MIT NUCLEAR REACTOR LABORATORY

AN MIT INTERDEPARTMENTAL CENTER

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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, 2017, to December 31, 2017, in compliance with paragraph 7.7.1 of the Technical Specifications issued November 1, 2010, for Facility Operating License R-37.

Sincerely,

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Enclosure: As stated

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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, 2017 – December 31, 2017

by

REACTOR STAFF

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MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JANUARY 1, 2017 – DECEMBER 31, 2017

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 pre-operational 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 operation, 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 that monitor system flows, temperatures, and pressures.

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-third annual report required by the Technical Specifications, and it covers the period from January 1, 2017, through December 31, 2017. 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 forty-first 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 CY2017, the reactor averaged 108 operating hours per week, compared to 112 hours per week for CY2016, 73 hours per week for CY2015, and 102 hours per week for CY2014. The lower average for CY2015 was the result of operating the reactor only as needed, when at times 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 CY2017, 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. With the four refuelings, nine new fuel elements were introduced into the reactor core and nine spent fuel elements were discharged from the core during CY2017.

The MITR-II fuel management program remains quite successful. During the period of CY2017, no discharged or 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 CY2017 include:

a) Irradiation of candidate cladding materials for accident tolerant fuel (ATF) development continued in the water loop. A shared irradiation for Ceramic Tubular Products with funding from the DOE GAIN voucher program and Oak Ridge National Laboratory occupied the loop from January to June. Samples included a variety of SiC composite materials (tubes and coupons) some with coatings, and FeCrAl tubes. Electrochemical corrosion potential (ECP) sensors were installed just above core to monitor the water chemistry. The first irradiation campaign for Phase 2 of a major ATF program by Westinghouse Electric Company (WEC), supported by the DOE, was irradiated from August to December. Again, a variety of SiC composite materials, some with end plugs and experimental coatings and coated Zircaloy tubing made up the sample matrix. Several samples were previously irradiated in the Phase 1 program. A prototype test for a wireless fuel temperature sensor under development by WEC, and additive manufactured Zircaloys for advanced fuel spacer grids were also included in the irradiation.

b) The second in-core sensor irradiation in the ICSA – ULTRA2 – was irradiated in the second, third and fourth reactor cycles of 2017 and will continue for the first cycle of 2018. As in the first ULTRA irradiation, the behavior of ultrasonic sensors provided by INL is being investigated. ULTRA2 also includes a number of fiber optic temperature sensors from the University of Pittsburgh and the French Commissariat à l'énergie atomique (CEA). All of these sensors are interrogated in real time through cables and fibers fed through the ICSA top flange and the reactor core tank wall and connected to data acquisition systems on the reactor floor. In addition to the sensors under test, a set of glass samples for radiation resistant optical fibers is being irradiated and will be evaluated by post-irradiation examination.

c) A week-long instrumentation test in support of the TREAT transient test reactor at INL was carried out in July. A test capsule with neutron detectors and companion flux wires and thermocouples was placed in an in-core location and operated at low reactor power (<100 kW) with the reactor lid off and zero primary coolant flow. Response of the neutron detectors to positive and negative power transients initiated by reactor control blade movements were tested. Neutron detectors were provided by Kansas State University, INL and the CEA. As a result of some technical problems, the entire planned test matrix was not completed, but the feasibility of operating at low power with the reactor lid off and other essential features of the test were demonstrated. Lessons learned will be applied to a second round of testing in January 2018 to complete the desired test matrix.

d) Extraction and post-irradiation examination (PIE) of samples from the first three fluoride salt irradiations continued during 2017. One of the major activities was disassembly of the FS-3 rig, irradiated November-December of 2016. All of the graphite salt crucibles have been extracted and the Chinese Academy of Science samples have been retrieved from the salt.

e) 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" sponsored by the Institute for Nuclear Power Operations), including: 1) measurements of leakage neutron energy spectrum to determine reactor temperature; 2) measurement of neutron wavelength and time-of-flight; 3) measurement of attenuation coefficients for a variety of shielding materials; and 4) Bragg diffraction of neutrons in a copper single crystal. Note that repairs to the 4DH1 port collimator undertaken in July dramatically restored and increased the thermal neutron flux at the beam port and thereby greatly improved data quality, reduced data acquisition times, and permitted experiments on the diffracted beam.

