRRADIATION REQUEST FORM

The IRF should be completed according to the following steps:

1. **IRRADIATION REQUEST** - This section of the IRF should be completed by the experimenter.

    a. **Sample Description** - Describe the sample material to be irradiated (e.g. dried tobacco leaves, powdered milk, gold foil, etc.)

    b. **Physical Form** - Specify the physical form of the sample material (e.g, powder, ash, liquid, etc).

    c. **Encapsulation** - Check the box marked "Poly-vial" or check "other" and describe.

    d. **Irradiation Location** - Specify the irradiation facility to be used. More than one facility may be authorized on a single IRF. If "Other" is specified, describe the irradiation location (for example: "wire stringer in Grid Position C-3").

    e. **Irradiation Limits** - Specify the irradiation limits as follows:

        1) **Power** - Specify the maximum reactor power for irradiation. Samples may **NOT** be irradiated at powers higher than specified.

        2) **Time** - Specify the irradiation time for the sample(s) at the maximum power. Samples may be irradiated at lower powers for times longer than the specified irradiation time as long as the total fluence (i.e. kW-hrs) does not exceed the product of the specified maximum power and irradiation time.

        3) **Mass** - Specify the maximum sample mass (grams) to be irradiated in any single irradiation.

    Handwritten revisions to the limits are allowed bsed on the measured dose rate from the initial irradiation. Assume dose rate is a linear function of power, irradiation time, and sample mass. Revised irradiation limits require the review and approval of either the SRO on Duty, Reactor Manager, or Reactor Director as signified by their initials with dates. | Rev

f. **Expected Dose Rate** - Specify the expected 1 foot dose rate when the sample comes out of the reactor based on one of the categories below:

Experience - The expected dose rate may be based on measurements made during previous similar irradiations. In such instances, record the IRF number of the previous similar irradiation.

Calculations - The expected dose rate may be calculated using the DR=6CE rule (or other appropriate method) where DR is the 1 foot dose rate in mrem/hr, C is the expected activity in mCi, and E is the gamma energy in MeV. The expected activity can be calculated using $A = N\sigma\varphi(1 - e^{-\lambda t_{irr}})$where N is the number of target atoms, σ is the cross section, φ is the neutron flux, λ is the decay constant and t_{irr} is the irradiation time.

Completely Unknown - A trial irradiation is required if the expected dose rate is completely unknown. The irradiation limits for a trial irradiation are normally reactor power $\leq$ 2 kW, irradiation time $\leq$ 1 minute, and sample mass $\leq$ 1 gram. The reviewers may approve different trial irradiation limits at their discretion. Dose rates for higher powers, masses and times can then be linearly extrapolated based on the measured dose rate resulting from the trial irradiation.

g. **Reactivity Worth** - Estimate the reactivity worth of the sample based on one of the categories below:

Default - A default reactivity worth of <0.05% Δk/k may be used for the rabbit facilities if the sample mass is less than 7 grams. A default reactivity worth for core periphery stringers of <0.1% Δk/k may be used for holders with a volume of 35 cm^3 or less and a sample mass of 7 grams or less. (Note: The default mass and location values are based on a report by Wagner, 1992.) Beamport and thermal column irradiations have a default reactivity of 0.0%.

Experience - The estimated reactivity worth based on previous "experience" may be specified along with the applicable IRF number. If no previous experience exists, estimate the reactivity worth using SOP 306.

Completely Unknown - If reactivity worth is completely unknown and not easily calculated, it must be experimentally determined.

h. **Comments** - Provide additional comments, if any.

i. **Request Completed By** - The person completing items **a** through **h** above should sign their name in the blank provided.

2. **REVIEW AND APPROVAL** - This portion of the IRF is to be completed by one of the reviewers and approved by both of the reviewers.

   a. **Analysis of Potential Hazards** - Reviewers shall analyze potential hazards associated with the experiment with regard to following:

      1) **Reactivity** - Review the expected reactivity worth information. Assure that the Technical Specification Section 3.7 requirements are met. Check the box marked "None" or "Other" as appropriate. If "Other" is specified, explain.

