NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

EDWARD S. LAU
Assistant Director of
Reactor Operations

138 Albany Street, Cambridge, MA 02139-4296
Telefax No. (617) 253-7300
Tel. No. (617) 253-4211

Facility Tours
Education & Training
Activation Analysis
Coolant Chemistry
Nuclear Medicine

March 29, 2014

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn.: Document Control Desk

Subject: Annual Report, Docket No. 50-20, License R-37, Technical Specification 7.7.1

Gentlemen:

Forwarded herewith is the Annual Report for the MIT Research Reactor for the period from January 1, 2013 to December 31, 2013, in compliance with paragraph 7.7.1 of the Technical Specifications issued November 1, 2010, for Facility Operating License R-37.

Sincerely,

John P. Foster
Superintendent for Operations & Maintenance
MIT Research Reactor

Edward S. Lau, NE
Assistant Director of Reactor Operations
MIT Research Reactor

Thomas H. Newton, Jr., Ph.D., PE
Director of Reactor Operations
MIT Research Reactor

ST/gw

Enclosure: As stated

cc: USNRC – Senior Project Manager
Research and Test Reactors Branch A
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

USNRC – Senior Reactor Inspector
Research and Test Reactors Branch B
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

A020
NRR

MIT RESEARCH REACTOR
NUCLEAR REACTOR LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ANNUAL REPORT

to

United States
Nuclear Regulatory Commission
for
the Period January 1, 2013 – December 31, 2013

by

REACTOR STAFF

Table of Contents

MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JANUARY 1, 2013 - DECEMBER 31, 2013

INTRODUCTION

This report has been prepared by the staff of the Massachusetts Institute of Technology Research Reactor for submission to the United States Nuclear Regulatory Commission, in compliance with the requirements of the Technical Specifications to Facility Operating License No. R-37 (Docket No. 50-20), Paragraph 7.7.1, which requires an annual report that summarizes licensed activities from the 1st of January to the 31st of December of each year.

The MIT Research Reactor (MITR), as originally constructed and designated as MITR-I, consisted of a core of MTR-type fuel, enriched in uranium-235, cooled and moderated by heavy water in a four-foot diameter core tank that was surrounded by a graphite reflector. After initial criticality on July 21, 1958, the first year was devoted to startup experiments, calibration, and a gradual rise to one megawatt, the initially licensed maximum power. Routine three-shift operation (Monday-Friday) commenced in July 1959. The authorized power level for MITR-I was increased to two megawatts in 1962 and to five megawatts (the design power level) in 1965.

Studies of an improved design were first undertaken in 1967. The concept which was finally adopted consisted of a more compact core, cooled by light water, and surrounded laterally and at the bottom by a heavy water reflector. It is under-moderated for the purpose of maximizing the peak of thermal neutrons in the heavy water at the ends of the beam port re-entrant thimbles and for enhancement of the neutron flux, particularly the fast component, at in-core irradiation facilities. The core is hexagonal in shape, 15 inches across, and utilizes fuel elements which are rhomboidal in cross section and which contain UAl_x intermetallic fuel in the form of plates clad in aluminum and enriched to 93% in uranium-235. The improved design was designated MITR-II. Much of the original facility, e.g., graphite reflector, biological and thermal shields, secondary cooling systems, containment, etc., has been retained.

After Construction Permit No. CPRR-118 was issued by the former U.S. Atomic Energy Commission in April 1973, major components for the modified reactor were procured and the MITR-I completed its mission on May 24, 1974, having logged 250,445 megawatt-hours during nearly 16 years of operation.

The old core tank, associated piping, top shielding, control rods and drives, and some experimental facilities were disassembled, removed, and subsequently replaced with new equipment. After preoperational tests were conducted on all systems, the U.S. Nuclear Regulatory Commission issued Amendment No. 10 to Facility Operating License No. R-37 on July 23, 1975. After initial criticality for MITR-II on August 14, 1975, and several months of startup testing, power was raised to 2.5 MW in December 1975. Routine 5-MW operation was achieved in December 1976. Three shift operations, Monday through Friday, was continued through 1995 when a gradual transition to continuous operation (24 hours per day, 7 days per week with a shutdown for maintenance every 4-5 weeks) was initiated.

In December 2000, a fission converter medical facility was commissioned. This facility generated the highest quality epithermal beam in the world for use in the treatment of certain types of cancer, and could again be made available.

From mid-April through mid-September 2010, all major piping in the primary and secondary coolant systems was replaced and upgraded. This included a titanium heat exchanger (replacing the three previous primary heat exchangers) and the major instrumentation sensors. On November 1, 2010, NRC approved the relicensing of the reactor for 6-MW operation through November 1, 2030. Reactor power was increased in small increments from 5 MW for observations and data collection, and reached 5.8 MW on April 23, 2011. Routine 5.8 MW operation began on May 25, 2011.

The current operating mode is generally continuous operation just under 6 MW when needed, with a maintenance shutdown scheduled every calendar quarter.

This is the thirty-ninth annual report required by the Technical Specifications, and it covers the period from January 1, 2013 through December 31, 2013. Previous reports, along with the "MITR-II Startup Report" (Report No. MITNE-198, February 14, 1977) have covered the startup testing period and the transition to routine reactor operation. This report covers the thirty-seventh full year of routine reactor operation, now at the 6-MW power level. It was another year in which the safety and reliability of reactor operation met and exceeded requirements and expectations.