f) A thermal neutron beam port 4DH4 is being prepared to measure void fraction in transient boiling heat transfer by neutron radiography. This project is in collaboration with Professor M. Bucci (MIT NSE). In addition, measurements of irradiated nuclear fuel by neutron diffraction are being prepared. This project is in collaboration with Idaho National Laboratory (INL).

g) Elemental analyses were performed using NAA on samples of the in-core components to be used in the WATF-2 irradiation 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 out-of-core neutron irradiation facilities.

h) Elemental analyses were performed using NAA on the flux wire samples used in the TREAT irradiation experiment described above.

i) Activation of an enriched Pt-192 foil for Los Alamos National Laboratory support efforts to perform the first calorimetric measurement of electron capture in Pt-193 with a transition edge sensor.

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

k) Activation of aluminum samples for a neutron damage study for the MIT Nuclear Science and Engineering Department.

l) Activation and NAA of saline samples for the MIT Center of Environmental Health Sciences.

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

n) Activation of cement samples to evaluate crack detection techniques for Radiation Monitoring Devices, Inc.

o) Activation of gold-198 seeds for brachytherapy.

p) Other 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").

An ongoing initiative is the partnership with the Department of Energy's Nuclear Science User Facilities (NSUF) for advanced materials, high temperature sensors, and fuel irradiation. The MITR became the first university research reactor to be a partner facility with the NSUF in 2008. MIT-NRL staff also worked with INL staff to jointly develop advanced reactor instrumentation, and reviewed 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 (manufactured by BWXT). 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. Two hundred sixteen elements fabricated by BWXT have been received, forty-five of which remain in use. One has been removed because of suspected excess out-gassing and one hundred seventy 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. In December CY2017, a report entitled "LEU Conversion Preliminary Safety Analysis Report for the MITR" was docketed with NRC to support a future application for licensing to convert from High Enriched Uranium (HEU) to LEU fuel. This PSAR provides analysis determining that a power increase from 6 MW with the current HEU core to 7 MW when using the LEU core is required in order to maintain core neutronic flux performance.

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 on-site 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 CY2017.

a) PM 3.3.1 "General Conduct of Refueling Operations", PM 3.3.1.1 "Fuel Element Transfers: Core/Storage Ring/Vault", PM 3.3.2 "General Conduct of Removal of Spent Fuel", and PM 3.3.2.1 "Fuel Element Transfers: Storage Ring/Storage Pool" were updated to reflect best practices, and current terminology and equipment. This made the checklists easier for staff with less experience to follow. To improve criticality safety, the instruction to pump up the reflector if the startup channels' neutron counters read <10 cpm was removed. (SR #2016-14)

b) PM 3.1.3 "Startup for Less than 100 kW Operation", PM 3.1.1.3 "Cooling Tower Operation and Full Power Checks", and PM 3.1.1.4 "Two Loop Restart Incorporating Required Quarterly Startup Surveillances" were updated to reflect previous changes in the full power startup checklists, best practices, and current equipment. There were no changes to human-machine interfaces and no cyber security issues. (SR #2016-30)

c) PM 3.1.10 "Placing Safety Channels in and out of Commission" was established in order to minimize the number of entries into the back of the console and to track channel disconnections and reconnections. It requires that all wire moves be logged in the wire removal binder. (SR #2016-36)

d) Flow calibrations PM 6.1.3.3A/B, 6.1.3.12A/B, 6.1.3.13A/B (for the primary, reflector, and shield coolant systems, respectively) were updated to reflect current equipment and best practices, and for clarity. This included splitting each into two separate procedures, for using the air pressure regulator assembly versus the Transmation Model 190 Calibrator. (SR #2016-37)

e) PM 3.5 "Daily Surveillance Check" and PM 3.2.3 "Maintenance Checklist" were updated to better harmonize the two procedures, to add clarifications, and to reflect current equipment and best practices, with no significant changes to human-machine interfaces and no cybersecurity issues. (SR #2017-4, SR #2017-23)

