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

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U.S. Nuclear Regulatory Commission
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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, 2015 to December 31, 2015, 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
Interim Director of Reactor Operations
MIT Research Reactor

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

Alberto Queirolo
Director of Reactor Operations Designate
MIT Research Reactor

EL/st

Enclosure: As stated

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

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

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MIT RESEARCH REACTOR
NUCLEAR REACTOR LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ANNUAL REPORT

to

United States Nuclear Regulatory Commission for the Period January 1, 2015 – December 31, 2015

by

REACTOR STAFF

Table of Contents

MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JANUARY 1, 2015 – DECEMBER 31, 2015

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. However, it retained much of the original facility, e.g., graphite reflector, thermal shield, biological shield, secondary cooling systems, containment, etc.

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 forty-first annual report required by the Technical Specifications, and it covers the period from January 1, 2015 through December 31, 2015. 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-ninth 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 about 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 CY2015, the reactor averaged 73 operating hours per week, compared to 102 hours per week for CY2014, 54 hours per week for CY2013, and 76 hours per week for CY2012. The lower average for CY2013 was the result of operating the reactor only as needed for the first half of that 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 CY2015, compensation for reactivity lost due to burnup was provided by four 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. Six new fuel elements were introduced into the reactor core during CY2015.

The MITR-II fuel management program remains quite successful. During the period of CY2015, 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 and Utilization

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 CY2015 include:

a) Activation of gold-198 seeds for brachytherapy.

b) Activation of uranium foils for detector calibration at the Los Alamos National Laboratories and Ciambrone Laboratory at Patrick AFB.

c) Activation of ocean sediments for the University of British Columbia's Department of Earth and Ocean Sciences.

d) Elemental analyses were performed using NAA on samples of the in-core components to be used in the WATF-1B1 water loop experiment described below. Neutron activation studies using a variety of metal foils were continued in order to better characterize the neutron flux and spectrum of the reactor's thermal neutron beam irradiation facilities.

e) Activation and NAA were performed on superconducting ribbon containing rare-earth metals for the MIT Plasma Science and Fusion Center in preparation for longer irradiations to investigate change of properties with neutron damage.

f) Experiments were performed at the 4DH1 radial beam port facility by MIT undergraduate, graduate, and executive education students (course 22.09/90 "Principles of Nuclear Radiation Measurement and Protection" and MIT NSE "Reactor Technology Course for Utility Executives"), 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 a variety of shielding materials.

g) Use of the reactor for training MIT student reactor operators and for MIT nuclear engineering and executive education classes (course 22.01 "Introduction to Nuclear Engineering and Ionizing Radiation", course 22.011 "Seminar in Nuclear Science and Engineering", and MIT NSE "Reactor Technology Course for Utility Executives").

h) Neutron activation of germanium wafers to study radiation-induced photonic defects for the MIT Materials Processing Center.

i) Activation and NAA of silicon, sapphire, and Teflon samples for further NAA studies for University of Alabama.

j) Activation of fusion laminate samples to study radiation damage effects for Composite Technology Development.

k) Extensive measurements of neutron background levels were made in the reactor basement in preparation for a neutrino detection project for the MIT Physics Department.

l) Irradiation of SiC/SiC composites and other candidate materials for accident tolerant fuel cladding continued in the MITR in-core water loop facility (WATF). Irradiations under the first phase of the project were completed in May 2015 and all samples were removed for post-irradiation examination (PIE). A new set of samples was installed in the water loop and began irradiation in December of 2015, with a scheduled completion date of September 2016.

m) Extraction and PIE of samples from the two fluoride salt irradiations continued during 2015. Design of a new salt irradiation to be carried out in 2016 was initiated. This irradiation is expected to incorporate electric heating in order to avoid salt radiolysis and fluorine gas evolution in the event of unscheduled reactor shutdowns.