A summary of operating experience and other activities and related statistical data are provided in Sections A through I of this report.

A. SUMMARY OF OPERATING EXPERIENCE

1. General

The MIT Research Reactor, MITR-II, is operated to facilitate experiments and research including in-core irradiations and experiments, neutron activation analyses, and materials science and engineering studies such as neutron imaging. It is also used for student laboratory exercises and student operator training, and education and outreach programs. Additionally, the reactor has been used for industrial production applications and other irradiation services. When operating, the reactor is normally maintained at slightly below 6 MW. For this reporting period, the nominal full power operating cycle was eleven weeks at a time, followed by a scheduled outage lasting about two weeks, for reactor and experiment maintenance, protective system surveillance tests, and other necessary outage activities. The reactor would then be re-started to full power and maintained there for another several weeks.

Throughout CY2013, the reactor averaged 54 operating hours per week, compared to 76 hours per week for CY2012, and 90 hours per week for CY2011. The lower average for CY2013 was the result of operating the reactor only as needed for the first half of the year, when there were no in-core experiments or other irradiations that called for continuous operation.

The reactor was operated throughout the year with 24 fuel elements in the core. The remaining three positions were occupied by solid aluminum dummies or in-core experiments. During CY2013, compensation for reactivity lost due to burnup was provided by three refuelings. These followed standard MITR practice which is to introduce fresh fuel to the inner portion of the core (the A- and B-Rings) where peaking is least and to place partially spent fuel into the outer portion of the core (the C-Ring). In addition, fuel elements were inverted and rotated so as to achieve more uniform burnup gradients in them. Three new fuel elements were introduced into the reactor core during CY2013. Fuel elements previously used in the fission converter were re-introduced into the core during this same period.

The MITR-II fuel management program remains quite successful. All of the original MITR-II fuel elements (445 grams U-235) have been permanently discharged. The overall burnup for the discharged ones was 42%. (Note: One was removed prematurely because of excess out-gassing.) The maximum overall burnup achieved was 48%. A total of two hundred twenty-six of the newer, MITR-II fuel elements (506 grams U-235) have been introduced to the core. Of these, one hundred seventy have attained the maximum allowed fission density and were discharged. Six fuel elements have been identified as showing excess out-gassing and three were suspected of this. All nine have been removed from service and returned to an off-site DOE storage facility. The other forty-seven are either currently in the reactor core, or have been partially depleted and are in the wet storage ring awaiting reuse or discharge. During the period of CY2013, eight spent fuel elements were returned to an off-site DOE facility.

As in previous years, the reactor was operated throughout the period without the fixed hafnium absorbers.

2. Experiments

The MITR-II was used for experiments and irradiations in support of research, training and education programs at MIT and elsewhere. Irradiations and experiments conducted in CY2013 include:

a) Activation of gold-198 seeds for brachytherapy.

b) Activation of uranium foils for detector calibration at the Los Alamos National Laboratories.

c) Activation of ocean sediments for the Woods Hole Oceanographic Institute.

d) Exploratory activation and NAA of the following materials: various components of ultrasonic detectors for Idaho National Laboratory (INL) and Pennsylvania State University; and all components and sample materials of the FS-1 Salt Capsule Experiment.

e) Activation and NAA of various flux wires for a detailed fast and thermal flux study of our different pneumatic, graphite, and in-core experimental facilities.

f) Activation and NAA of FLiBe salt crystals used in the University of Wisconsin out-of-core Corrosion Experiment that ran in parallel to our in-core experiment fluoride-salt-cooled high temperature reactor (FHR) project.

g) Experiments at the 4DH1 radial beam port facility by MIT undergraduate and graduate students, including: 1) measurements of leakage neutron energy spectrum to determine reactor temperature; 2) measurement of neutron wavelength and time-of-flight; and 3) measurement of attenuation coefficients for eight shielding materials.

h) Use of the reactor for training MIT student reactor operators and for MIT nuclear engineering classes (courses 22.06 "Engineering of Nuclear Systems", 22.09 "Principles of Nuclear Radiation Measurement and Protection").

i) Neutron transmutation doping of Ge wafers for the Italian Institute of Nuclear Physics working in conjunction with Lawrence Berkley National Labs. These wafers were then used for further neutrino detector research.

j) Activation and NAA of barium sulfate nanoparticles, cerium oxide nanoparticles, and tissue samples for radiotracer animal studies of nanomaterial toxicity for Harvard School of Public Health.

k) Activation and NAA of Si Photodiode and Phototube components for further NAA studies for University of Alabama.

l) Irradiation of SiC/SiC composites continued in the MITR in-core water loop facility. An ongoing project to evaluate the use of SiC/SiC composite materials for BWR channel boxes was started in 2013. The project is funded by the US DOE and the NRL was subcontracted by EPRI, the lead awardee, to perform an irradiation test under BWR coolant conditions. Corrosion coupons and creep samples were irradiated and removed for examination. SiC/SiC composite tube samples for potential application as control rod guide tubes were also irradiated.

m) In support of the MIT, UC Berkeley, and University of Wisconsin–Madison integrated research project on the fluoride-salt-cooled high temperature reactor (FHR) concept, a 1000-hour irradiation of a variety of metal alloy and non-metallic samples in molten FLiBe (Li_2BeF_4 salt) was completed at 700 °C in the controlled temperature ICSA facility. The 1000-hour operational period was accomplished in one continuous run with temperature control to within ±3°C. Post-irradiation examination of the samples is ongoing and a second irradiation in a dedicated in-core facility is planned for CY2014.

n) Use of the reactor (including the 4DH1 beam port facility) for educating participants of the Reactor Technology Course for Utility Executives in reactor control, neutron behavior, and radiation protection. The course is sponsored by the Institute for Nuclear Power Operations and hosted by the MIT Nuclear Science and Engineering Department faculty.