f) PM 7.6.5 "Waste Tank Cleaning" was established for cleaning the waste tank system by recirculating waste water through filters with gradually decreasing pore size, in order to reduce the need for change-outs of clogged filters during waste tank discharges. (SR #2017-9)

g) PM 3.3.4.1 "Fuel Shipping Supervisory Checklist", PM 3.3.4.1.1 "Receipt of BRR Cask and Removal from Transport Vehicle", PM 3.3.4.2 "Loading of BRR Cask", PM 3.3.4.3 "Fuel Element Transfers from SFP to BRR Cask", PM 3.3.4.4 "BRR Cask Vacuum Drying and Helium Leak Test", PM 3.3.4.5 "Placement on Transport Vehicle and Shipment of BRR Cask", PM 3.3.4.6 "Unloading of BRR Cask into SFP", and PM 3.3.4.7 "Fuel Element Transfers from BRR Cask to SFP" all received administrative updates corresponding to the new Revision 10 of the BRR cask's Safety Analysis Report. Accuracy and clarity of the procedures was maintained, and verbatim compliance requirements were satisfied. (SR #2017-29)

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. Thirty such tests and inspections are scheduled throughout the year with a frequency at least equal to that required by the Technical Specifications. Together with those not required by Technical Specifications, over 100 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 CY2017, there was one shipment scheduled, for reducing the inventory of spent fuel at MIT. These shipments are made using the BEA Research Reactor (BRR) package. The CY2017 shipment was aborted upon arrival of the BRR package when regulatory compliance by the new shipping company was discovered to be incomplete. The BRR package was never removed from its shipping trailer, and was returned empty. The U.S. Department of Energy has indicated that further shipments may be feasible in CY2018 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 CY2017) (normally at 5.8 MW)	340.4	336.2	249.5	351.8	1,277.9
b) MITR-II (MIT FY1976-CY2016)					37,199.1
c) MITR-I (MIT FY1959-FY1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					48,912.2
2. MITR-II Operation (hours): (MIT CY2017)					
a) At Power (> 0.5-MW) for Research	1,486	1,460	1,056	1,503	5,505
b) Low Power (< 0.5-MW) for Training(1) and Test	30	43	31	4	108
c) Total Critical	1,516	1,503	1,087	1,507	5,613

(1) These hours do not include reactor operator and other training conducted while the reactor is at or above 0.5 MW. Such hours are included in the previous line (row 2a of the table).

C. SHUTDOWNS AND SCRAMS

During this reporting period, there was one inadvertent scram and six 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. Control blade 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 noise during reactor startup switchover to ion chamber mode.	1
	Subtotal	1
2.	Process System Scrams	
	a) None.	0
	Subtotal	0

3. Unscheduled Shutdowns

a)	Shutdowns when MIT closed for snow storms.	2
b)	Minor scram initiated by operator upon observing or suspecting only one operable period channel on line during startup.	2
c)	Minor scram initiated by operator after Shim Blade #4 dropped from its magnet during power decrease to 90 kW.	1
d)	Shutdown for repair of in-core experiment charging pump.	1
	Subtotal	6
	Total	**7**

4. Experience during recent years has been as follows:

Calendar Year	Nuclear Safety and Process System Scrams
2017	1
2016	4
2015	8
2014	13
2013	4
2012	6
2011	9
2010	20
Fiscal Year	
2010	6
2009	2
2008	4

D. MAJOR MAINTENANCE

Major reactor maintenance projects performed during CY2017 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 reliability 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 CY2017 are summarized as follows:

1. Reactor staff performed maintenance on the load-side Silicon machine during the week of 1/9/2017.

2. Reactor staff repacked and replaced process system ion columns several times during the year. The primary system ion column was done in January, April, August, and October. Its inlet filter was also replaced in August and October. The D_2O reflector system ion column was done in April and October. The shield coolant system ion column was done in January and July; its inlet filter was replaced in May.

3. On 1/5/2017 the control room ventilation fan was replaced.

4. During the January outage, reactor staff replaced shim blade #2, as it was nearing its end of service life. This entailed replacing the boron stainless-steel blade and its offset assembly. The spent blade was stored in the spent fuel pool. After the outage, a reactivity worth measurement was completed at low power for the newly installed shim blade #2.