n) An irradiation of ultrasonic detectors for in-core sensor applications that was installed in February 2014 continued through May of 2015. The project (designated ULTRA) is funded under the National Scientific User Facility at INL-ATR (see below) and is led by Dr. Bernhard Tittmann of Penn State University (PSU). Two types of ultrasonic sensors (piezoelectric and magnetostrictive) were irradiated in the ICSA facility at temperatures up to about 430 °C, with temperature and self-powered gamma and neutron instrumentation. PIE on the sensors and on samples of the piezo-electric and magnetostrictive sensing elements was completed with participation from INL and PSU. Planning for a follow-on irradiation was initiated with a meeting at MIT.

o) Following completion of the Phase 1A accident tolerant fuel clad samples in the water loop, the loop facility was upgraded with a new autoclave and thimble using a "stepped" design (the in-core sections have smaller diameter than the above-core sections) to reduce neutron streaming at the reactor top. A specialized set of internals was installed in this autoclave for a demonstration of the real time crack growth monitoring using an actively loaded crack sample and DC potential drop crack growth measurement. This project was undertaken in collaboration with INL staff and the systems developed are intended for application both in the MITR and the ATR at INL.

p) 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 the INL Advanced Test Reactor National Scientific User Facility (ATR-NSUF) for materials testing and sensor development. The MITR was selected in 2008 as the first university research reactor to be a partner facility with the ATR-NSUF. MITR staff also worked with INL staff to jointly develop advanced reactor instrumentation, and reviewed ATR-NSUF's user proposals.

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 excellent. 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 ninety-eight elements fabricated by B&W have been received, forty-three of which remain in use. One has been removed because of suspected excess out-gassing and one hundred fifty-four 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 high-density 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 CY2015.

a) PM 8.0, "Respiratory Procedures", was completely revised to give a high-level overview of the respiratory protection program and its requirements. The details of each segment of the program will be maintained by the MIT department (Medical, EHS, etc.) responsible for that segment. (SR #2015-6)

b) PM 3.5 "Daily Surveillance Check" and PM 3.1.1.3 "Cooling Tower Operation and Full Power Checks" were updated to incorporate temporary changes and to reflect current equipment and best practices. There were no changes to displays, no human-machine interface or cybersecurity issues, and no additional training needed with these updates. (SR #2015-10, SR #2015-13)

c) AOP 5.4.4, "Low Flow HF-1", had its descriptive section updated to reflect current equipment, and AOP 5.6.5, "High Radiation Core Purge", received new text recognizing that excess MM-2 pump speed could splash primary water into the core purge system, causing core purge monitor spikes. (SR #2015-14)

d) PM 3.2.2, "Shutdown from Less than 100 kW Operation", and PM 3.2.3, "Maintenance Checklist", received similar sets of clarifications, plus updates reflecting current practices and equipment. (SR #2015-17, SR #2015-18)

e) PM 3.3.4.6, "Unloading of BRR Cask into Spent Fuel Pool", and PM 3.3.4.7, "Fuel Element Transfers from BRR Cask to Spent Fuel Pool", were established and evaluated as free of negative effects on safety, equipment, and ALARA. Regulatory compliance was maintained through verbatim inclusion of BRR Cask SAR "Wet Unloading" procedure steps. (SR #2015-22)

f) PM 3.1.6, "Restart Checklist", was revised to clarify the neutron scaler settings when Channels #1 & #2 are placed in fission chamber mode. (SR #2015-25)

g) AOP 5.5.14, "High or Low Level D_2O Gasholder", received an administrative change to its descriptive section, to correct the normal band for the D_2O gasholder and to specify the alarm setpoints. There were no safety concerns involved. (SR #2015-28)

h) AOP 5.6.1, "High Radiation Set-Up Area Vault", and AOP 5.6.4, "Trouble NW12 Gamma Monitor", were updated to correct the method of resetting the monitor. – Current system configuration mandates local reset. (SR #2015-29)

i) PM 1.1.4, "New Employee Access and EHS Training", was revised to include an Employee Entrance Material Checklist and an Employee Exit Material Checklist, which list the items and activities required by Reactor Operations, Reactor Radiation Protection, and the individual, to ensure all the appropriate physical access authorizations and access to various MIT and NRL resources. (SR #2015-31)