An ongoing initiative is the partnership with INL Advanced Test Reactor User Facility (ATR-UF) for materials testing. The MITR is the first university research reactor selected as a partner facility with the ATR-UF. MITR staff also worked with INL staff to jointly develop advanced reactor instrumentation, and reviewed ATR-UF's user proposals. An irradiation capsule for a long-term irradiation of ultrasonic transducers was designed and constructed in 2013. A set of transducers with temperature and self-powered neutron and gamma detectors will be irradiated in 2014. Also in 2013, final design of an in-core crack growth monitor for use in the MITR and the Advanced Test Reactor (ATR) at the Idaho National Laboratory was completed at MIT. A test crack growth unit was manufactured and provided to INL for out-of-core autoclave testing in 2014. The objective of this program is to test a crack growth monitor in-core at the MITR in CY 2015.

3. Changes to Facility Design

Except as reported in Section E, no changes in the facility design were made during this calendar year. The nominal uranium loading of MITR-II fuel is 34 grams of U-235 per plate and 510 grams per element (made by B&W). Performance of these fuel elements has been good. The loading results in 41.2 w/o U in the fuel meat, based on 7% voids, and corresponds to the maximum loading in Advanced Test Reactor (ATR) fuel. One hundred eighty-six elements fabricated by B&W have been received, forty-seven of which remain in use. One has been removed because of suspected excess out-gassing and one hundred thirty-eight have been discharged because they have attained the fission density limit.

The MITR is actively involved in studies for the use of low enrichment uranium (LEU) in the MITR, partially supported by the Reduced Enrichment for Research and Test Reactors (RERTR) Program at DOE. These studies principally focus on the use of monolithic U-Mo fuels with uranium densities in excess of 15 g/cm^3 (compared with 1.5 g/cm^3 for UAl_x fuel), currently under development by the RERTR Program. Although initial studies show that the use of these fuels is feasible, conversion of the MITR-II to lower enrichment must await the final successful qualification of these fuels.

4. Changes in Performance Characteristics

Performance characteristics of the MITR-II were reported in the "MITR-II Startup Report." Minor changes have been described in previous reports. Performance characteristics of the Fission Converter Facility were reported in the "Fission Converter Facility Startup Report", and in the FY2006 report which described a 20% improvement in the intensity of the unfiltered epithermal neutron beam. In CY2012, fuel was removed from the fission converter. It will remain unfueled pending resumption of epithermal beam research. In CY2013, the D_2O coolant was removed from the fission converter and replaced with demineralized light water. The D_2O was put into storage for future use.

5. Changes in Operating Procedures

With respect to operating procedures subject only to MITR internal review and approval, a summary is given below of changes implemented during the past year. Those changes related to safety and subject to additional review and approval are discussed in Section E of this report.

a) PM 1.0, "Administrative Procedures", and PM 7.0, "Maintenance Procedures", received general updates to reflect current practices, terminology, and Technical Specification references. Several procedures were streamlined, and section 1.14.2.4 on storage and use of plutonium was removed. New employee training requirements were added, as were work time limits for licensed individuals. Safety was also improved in the lockout/tagout program by having a second licensed SRO verify proper installation of lockout devices. New lines were added to the Job Workbook form requiring checks for repetitive malfunctions and Tech Spec significance, and requiring additional reviews by the Director of Reactor Operations. (SR #0-12-5, #0-13-17)

b) PM 3.4.1, "Replacement of a Shim Blade, Magnet or Drive Mechanism", was modified for increased clarity and to add steps specific to the newer drive design used for shim blade drives #1 and #6. ALARA was improved by re-ordering sections to do as much as possible with the core tank level at nominal, either before it is lowered or after it gets restored. PM 3.4.2, "Replacement of Control Blade", was modified for alignment with current best practices, particularly for promotion of ALARA. (SR #0-12-23, #0-13-8)

c) Several test and calibration procedures were updated to include more information and clarity, and to take advantage of new hardware and instrumentation for testing: PM 6.1.4.3, "Damper Closing Time Measurement using a Digital Oscilloscope", PM 6.1.3.11, "Emergency Power Transfer Test", PM 6.1.2.5, "Charcoal Filter Efficiency Test", and PM 6.5.6.2, "System Pressure Gage Calibration – PSI Range". The modification of PM 6.1.3.5, "Building ΔP Indicator and Recorder Calibration", also included a piping change re-positioning a valve in order to allow all ΔP instruments to be equalized rather than just the recorder. The piping change was verified not to affect the ΔP system's indications. (SR #0-13-1, #0-13-3, #0-13-5, #0-13-15, #0-13-21)

d) PM 3.8.1A, "Makeup Water Startup of Inlet D.I. System in Standby (recirculation) Mode", PM 3.8.5, "Makeup Water Transfer from Storage", and PM 3.9, "Transfer of D_2O Between Storage and Dump Tanks", received administrative changes for clarity and readability. There were no safety concerns involved. (SR #0-13-6, #0-13-18, #0-13-19)

e) PM 7.1.2.5, "Fuel Sipping", was established to document and formalize the steps necessary to draw samples through fuel elements in the core tank. Standard foreign material exclusion control is enforced. (SR #0-13-7)