5. During the April outage, the electromagnet and shim blade drive for shim blade #2 were replaced as preventive maintenance. Reactor staff rebuilt the blade drive and fabricated in house a new electromagnet prior to the outage.

6. Reactor staff coordinated with Siemens Building Technologies and MIT Police to perform the annual system-wide test of the reactor security system in the spring of 2017, along with replacement of more than 35 backup batteries for the system.

7. During the month of April the Cathodic Protection System for the NW12 containment building was entirely replaced and upgraded. A total of 19 new electrodes were installed in holes drilled 15-20 feet deep, including two in new

locations within the Utility Room. This expanded the system from six electrodes. Afterward, the system was powered and conditioned with two new rectifiers for 90 days. In August, the system was fully commissioned and operational

8. For two weeks during the April outage, reactor staff replaced the main piping manifold for the shield coolant system in the equipment room. This manifold had aged sufficiently that it was prone to chronic leakage. Prior to the outage, reactor staff designed and fabricated the new manifold using stainless steel piping. During the October outage, reactor staff replaced all the shield coolant system flow meters on the reactor's Utility Shelf.

9. During the month of April, a signal cable for Mirion DWK 250 Channel 4 was re-routed to reduce interference. This channel will be part of the new Nuclear Safety System currently under license amendment review by NRC.

10. During the April outage, reactor staff replaced shim blade #6 as it was at the end of its life. This entailed replacing the boron stainless-steel blade and its offset assembly. The spent blade was stored in the spent fuel pool.

11. During the week of 5/1, reactor staff completed worth measurements for the regulating rod and all six shim blades.

12. Compressed air regulator CV-4 was replaced by reactor staff on 5/1.

13. On 6/28 reactor staff coordinated with MIT Facilities to replace one of two large A/C units, located on the roof of NW12-100D Utility Room, which service the containment building.

14. On 7/5 reactor staff replaced the remote operation key switch for HV-15 after it failed.

15. On 7/11 reactor staff completed the annual gain determination for nuclear safety channels #5 and #6 low-range amplifiers.

16. On 7/13 reactor staff completed the annual efficiency test for the ventilation system charcoal filters.

17. During the month of July, reactor staff worked to resolve a long-term issue with the 4DH1 neutron beam. The beam port was opened up, cleaned out, repaired, and reassembled, restoring the beam's original characteristics and greatly improving its usability.

18. On 7/18 reactor staff replaced the electronic transducer for primary system pressure sensor MP-4.

19. During the month of July the stack gas #2 effluent monitor was repaired and reinstalled.

20. During the month of July the slide wire for the D_2O gasholder was cleaned and serviced.

21. In late August, reactor staff worked with MIT Facilities to replace the air dryer for the reactor's compressed air system, and all associated piping, in the Utility Room. The dryer had failed in prior weeks indicating a high temperature condition.

22. Reactor staff worked with MIT Facilities to abate two large laboratory areas of asbestos floor tiles and complete renovations.

23. For one week during the October outage, reactor staff coordinated with contractors to replace one cooling tower support leg that had been previously damaged by a shipping truck. After the replacement, reactor staff filled the cooling tower with water and put the system in full flow for leak testing, which passed satisfactorily.

24. On 10/12 reactor instrumentation staff replaced electrical cabling and connectors on the main airlock inner door.

25. During the month of October all the relays in the Withdraw Permit Circuit were replaced as preventive maintenance after two failed prematurely. Afterward, reactor staff performed an extensive testing procedure to confirm the Withdraw Permit Circuit operational.

26. During the month of October reactor staff completed the annual inventory of heavy water.

27. On 11/22 the motor for shim blade 3 was inspected and serviced.

28. On 12/29 and 1/3/18 reactor staff coordinated with MIT Facilities to repair two ruptured steam coils in the containment building air handler unit heating coil bank. The two steam coils had failed and flooded the adjacent floor.

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 NRC Document Control Desk.