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, surveillance frequencies have been at least equal to those required by the Technical Specifications, 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 CY2015, 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 CY2016 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 CY2015) (normally at 5.8 MW)	212.0	356.4	119.7	159.7	847.8
b) MITR-II (MIT FY1976-CY2014)					34,981.5
c) MITR-I (MIT FY1959-FY1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					46,264.5
2. MITR-II Operation (hours): (MIT CY2015)					
a) At Power (> 0.5-MW) for Research	944	1539	510	689	3682
b) Low Power (< 0.5-MW) for Training[1] and Test	58	37	10	34	139
c) Total Critical	1002	1576	520	723	3821

[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 (row 2a of the table).

C. SHUTDOWNS AND SCRAMS

During this reporting period, there were eight inadvertent scrams and eight 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 #1 as result of failure of a BNC connector for the channel's ion chamber.	1
	b)	Trip on Channel #5 as result of spurious electronic noise.	3
	c)	Trip on Channel #6 caused by human error, using non-equilibrium thermal power for its trip set point calculation.	1
	d)	Scram on low voltage chamber power supply for Channel #2 caused by human error during ion chamber plateau testing.	1
	e)	Major Scram caused by human error creating a short while examining the auto-controller circuit.	1
		Subtotal	7
2.	Process System Scrams		
	a)	Low flow primary coolant scram from human error while flow was being manually reduced to assess the effect on reactivity fluctuations.	1
		Subtotal	1

3. Unscheduled Shutdowns

a)	Shutdowns in response to reactivity fluctuations that repeatedly transferred the reactor power auto-controller to manual control.	3
b)	Shutdown in response to failure of the reactor power auto-controller's pre-amplifier.	1
c)	Shutdown by dip in off-site electric power.	1
d)	Shutdown as result of shim blade drop upon failure of the magnet for shim blade #6.	1
e)	Shutdowns when MIT closed for snow storms.	2
	Subtotal	8
	Total	**16**

4. Experience during recent years has been as follows:

Calendar Year	Nuclear Safety and Process System Scrams
2015	8
2014	13
2013	4
2012	6
2011	9
2010	20
Fiscal Year	
2010	6
2009	2
2008	4
2007	5

D. MAJOR MAINTENANCE

Major reactor maintenance projects performed during CY2015 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.

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.

Major maintenance items performed in CY2015 are summarized as follows:

1. On 1/5 reactor staff replaced the absorber, magnet, and drive for shim blade #3.

2. On 1/6 the primary ion column was replaced.

3. On 1/7 and 1/8 reactor staff coordinated with RRP to remove the cooling jacket from 3GV5. On 1/9 they installed the third new Mirion fission chamber along with a new port plug into 3GV5.

4. During the week of 1/5 MIT Facilities replaced the intake air handler filters and belts.

5. During the week of 1/5 the Massachusetts state inspection was completed on the containment elevator.

6. During the week of 1/19 reactor staff replaced and calibrated in-core temperature sensors MTS-1 and MTS-1A.

7. During the week of 1/19 reactor staff replaced the secondary water monitor flow indications both locally and remotely in the control room.

8. During the week of 1/19 reactor staff completed hardware installation to provide local and remote indications of the status of the reactor weekend alarm and intrusion alarm systems.

9. On 1/22 reactor staff installed the fourth Mirion fission chamber into the 4IH4 horizontal instrumentation port.

10. On 2/3 reactor staff replaced the drive and magnet assembly for shim blade #2.

11. During the week of 3/30 MIT Facilities and their contractors installed safety equipment for the containment polar crane to improve fall protection.

12. On 5/18 reactor staff replaced the shim blade #2 proximity switch.

13. On 5/21 the reactor staff replaced the D_2O ion column.

14. On 6/9 MIT Facilities contractors performed asbestos abatement to remove the floor tiles inside the main airlock.

15. On 7/11 MIT Facilities performed scheduled maintenance and cleaning of 13.8 kilovolt feeder lines and the main electrical distribution system including Motor Control Centers 1 & 2.