f) PM 7.3.8, "Removal/Maintenance/Replacement of DM-1 Pump Rotating Assembly", was established to document and formalize the steps for working on the D_2O reflector system's main pump. The procedure covers system lockout/tagout, precautions regarding the D_2O, connection points for draining and venting, valve lineups, and pipe draining sequences. (SR #0-13-10)

g) PM 3.1.4, "Non-Routine Reactor Startup", received administrative updates to reflect the change in operating power limit to 6 MW, and to clarify the uses of neutron flux Channels #7, #8, and #9. (SR #0-13-14)

h) PM 3.1.1.1 & 3.1.1.2, "Full Power Startup Checklists", PM 3.1.1.3, "Cooling Tower Operation and Full Power Checks", PM 3.1.1.4, "Two Loop Restart Incorporating Required Quarterly Startup Surveillances", PM 3.1.3, "Startup for Less than 100 kW Operation", PM 3.1.6, "Restart Following an Unanticipated or a Brief-Duration Scheduled Shutdown", and PM 3.5, "Daily Surveillance Check" were cross-checked and updated as a group to incorporate temporary changes and to reflect current equipment configurations and best practices. An update of the "Special Procedure for Activation of Charcoal Filter Bank" was included, replacing the Pressure Relief System portion of the startup checklists. Likewise included were the posted procedures for sampling the primary and shield system coolant. All the changes were evaluated as free of negative effects on safety, equipment, and ALARA. (SR #0-13-13)

i) PM 3.7.1, "Weekly Security Checklist", was updated to reflect revisions in the Physical Security Plan (SR #0-13-16 portions that do not have the potential to require a license amendment request), clarifications, and current equipment capabilities and practices. Safety and security were both evaluated as improved by this update. (SR #0-13-24)

j) "Estimated Critical Position (ECP) Calculator" was created to review and authorize a computerized operator aid for ECP calculation. (SR #0-13-20)

k) "Hydride Fuel Irradiation Experiment Test and Handling Procedures" sub-item HYFI-8, "Hydride Fuel Irradiation Experiment Transfer of Irradiated Capsule with Contaminated Gas Sampling Line from Wet Storage Ring to Spent Fuel Pool", was established for the transfer of previously irradiated HYFI Capsule 2. The new special procedure detailed additional equipment, precautions, and steps appropriate for the potential contamination in its attached gas sampling tube. (SR #0-11-16)

6. Surveillance Tests and Inspections

There are many written procedures in use for surveillance tests and inspections required by the Technical Specifications. These procedures provide a detailed method for conducting each test or inspection and specify an acceptance criterion which must be met in order for the equipment or system to comply with the requirements of the Technical Specifications. The tests and inspections are scheduled throughout the year with a frequency at least equal to that required by the Technical Specifications. Thirty such tests and calibrations are conducted on an annual, semi-annual, or quarterly basis.

Other surveillance tests are done each time before startup of the reactor if shut down for more than 24 hours, before startup if a channel has been repaired or de-energized, and at least quarterly; a few are on different schedules. Procedures for such surveillance are incorporated into daily or quarterly startup, shutdown, or other checklists.

During this reporting period, the surveillance frequency has been at least equal to that required by the Technical Specification, and the results of tests and inspections were satisfactory throughout the year for Facility Operating License No. R-37.

7. Status of Spent Fuel Shipment

In CY2013, there was one shipment made, reducing the inventory of spent fuel at MIT. These shipments were made using the BEA Research Reactor (BRR) package. The U.S. Department of Energy has indicated that further shipments may be feasible in CY2014 for future fuel discharges.

B. REACTOR OPERATION

Information on energy generated and on reactor operating hours is tabulated below:

	Calendar Quarter 1	2	3	4	Total
1. Energy Generated (MWD):					
a) MITR-II (MIT CY2013) (normally at 5.8 MW)	125.5	72.1	222.5	206.1	626.2
b) MITR-II (MIT FY1976-CY2012)					33,257.6
c) MITR-I (MIT FY1959-FY1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					44,319.0
2. MITR-II Operation (hours): (MIT CY2013)					
a) At Power (≥ 0.5-MW) for Research	552	337	1015	859	2763
b) Low Power (< 0.5-MW) for Training[1] and Test	6	44	7	1	58
c) Total Critical	558	381	1022	860	2821

[1] These hours do not include reactor operator and other training conducted while the reactor is at full power for research purposes (spectrometer, etc.) or for isotope production. Such hours are included in the previous line.

C. SHUTDOWNS AND SCRAMS

During this reporting period, there were four inadvertent scrams and five unscheduled shutdowns.

The term "scram" refers to shutting down of the reactor through protective system automatic action when the reactor is at power or at least critical, while the term "shutdown" refers to an unscheduled power reduction to subcritical by the reactor operator in response to an abnormal condition indication. Rod drops and electric power loss without protective system action are included in unscheduled shutdowns.

The following summary of scrams and shutdowns is provided in approximately the same format as for previous years in order to facilitate a comparison.