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. This includes all in-core experiments, which are additionally reviewed and approved by the MIT Reactor Safeguards Committee (MITRSC) prior to installation in the reactor core. All experiments not carried out under the provisions of 10 CFR Part 50.59 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. A later version of this loop, designated the Westinghouse Accident-Tolerant Fuel (WATF) experiment, was installed in 2014 and operated until May 2015, and again from December 2015 until July 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. In 2017, from January to June, the ACI facility was used for the COATI irradiation ("CTP and ORNL Accident Tolerant Irradiation") of a variety of silicon carbide composite materials. From August to December 2017, it was used for a Phase 2 WATF experiment, which also included prototype test for a wireless fuel temperature sensor.

Heated In-Core Sample Assembly Experiment (ICSA)
SR #0-04-19 (12/01/2004), SR #M-04-2 (12/30/2004), SR #0-05-11 (07/22/2005), SR #M-09-1 (07/30/2009), SR #M-09-2 (12/11/2009), SR #0-10-2 (03/28/2010), SR #0-12-17 (06/04/2012), SR #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 remained in regular use in CY2017 for in-core experiments and irradiations. – See section A.2, item (n).

High Temperature Irradiation Facility (HTIF) FS-2 and FS-3
SR #2014-12 (06/11/2014), SR #2016-31 (11/04/2016)

The MITRSC In-Core Experiments Subcommittee approved the HTIF FS-2 test rig by mail ballot between 6/07/2014 and 6/11/2014. The experiment then

operated successfully in core from July 2014 to August 2014. Its successor, the HTIF FS-3, operated in core from November 2016 to December 2016. There were no HTIF irradiations in 2017.

DWK 250 Wide Range Monitors and Mirion Fission Chamber Detectors
SR #O-12-21 (10/19/2012), SR #O-13-22 (07/11/2013), SR #O-13-27 (11/08/2013)
SR #2017-52 (10/04/2017)

All four DWK 250 Wide Range Monitors and their associated fission chamber detectors have been installed in the control room and the reactor respectively, along with their corresponding TKV23 pre-amplifiers. Reactor staff completed fabrication and bench testing of all downstream supporting modules. These include the Signal Distribution Module, Scram Logic Card Modules, LED Scram Display, <100 kW Key-Switch Module, the PLC module, the DWK 250 "Test" Condition Bypass Assembly, and the magnet power supply and rundown relay module. Additionally, reactor staff completed modification and testing of the Withdraw Permit Circuit Bypass Panel in preparation for future installation of the new Nuclear Safety System. Reactor staff assembled all of the modules into a single instrumentation rack in the control room. Written procedures were developed to perform pre-operational global testing of the system. The integrated system is operating in parallel in the control room, but is not connected to the existing reactor scram circuits. NRC performed an on-site audit of the system in July 2017, followed by issuance of Request for Additional Information (RAI) in October. In November, reactor staff drafted a response, including updated module descriptions and safety analysis documentation, to the RAI for review and approval by the MITRSC Standing Subcommittee. In December, reactor staff submitted the response to the RAI.

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), SR #2017-29 (08/30/2017)

The reactor's Standard Operating Plan was modified to allow designated omission of the inverse multiplication measurements, as approved by the MITRSC in 2012. The PM 3.3.4 Spent Fuel Shipping 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 in 2014 and deemed satisfactory. The procedures, with further updates, were also used satisfactorily in September 2015 and May 2016. Prior to the 2016 shipment, the NRL reached an agreement with DOE to fund on-site inspection of the BRR cask for each shipment by an independent contractor, prior to loading and again after loading. Reactor staff and the independent contractor developed written procedures for these inspections to document the condition of the cask and to ensure compliance with the cask SAR. In 2017, all the procedures were revised to maintain verbatim agreement with the recently-released Revision 10 of the BRR cask's Safety Analysis Report.

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), SR #2017-5 (2/14/2017)

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. In 2017, the Plan was revised in response to an NRC Request for Additional Information regarding incorporation of material from NRL's responses to NRC Compensatory Action Letters. The revision and response to NRC were approved by the MITRSC Special Subcommittee for Security.

Stack Effluent & Water Monitor Project
SR #2015-30 (pending), SR #2015-30A (12/02/2015), SR #2015-30B (07/08/2016), SR #2015-30C (03/31/2016)

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. A new climate-controlled shed, the "stack monitor shed", was constructed in the reactor's back yard in CY2016, with the two new stack monitor stations fully mounted within. In 2017, this newly-installed system continued to operate in parallel with the existing stack effluent and water monitoring systems.