16. On 7/13 reactor staff replaced the primary ion column and its inlet filter.

17. On 8/13 reactor staff replaced the shield ion column.

18. During the week of 8/24 reactor staff upgraded the auxiliary intake damper controls including the addition of remote operation from the control room.

19. On 9/22 reactor staff installed new controls for the power supply to the main airlock's hydraulics. MIT electricians completed the wiring connections.

20. On 9/22 reactor staff installed an isolation device for the auto controller pre-amplifier. The controller pre-amplifier will be better protected from challenges resulting from stray electrical noise.

21. On 10/2 reactor staff replaced the primary ion column.

22. On 9/28 MIT Facilities began replacement of the air handler unit for building NW12 (AHU-1). (The NW12 ventilation system is independent from the containment building's ventilation system.)

23. On 10/13 reactor staff replaced the magnet for shim blade #6 along with a refurbished blade drive mechanism.

24. During the week of 10/19 reactor staff installed and tested a new containment building penetration.

25. On 11/9 reactor staff replaced the D_2O ion column.

26. On 11/9 MIT Facilities coordinated the Massachusetts state inspection of all NW12 and containment elevators.

27. During the months of November and December, reactor staff coordinated the installation of a new equipment shed, including electrical and HVAC systems, for eventual housing of stack effluent monitoring equipment.

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

E. SECTION 50.59 CHANGES, TESTS, AND EXPERIMENTS

This section contains a description of each change to the reactor facility and associated 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.

Changes that affect only the operating procedures and that are subject only to MITR internal review and approval, including those that were carried out under the provisions of 10 CFR 50.59, are similarly discussed in Section A.5 of this report.

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".

Advance Cladding Irradiation Facility (ACI) \ Water Loop
SR #0-06-4 (04/03/2006), SR #0-06-6 (05/18/2006), SR #2015-8 (05/22/2015), SR #2015-9 (05/22/2015)

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. The current version of this loop, designated the Westinghouse Accident-Tolerant Fuel experiment, was installed in 2014 and operated until May 2015, and again from December 2015 into 2016. The latter run featured a stepped thimble to minimize neutron streaming to the reactor top. Additionally, from may 2015 to August 2015, the facility was used to test an In-Core Crack Growth Measurement (ICCGM) system.

Heated In-Core Sample Assembly Experiment (ICSA)
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. The ICSA facility remains in regular use for in-core experiments and irradiations.

High Temperature Irradiation Facility (HTIF) FS-2
SR #2014-12 (06/11/2014)

The MITRSC In-Core Experiments Subcommittee approved the latest HTIF test rig (FS-2) by mail ballot between 6/07/2014 and 6/11/2014. The experiment then operated successfully in core from July 2014 to August 2014.

DWK 250 Wide Range Monitors and Mirion Fission Chamber Detectors
SR #O-12-21 (10/19/2012), #O-13-22 (07/11/2013), #O-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.

Ventilation Damper System Upgrades
SR #M-13-2 (01/06/2014), SR #2014-22 (11/20/2014), SR #2015-15 (08/19/2015)

In 2014, the main exhaust damper motor control contactor protection hardware was replaced with thermal overload protection of a rating more appropriate to its environment. Additionally, the mechanism for holding the auxiliary exhaust damper open was re-designed such that the damper could be reset by electrical means rather than by pulling on it manually via a cable. In 2015, the latter modification project was successfully expanded to include the auxiliary intake damper.

Procedures Governing Shipment of Spent Fuel
SR #O-12-22 (03/21/2013), SR #O-13-2 (03/28/2013), SR #O-13-12 (06/28/2014), SR #O-13-12A (07/03/2014), SR #O-13-12B (07/22/2015), SR #2015-22 (08/26/2015)

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 and the other implementing procedures were updated to expand and improve oversight and coordination of the spent fuel shipment process, and for verbatim compliance with the shipping cask's Safety Analysis Report Chapters 7 and 8. These updates were inspected by NRC during an actual shipment and were deemed satisfactory. The procedures, with further updates, were also used satisfactorily in September 2015.