			Total
1.	Nuclear Safety System Scrams		
	a)	Trip on Channel #3 as result of spurious electronic noise upon reset of its low level indicator during startup.	2
	b)	Trip on low voltage chamber power supply for Channel # caused by operator error during ion chamber plateau testing.	1
		Subtotal	3
2.	Process System Scrams		
	a)	Low flow core purge scram because of water accumulation inside the purge line.	1
		Subtotal	1

3. Unscheduled Shutdowns

b)	Shutdown as result of momentary loss of off-site electricity.	2
a)	Shutdown to troubleshoot automatic controller and its associated Channel #9.	1
c)	Shutdown to correct elevated fission converter tank temperature caused by pump cavitation.	1
d)	Shutdown upon news of shooting of an MIT Police Officer on campus (by the Boston Marathon bombing suspects).	1
	Subtotal	5
	Total	**9**

4. Experience during recent years has been as follows:

Calendar Year	Nuclear Safety and Process System Scrams
2013	4
2012	6
2011	9
2010	20
Fiscal Year	
2010	6
2009	2
2008	4
2007	5
2006	6

D. MAJOR MAINTENANCE

Major reactor maintenance projects performed during CY2013 are described in this Section. These were planned and performed to improve safety, reliability and efficiency of operation of the MIT Research Reactor, and hence improve the predictability of the reactor operating schedule and the availability of the reactor for experiments, research and training purposes. Additionally, Reactor Operations staff performed safety reviews for all reactor experiments and their operating procedures. The staff also provided support for installations and removals of reactor experiments, and monitored key performance data from the experiments during reactor operations. In CY2013 these experiments included the SiC/SiC composite material irradiation for EPRI in the Advanced Clad Irradiation water loop facility, and the FS-1 Salt Capsule irradiation in the In-Core Sample Assembly (ICSA).

For continuous support of neutron transmutation doping of silicon, reactor staff performed routine irradiation and shipping activities. There is an annual external audit to review the program for maintaining the ISO 9001 Certification. Preventive maintenance on conveyor machinery, such as alignment of conveyor carriages, was performed during major outages. No component replacements for instrumentation or controls was needed during this calendar year.

Major maintenance items performed in CY2013 are summarized as follows:

1. During the week of 01/7/2013 the CO_2 purge line to the FC tank was repaired. The helium blowdown line that tests the FC tank low level scram was also repaired.
2. The FC alarm panel was replaced with an in-house spare during the week of 01/14/2013.
3. Bernoulli Filter B piston was repaired on 01/15/2013; Bernoulli Filter A piston was repaired on 01/22/2013. Maintenance was performed on all three Bernoulli Filters on 04/08/2013 and 11/17/2013.
4. The FC heat exchanger was replaced during the week of 02/11/2013.
5. The primary ion column was repacked and replaced on 03/04/2013, 07/23/2013, and 11/14/2013.
6. The primary ion column inlet filter was replaced on 07/23/2013.
7. The D_2O storage tank blowout patch was replaced on 03/04/2013.
8. A failed truck lock hydraulic line was replaced on 04/03/2013.
9. The main reflector system pump (DM-1) shaft seal was replaced on 04/10/2013.
10. Two new pre-amplifier modules for the new safety system were installed in new electrical boxes on 05/02/2013.

11. Shim blade #1 was replaced on 05/08/2013.

12. The regulating rod auto-controller was repaired on 05/13/2013.

13. The regulating rod absorber and drive were replaced during the week of 05/20/2013.

14. During the week of 05/20/2013, two conduit paths were cleared of old cables in support of the new safety system.

15. During the week of 05/20/2013, MIT Facilities installed eight new self-contained battery operated emergency lights.

16. MIT Facilities replaced the control room A/C compressor during the week of 05/27/2013.

17. Channel 2 & 3 safety amplifier power supplies were replaced on 05/30/2013.

18. MIT Facilities replaced the containment building exhaust ventilation filters on 06/10/2013.

19. The blade drive motor for shim blade #3 was rebuilt on 06/20/2013.

20. The D_2O in the FC tank was replaced with deionized water during the week of 07/08/2013.

21. The primary pump MM-1A VFD electrical contactor was replaced on 07/12/2013.

22. The first Mirion safety channel detector was installed in 3GV2 on 07/12/2013.

23. Stack Gas 1 & 2 instruments were upgraded during the week of 07/29/2013.

24. The blade drive for shim blade #6 was replaced on 09/06/2013.

25. A new motion sensor with alarms was installed at the entrance to the reactor floor high radiation storage area during the week of 09/09/2013.

26. A leak in the cooling line for the 3GV5 vertical port was repaired on 10/01/2013.

27. A new port plug and the second Mirion fission chamber detector were installed in 4IH3 on 11/05/2013.

28. During a period of one week starting on 11/06/2013, the city water makeup line for the secondary system was relocated from the cooling tower outlet pipe to the cooling tower inlet.

29. An underground 480-volt electrical conduct was repaired on 11/12/2013.

30. The blade drive and magnet for shim blade #4 were replaced on 12/09/2013.

31. The proximity switch for shim blade #5 was replaced on 12/16/2013.

Many other routine maintenance and preventive maintenance items were also scheduled and completed throughout the fiscal year.

E. SECTION 50.59 CHANGES, TESTS, AND EXPERIMENTS

This section contains a description of each change to the reactor facility or procedures and of the conduct of tests and experiments carried out under the conditions of Section 50.59 of 10 CFR 50, together with a summary of the safety evaluation in each case.

The review and approval of changes in the facility and in the procedures as described in the SAR are documented in the MITR records by means of "Safety Review Forms". These have been paraphrased for this report and are identified on the following pages for ready reference if further information should be required with regard to any item. Pertinent pages in the SAR have been or are being revised to reflect these changes, and they either have or will be forwarded to the Document Control Desk, USNRC.