      2) **Dose Rate** - Review the expected dose rate information and assess potential dose rate hazards. Check the box marked "None" or "Other" as appropriate. If "Other" is specified, explain.

      3) **Reactor Equipment** - Verify that no corrosion problems exist. Verify that no explosive materials or fueled experiments are to be irradiated without Radiation Safety Committee approval. Verify that proper provisions for cooling have been made. Evaluate the experiment with respect to potential hazards to the reactor or reactor operations (for example, detector "shadowing"). Check the box marked "None" or "Other" as appropriate. If "Other" is specified, explain.

      4) **Other** - Evaluate the experiment for any other types of conceivable hazards to personnel or equipment.

   b. **Additional Restrictions/Requirements** - The reviewers are to specify any additional restrictions or requirements deemed appropriate.

   c. **Approvals** - Reviewers shall signify approval of the experiment by signing and dating in the appropriate blank. Two signatures are required from either the Director, Manager, SROs, or the Health Physicist.

D. PROCEDURE - SAMPLE IRRADIATION LOG

A Sample Irradiation Log will accompany each IRF to document sample irradiation information. An entry shall be made on the Sample Irradiation Log for each sample irradiated.

1. **Date** - Specify the date of the sample irradiation.
2. **Sample ID** - Specify the sample identification number or name.
3. **Experimenter's Name** - Provide the name of the experimenter responsible for the sample.
4. **Location** - Specify the irradiation location.
5. **Power** - Specify the power level at which the irradiation is performed.
6. **Time In** - Specify the console time at which the irradiation began.
7. **Time Out** - Specify the console time at which the irradiation ended.
8. **Total Time** - Specify the total time of the irradiation.
9. **Dose Rate @ 1 foot** - Record the 1 foot dose rate from the sample at the time of initial sample handling.
10. **Decay Time** - Specify the approximate decay time between the end of the irradiation and the time of the dose rate measurement.
11. **Initials** - Either the console operator (licensed operator, student, or trainee) or the experimenter will provide their initials signifying that sample irradiation information is complete.

IRRADIATION REQUEST FORM

IRF # _____

1. IRRADIATION REQUEST

a. **Sample Description:** _____

_____

b. **Physical Form:** _____ c. **Encapsulation** ( ) **Poly-Vial** ( ) **Other** _____

d. **Irradiation Location:** ( ) **Bare Rabbit** ( ) **Cad Rabbit** ( ) **Beam Port** ( ) **Thermal Column**
( ) **Other** _____

e. **Irradiation Limits: 1) Power:** _____ **2) Time:** _____ **3) Mass:** _____**gm**

f. **Expected 1 Foot Dose Rate:**_____**mrem/hr** **Based on:** ( ) **experience (IRF#** _____**)**
( ) **calculations (attached)**
( ) **completely unknown**

g. **Expected Reactivity Worth:** _____**% k/k** **Based on:** ( ) **default**
( ) **experience (IRF#**_____**)**
( ) **SOP 306 calculations (attached)**
( ) **completely unknown**

h. **Comments:** _____

_____

i. **Request Completed By:** _____

2. REVIEW AND APPROVAL

a. **Analysis of Potential Hazards:**

1.	**Reactivity**	( ) **None** ( ) **Other** _____
2.	**Dose Rate**	( ) **None** ( ) **Other** _____
3.	**Reactor Equipment**	( ) **None** ( ) **Other** _____
4.	**Other**	( ) **None** ( ) **Other** _____

b. **Additional Restrictions/Requirements**_____

_____

_____

_____

c. **Irradiation Request Reviewed and Approved (two signatures required):**

Director _____ **Date** _____, **Manager** _____ **Date** _____
SRO _____ **Date** _____, **SRO** _____ **Date** _____
Health Physicist _____ **Date** _____

Revised By: Craig T Resiner

Craig T Resiner

Approved By: William Bonzer

William Bonzer

IRF #

Page #_______

SAMPLE IRRADIATION LOG

Date	Sample ID	Experimenter's Name	Irradiation Information					Dose Rate @ 1 ft (mR/hR)	Decay Time (Approx.)	Initials
			Location	Power	Time In	Time Out	Total Time			

Revised By: Craig T Resiner

Approved By: William Bonzer