Physical Security Plan Revision
SR #O-13-16 (05/12/2014), SR #O-13-30 (12/24/2013), SR #2014-19 (11/07/2014), SR #2014-23 (02/18/2015), SR # 2015-5 (01/23/2015)

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, for which approval was received on 5/12/2014. The PM 3.2.4.*, "Response to Weekend Alarms" procedures were then revised accordingly, along with those under PM 3.7.3, "Normal Containment Entry/Exit". In 2015, a security alarm coincidence monitoring system was installed to provide local and remote notification should the weekend alarm or an intrusion alarm become deactivated during periods of unattended shutdown. Procedures were revised to incorporate use of this monitoring system.

Digital Logbook
SR #2014-14 (06/25/2014), SR #2015-32 (10/20/2015)

After a full safety review, several sets of control console instruments were relocated to other parts of the console in 2014 to accommodate a new display for the digital logbook computer. In October 2015, after a total of two years of parallel usage, the paper chronological logbook was replaced by the digital version. The digital logbook operates from two on-site database servers running in parallel, backed up nightly to MIT Information systems & Technology's servers on campus and off-site.

Containment Polar Crane (Radial Hoist) Access Safety Upgrade
SR #2015-7 (05/06/2015)

The access ladder from the containment building's catwalk to the polar crane bridge was replaced with one of new design to meet modern industrial safety standards for fall protection. Access from the crane bridge deck to the containment dome light fixtures was similarly improved, by installation of an A-frame "up-and-over" platform, and installation nearby of a bespoke davit system for lifting equipment. Written safety procedures for the installation process were agreed upon in advance. The new hardware does not interfere with operation of the crane or the reactor.

Neutron Flux Channel #7 Chamber Power Supply
SR #2014-13 (03/04/2015), SR #2014-13A (03/27/2015)

A new power supply was designed and installed for linear flux Channel #7, with higher impedance to earth ground in order to prevent ground loops which cause signal noise. The chamber plateau test procedure received a corresponding revision.

MT-1 and MT-1A Sensors
SR #2015-2 (01/16/2015), SR #2015-2A (06/08/2015)

The core tank outlet temperature sensors MT-1 and MT-1A were changed from thermocouples to resistance temperature detectors. The calibration procedure received a corresponding revision. Alarm, scram, and display functions at the console panel meters were unchanged.

Water Monitor Flowmeters
SR #2015-3 (01/21/2015), SR #2015-3A (05/27/2015)

The sightglass flowmeters and mechanical low flow alarm switches for the secondary water monitors were replaced with inductive magnetic flowmeters that provide local display, remote display, and alarm function based on 4-20 milliamp analog output signals. The alarm test procedure received a corresponding revision.

Auto-Controller Pre-Amplifier Signal Isolation
SR #2015-23 (09/22/2015)

A hardware upgrade added an isolation barrier between the picoammeter for the neutron flux level channel used by the reactor auto-controller, and the auto-controller subsystem itself, in order to reduce component-level stress in the auto-controller's pre-amplifier. Existing hardware remained unchanged, with the only effect of the isolation barrier being to limit offset biasing between the subsystems.

Key-Switch for Main Airlock Hydraulic Pump Power
SR #2015-24 (09/24/2015)

For personnel electrical safety, a key-switch was installed to turn electrical power on and off for the main airlock's hydraulic pump. Previously the pump's 480-volt circuit breaker was manually operated each time the airlock needed to be secured. Procedures for securing and re-opening the containment building were revised accordingly.

Stack Effluent & Water Monitor Project
SR #2015-30 (pending), SR #2015-30A (12/02/2015)

As part of a project to install new stack effluent monitors and secondary water monitors using detectors located outside the containment building, a new 1-1/4" diameter piping penetration was installed on the south side of the containment building, about four feet below ground. It was tested as satisfactory per existing procedures for pressure-testing new penetrations. Until such time as it is connected to the main system piping, the new piping will remain blank-flanged, or isolated and tagged out, in order to ensure containment integrity is maintained.