The conduct of tests and experiments on the reactor are normally documented in the experiments and irradiation files. For experiments carried out under the provisions of 10 CFR 50.59, the review and approval is documented by means of the Safety Review Form. All other experiments have been done in accordance with the descriptions provided in Section 10 of the SAR, "Experimental Facilities".

<u>Advance Cladding Irradiation Facility (ACI)</u>
SR #0-06-4 (04/03/2006), #0-06-6 (05/18/2006)

An in-core experiment loop was installed on May 22, 2006, to investigate the effects at various stages of irradiation on specimens of silicon carbide intended for use in advanced fuel cladding designs. Its envelope of operating conditions is very similar to that of previous in-core experiments such as the Zircaloy Corrosion Loop and the Electro-Chemical Potential Loop. No new safety issues were raised. Operation continued until October 2007. A second advanced cladding loop, designated ACI-2, operated in core from March 2009 through mid-December 2009, March to April 2010, December 2010 through June 2011, from October 2011 to July 2012, and from August through October 2013.

<u>Heated In-Core Sample Assembly Experiment (ICSA)</u>
SR #0-04-19 (12/01/2004), #M-04-2 (12/30/2004), #0-05-11 (07/22/2005),
SR #M-09-1 (07/30/2009), #M-09-2 (12/11/2009), #0-10-2 (03/28/2010),
SR #0-12-17 (06/04/2012), #0-12-19 (07/09/2012)

High-temperature sample capsules were used with the redesigned titanium 2" ICSA tube to provide a heated irradiation environment for the specimens within. These capsules include gamma-heating susceptors similar in principal to the High Temperature Irradiation Facility. No new safety issues were raised. An alternate 16" plug was designed and installed in the reactor top shield lid to allow simultaneous use of the ICSA and the ACI-2 in-core experiments. The ICSA operated in core from December 2009 through April 2010, from August 2010 to January 2012, from April to July 2012, and from mid-September through October 2013 for various sample irradiations using heated and unheated capsules. The MIT Reactor Safeguards Committee (MITRSC) approved two ICSA Safety Evaluation Report amendments in early 2013 to allow the 2013 irradiation of molten fluoride salt in-core using a nickel capsule inside the ICSA.

<u>LUNA-HTIF</u>
SR #0-12-20 (07/23/2012)

A test fit procedure was established and performed for a future high-temperature fiber-optic sensor test that will be done in a custom-built in-core High Temperature Irradiation Facility with real time read-out of the fiber sensors. Set-up requirements and radiological controls were maintained to match existing in-core handling procedures.

<u>New Digital Recorders for the Control Room</u>
SR #E-12-1 (10/11/2012), #E-12-2 (07/23/2012), # E-13-1 (01/24/2013),
#E-13-2 (05/01/2013), #E-13-5(10/29/2013)

A program is underway to replace aged analog recorders in the control room with new digital paperless equivalents. The multipoint temperature recorder and the

radiation monitor recorder were replaced in CY2012. A third recorder was installed in CY2013 to replace three separate recorders – the building delta-P recorder, the D_2O gasholder recorder, and the Gould effluent recorder. A fourth recorder was installed in CY2013 replacing two separate recorders – the primary flow/ΔT recorder and the secondary/shield/D_2O flow recorder. An LCD monitor / computer recorder was also tested and then installed in CY2013, replacing three separate recorders – the log flux level, linear flux level, and core outlet temperature recorders. None of these recorders provide any reactor control functions, nor do they initiate any scram signals. The alarm functions of the temperature recorder were verified to remain unchanged. The greater reliability of the digital equipment was judged to be an improvement in safety.

<u>DWK 250 Wide Range Monitors and Mirion Fission Chamber Detectors</u>
SR #0-12-21 (10/19/2012), #0-13-22 (07/11/2013), #0-13-27 (11/08/2013)

Three analog display meters were added to the control console from a new nuclear instrument channel (a DWK 250 Wide Range Monitor) that is under test. These meters are completely independent of the reactor protection and reactor control systems and do not interfere with normal use of required control room instrumentation. All the display meters are labelled "unofficial instrument", as use of the DWK 250 system is pending NRC review and approval. Two sets of DWK 250 flux monitors, and their associated pre-amplifiers and fission chambers, were installed for on-line testing in 2013. The DWK 250 monitors were installed in the control room console. The fission chamber for one was installed in 3GV2, and for the other in 4IH3. The TKV23 pre-amplifier modules for both these fission chambers were installed in protective electrical boxes on the reactor utility shelf.

<u>Ch. 2 Fission Chamber Signal Using TKV23 Pre-Amplifier</u>
SR #E-13-4 (08/01/2013)

The non-discriminated pulse signal from the new fission chamber in 3GV2, passing without distortion in analog form through a DWK 250 flux monitor, was used as input to the existing nuclear safety Channel #2 for source-range startup application. The non-discriminated signal does not go through the signal processing path within the DWK 250.

<u>Procedures Governing Shipment of Spent Fuel</u>
SR #0-12-22 (03/21/2013), #0-13-2 (03/28/2013)

Section 2.7.5 in the reactor's Standard Operating Plan was modified to allow omission of the inverse multiplication measurements when loading spent fuel elements into the shipping cask with U-235 masses similar to or less than that of a previous loading. This change had been reviewed and approved by the MITRSC on 11/06/2012. The PM 3.3.4 Spent Fuel Shipping Procedures were updated accordingly. Furthermore, PM 3.3.4.1 Fuel Shipping Supervisory Checklist was updated to expand and improve oversight and coordination of the spent fuel shipment process.