Technical Specification 7.1.4 Amendment to DRO License Requirement
SR #2015-11 (05/21/2015)

A Technical Specification amendment request was submitted to NRC on 5/28/2015 to allow the MITR Director of Reactor Operations to use a Senior Reactor Operator license at another facility as an alternative to holding or having held such a license for the MIT Reactor. Wording consistent with ANSI/ANS-15.4-2007, "Selection and Training of Personnel for Research Reactors," Section 4.3, was added. The amendment received NRC approval on 8/13/2015.

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 (01/01/15 – 12/31/15)
North	0.34 mrem
East	0.63 mrem
South	0.35 mrem
West	0.63 mrem
Green (east)	0.05 mrem

Calendar Year Average

2015	0.4 mrem
2014	0.8 mrem
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

G. RADIATION EXPOSURES AND SURVEYS WITHIN THE FACILITY

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

January 1, 2015 - December 31, 2015

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	53
Measurable – < 0.1	21
0.1 – 0.25	5
0.25 – 0.50	1
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 = 1.7   Total Number of Personnel = 80

From January 1, 2015, through December 31, 2015, 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 5,583,628 liters discharged during CY2015 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 218.1 μCi for CY2015. The total tritium was 104.1 mCi. The total effluent water volume was 5,636,622 liters, giving an average tritium concentration of 18.5E-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 1014.43 Ci of Ar-41 was released at an average concentration of 1.65E-10 μCi/ml. This represents 1.65% of EC (Effluent Concentration (1E-08 μCi/ml)).

3. Solid Waste

Three 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 2015

	Ar-41 Discharged (Curies)	Average Concentration[1] (μCi/ml)
January 2015	0.00	0.00 E-10
February	84.71	1.77 E-10
March	170.79	2.86 E-10
April	90.75	1.90 E-10
May	100.25	1.68 E-10
June	73.45	1.54 E-10
July	74.25	1.55 E-10
August	49.83	8.34 E-11
September	165.12	3.45 E-10
October	17.17	2.87 E-11
November	83.88	1.75 E-10
December	104.24	2.18 E-10
Totals (12 Months)[2]	**1014.43**	**1.65 E-10**
EC (Table II, Column I)		1×10^{-8}
% EC		**1.65%**

(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 2015

Description	
Volume	164 ft^3
Weight	4722 lbs.
Activity	145 mCi
Date of shipment	April 10, 2015
Disposition to licensees for burial	Energy Solutions, Clive, UT, and Toxco Material Management Center, Oak Ridge, TN
Waste broker	Ecology Services Inc., Columbia, MD

Description	
Volume	62 ft^3
Weight	424 lbs.
Activity	17 mCi
Date of shipment	October 14, 2015
Disposition to licensee for burial	Energy Solutions, Clive, UT
Waste broker	Ecology Services Inc., Columbia, MD

Description	
Volume	105 ft^3
Weight	3564 lbs.
Activity	9459 mCi
Date of shipment	December 3, 2015
Disposition to licensee for burial	Energy Solutions, Clive, UT
Waste broker	Energy Solutions, Clive, UT

TABLE H-3

LIQUID EFFLUENT DISCHARGES
CALENDAR YEAR 2015

	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. 2015	.542	.404	26,832	15.0
Feb.	178	33.6	545,160	61.6
Mar.	.947	26.4	992,355	26.6
Apr.	NDA[2]	1.90	974,549	1.95
May	3.43	2.54	418,281	6.06
June	1.32	.795	659,925	1.20
July	6.57	1.16	349,389	3.32
Aug.	5.56	.504	65,244	7.73
Sept.	1.71	1.08	412,731	2.63
Oct.	1.14	5.19	300,353	17.3
Nov.	12.6	30.1	380,371	79.2
Dec.	6.28	.424	511,432	.829
12 months	218.10	104.10	5,636,622	18.5

(1) Volume of effluent from cooling towers, waste tanks, and NW12-139 Engineering Lab sink. Does not include other diluent from MIT estimated at $1.0x10^7$ liters/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.