Update of Emergency Plan and Procedures
SR #0-12-15 (07/23/2013), #E-13-3 (07/26/2013), #0-13-25 (10/28/2013)

The MITR Emergency Plan and Procedures were upgraded to reflect current practices and improve coordination with current MIT campus emergency protocols, making greater use of campus resources currently available. The upgrade also took advantage of modern methods of evaluation and communication technologies to streamline emergency notification and response. Most importantly, the upgrades adjusted the Emergency Action Levels (EALs) as permitted by the Technical Specifications that were approved by NRC along with the November 2010 relicensing. The changes to the Emergency Plan and Procedures were reviewed and approved by the MITRSC on 5/16/2013. Three Abnormal Operating Procedures were updated to reflect the changes in the Emergency Plan and Procedures, especially the new EALs. Furthermore, the two Stack Gas monitors were modified to accommodate the higher range of the new EALs. These modifications included installation of attenuator plates in the corresponding radiation detectors, implementation of high-range meter scales, and new calibrations. Implementation of the new E-Plan and Procedures took place on 8/5/2013 when Stack Gas 1 monitor upgrade was completed. The Stack Gas 2 monitor upgrade was completed on 8/7/2013. The new E-Plan and Procedures were submitted to NRC on 8/13/2013 as per 10 CFR 50.54 (q) (5).

Safety Analysis Report (SAR) Update
SR #0-13-11 (11/14/2013), #0-13-26 (09/16/2013)

The MITR Safety Analysis Report (SAR) was updated twice in 2013. The first was a revision of the entire document to reflect current equipment and practices, such use of MCNP, which was now a routine fuel management tool. The revision package was reviewed and approved by MITRSC on 5/16/2013. The second update applied only to SAR Section 2.4 Hydrology, clarifying the mechanisms and risks of seismically-induced flood at the reactor site. This change was reviewed and approved by MITRSC by mail ballot on 11/1/2013. Both SAR modifications were submitted to NRC as items of information dated 11/7/2013.

Physical Security Plan Revision
SR #0-13-16 (pending)

MITRSC approval for revised Plan was granted per the Security Subcommittee meeting of 6/6/2013. It was then submitted to NRC as a License Amendment Request.

Modification of City Water Feed to Secondary Piping
SR #M-13-1 (12/04/2013)

The 3" city water make-up line for the secondary system was relocated from the cooling tower outlet pipe to the cooling tower inlet pipe. This will help reduce the impact of city water temperature to the reactor by allowing maximum mixing of the colder city water with the secondary coolant prior to entering the main heat exchanger.

F. ENVIRONMENTAL SURVEYS

Environmental monitoring is performed using continuous radiation monitors and passive dosimetry devices (TLD). The radiation monitoring system consists of detectors and associated electronics at each remote site with data transmitted continuously to the Reactor Radiation Protection office and recorded electronically in a database. The remote sites are located within a quarter mile radius of the facility. The calendar year totals per sector, due primarily to Ar-41, are presented below. The passive TLDs were in place at all times throughout the year and are exchanged quarterly.

Site	Exposure (01/01/13 – 12/31/13)
North	0.17 mrem
East	0.35 mrem
South	0.16 mrem
West	0.35 mrem
Green (east)	0.01 mrem

Calendar Year Average

2013	0.2 mrem
2012	0.3 mrem
2011	0.3 mrem
2010	0.1 mrem

Fiscal Year Average

2010	0.2 mrem
2009	0.3 mrem
2008	0.3 mrem
2007	0.2 mrem
2006	0.2 mrem
2005	0.2 mrem

G. RADIATION EXPOSURES AND SURVEYS WITHIN THE FACILITY

A summary of radiation exposures received by facility personnel and experimenters is given below:

January 1, 2013 - December 31, 2013

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	38
Measurable – < 0.1	30
0.1 – 0.25	1
0.25 – 0.50	0
0.50 – 0.75	0
0.75 – 1.00	0
1.00 – 1.25	0
1.25 – 1.50	0
1.50 – 1.75	0
1.75 – 2.00	0
Total Person Rem = 1.2	Total Number of Personnel = 69

From January 1, 2013, through December 31, 2013, the Reactor Radiation Protection program provided radiation protection services for the facility which included power and non-power operational surveillance (performed on daily, weekly, monthly, quarterly, and other frequencies as required), maintenance activities, and experimental project support. Specific examples of these activities included, but are not limited to, the following:

1. Collection and analysis of air samples taken within the containment building and in the exhaust/ventilation systems.
2. Collection and analysis of water samples taken from the secondary, D_2O, primary, shield coolant, liquid waste, and experimental systems, and fuel storage pool.
3. Performance of radiation and contamination surveys, radioactive waste collection and shipping, calibration of area radiation monitors, calibration of effluent and process radiation monitors, calibration of radiation protection/survey instrumentation, and establishing/posting radiological control areas.
4. Provision of radiation protection services during fuel movements, in-core experiments, sample irradiations, beam port use, ion column removal, diffractometer beam testing, etc.

The results of all surveys and surveillances conducted have been within the guidelines established for the facility.

H. RADIOACTIVE EFFLUENTS

This section summarizes the nature and amount of liquid, gaseous, and solid radioactive wastes released or discharged from the facility.

1. Liquid Waste

Liquid radioactive wastes generated at the facility are discharged only to the sanitary sewer serving the facility. The possible sources of such wastes during the year include cooling tower blowdown, the liquid waste storage tanks, and one controlled sink in the Restricted Area (Engineering Lab). All of the liquid volumes are measured, by far the largest being the 3,115,172 liters discharged during CY2013 from the cooling towers. (Other large quantities of non-radioactive waste water are discharged to the sanitary sewer system by other parts of MIT, but no credit for such dilution is taken because the volume is not routinely measured.)

Total activity less tritium in the liquid effluents (cooling tower blowdown, waste storage tank discharges, and engineering lab sink discharges) amounted to 33.1 μCi for CY2013. The total tritium was 104.0 mCi. The total effluent water volume was 3,157,527 liters, giving an average tritium concentration of 32.9E-6 μCi/ml.

The above liquid waste discharges are provided on a monthly basis in the following Table H-3.

All releases were in accordance with Technical Specification 3.8-1, including Part 20, Title 20, Code of Federal Regulations. All activities were substantially below the limits specified in 10 CFR 20.2003. Nevertheless, the monthly tritium releases are reported in Table H-3.

2. Gaseous Waste

Gaseous radioactivity is discharged to the atmosphere from the containment building exhaust stack. All gaseous releases likewise were in accordance with the Technical Specifications and 10 CFR 20.1302, and all nuclides were substantially below the limits, using the authorized dilution factor of 50,000 (changed from 3,000 starting with CY2011 per the renewed license's Technical Specifications). The only principal nuclide was Ar-41, which is reported in the following Table H-1. The 604.93 Ci of Ar-41 was released at an average concentration of 8.79E-11 μCi/ml. This represents 0.879% of EC (Effluent Concentration (1E-08 μCi/ml)).

3. Solid Waste

Two shipments of solid waste were made during the calendar year. The information pertaining to these shipments is provided in Table H-2.

TABLE H-1

ARGON-41 STACK RELEASES

CALENDAR YEAR 2013

		Ar-41 Discharged (Curies)	Average Concentration[1] (μCi/ml)
January 2013		10.73	1.87 E-11
February		49.67	8.66 E-11
March		48.99	8.54 E-11
April		41.42	7.22 E-11
May		49.10	8.56 E-11
June		33.38	5.82 E-11
July		3.69	6.44 E-12
August		96.19	1.68 E-10
September		66.28	1.16 E-10
October		134.30	2.34 E-10
November	(shutdown)	0	0
December		71.20	1.24 E-10
	Totals (12 Months)[2]	**604.93**	**8.79 E-11**
	EC (Table II, Column I)		1×10^{-8}
	% EC		**0.879%**

(1) Average concentrations do not vary linearly with curies discharged because of differing monthly dilution volumes.

(2) Last decimal place may vary because of rounding.

TABLE H-2

SUMMARY OF MITR-II RADIOACTIVE SOLID WASTE SHIPMENTS

CALENDAR YEAR 2013

Description	
Volume	52 ft^3
Weight	1,513 lbs.
Activity	3.1 mCi
Date of shipment	April 25, 2013
Disposition to licensee for burial	Energy Solutions, Clive, UT
Waste broker	Ecology Services Inc., Columbia, MD

Description	
Volume	237 ft^3
Weight	2,624 lbs.
Activity	27 mCi
Date of shipment	October 16, 2013
Disposition to licensee for burial	Energy Solutions, Clive, UT
Waste broker	Ecology Services Inc., Columbia, MD

TABLE H-3

LIQUID EFFLUENT DISCHARGES
CALENDAR YEAR 2013

	Total Activity Less Tritium	Total Tritium Activity	Volume of Effluent Water[1]	Average Tritium Concentration
	($x10^{-6}$ Ci)	(mCi)	(liters)	($x10^{-6}$ μCi/ml)
Jan. 2013	0.835	38.4	470,187	81.7
Feb.	NDA[2]	7.91	302,111	26.2
Mar.	10.7	4.71	434,475	10.8
Apr.	.961	4.35	202,080	21.5
May	.432	.937	150,563	6.22
June	NDA[2]	1.55	113,357	13.6
July	NDA[2]	3.60	59,445	60.6
Aug.	NDA[2]	4.39	1,083,567	4.05
Sept.	1.02	13.2	53,067	249.0
Oct.	1.88	2.52	85,200	29.6
Nov.	16.7	8.13	154,287	52.7
Dec.	.536	14.3	49,189	291.0
12 months	33.1	104.0	3,157,527	32.9

(1) Volume of effluent from cooling towers, waste tanks, and NW12-139 Engineering Lab sink. Does not include other diluent from MIT estimated at 2.7 million gallons/day.

(2) No Detectable Activity (NDA): less than $1.26x10^{-6}$ μCi/ml beta for each sample.

I. SUMMARY OF USE OF MEDICAL FACILITY FOR HUMAN THERAPY

The use of the medical therapy facility for human therapy is summarized here pursuant to Technical Specification No. 7.7.1.9.

1. Investigative Studies

Investigative studies remain as summarized in the annual report for FY2005.

2. Human Therapy

None.

3. Status of Clinical Trials

The Phase I glioblastoma and melanoma trials with BIDMC have been closed. A beam that is superior to the original epithermal beam in the basement Medical Therapy Room in both flux and quality could again be made available from the Fission Converter Facility. No use of that beam is anticipated in the near term because of a nationwide funding hiatus for work of this type.