Camera System Upgrade – Phase I
SR #2016-28 (09/23/2016)

A new camera system, with 19 cameras, was installed in October 2016 and tested satisfactorily. 15 of these replaced cameras from the existing system, and four were in newly-selected locations. The new system uses updated imaging technology and improved secure data transmission and communication. The display locations and configurations remain unchanged at NW12, but with ease of control and improved human interface. The camera images are now also available at MIT Police Dispatch. NRL management is engaging with the MIT Reactor Safeguards Committee and MIT's Information Technology Policy Committee to modify MIT policy on data handling as it applies to the needs of the NRL. Phase II is planned, and funding is being explored.

Ultrasonic Anemometer
SR #2016-27 (10/24/2016)

A new anemometer was installed to replace the previous unit, which was aged and no longer responsive to low-speed winds. The new unit uses ultrasound technology to measure wind speed and direction, and has no moving parts. Readouts continue to be displayed in the control room and the Operations Office. The system is not connected to any public network and therefore has no cybersecurity concerns.

MIT Police Patrol "Guard Tour" Card Reader System
SR #2016-35 (06/19/2017)

A "guard tour" card reader system was installed to read MIT Police badges. This reader provides verification and recording that MIT Police on-site patrols have taken place at the frequency required by the Physical Security Plan. It provides electronic notification to designated reactor staff if a patrol check-in is missed, such that compensatory action can be implemented promptly.

Iris Reader System Upgrade
SR #2017-10 (03/20/2017)

A new iris reader system was installed to replace the previous system, which had aged enough that there was a lack of replacement parts. The new system improves security, expands storage capacity, and runs on a faster microprocessor.

Cathodic Protection System Upgrade
SR #2017-14 (04/07/2017)

The reactor containment building's cathodic protection system was entirely replaced and upgraded, going from six anodes to 19, with two new locations beneath the utility room floor. The upgrade improved the cathodic current illuminating and protecting the underground portion of the containment shell to a minimum of 7.2 amps. It has at least 20 amps capacity in order to account for all other buried metal structures, and for uneven distribution along the containment shell. Installation was completed in April 2017. After a 90-day initialization period, the system was commissioned in August and became fully operational.

<u>TREAT Core Instrumentation Low Power Experiment</u>
SR #2017-19 (06/27/2017), SR #2017-19A (07/18/2017), SR #2017-19B (07/26/2017), SR #2017-19C (07/27/2017)

This week-long experiment was carried out in July 2017. A test capsule with neutron detectors, flux wires, and thermocouples was placed in a designated in-core location. During the experiment, the reactor operated at <100 kW, with the reactor top shield lid off, and zero primary coolant flow. Along with the experiment itself, written procedures were reviewed and approved by the MITRSC Special Subcommittee for In-Core Experiments in meetings on 1/27/2017 and 7/5/2017, to be followed by the console operator for the performance of the experiment. Because of a capsule loading issue, only part of the planned tests were completed in 2017.

<u>4DH1 Plug Neutron Shield Replacement</u>
SR #2017-27 (08/21/2017)

In July 2017, the 4DH1 student spectrometer beam port was opened to investigate the cause of the neutron beam diminishing over time. This required disassembly of the Silicon system's load-side cell shielding. Reactor staff cleaned off accumulated corrosion surrounding the beam path, and replaced the deformed cadmium neutron shield on the tip of the port plug with a new Boral "hat" inner neutron shield. This new inner shield is expected to be as effective as the cadmium in minimizing neutron activation of the port plug, while maintaining better rigidity than the cadmium, which had collapsed into the beam path. The result of the work was a much-improved neutron beam, restoring the beam port to its designed usability.

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 (01/01/17 – 12/31/17)
North	0.18 mrem
East	0.65 mrem
South	0.29 mrem
West	0.65 mrem
Green (east)	0.04 mrem

Calendar Year Average

2017	0.4 mrem
2016	0.6 mrem
2015	0.4 mrem
2014	0.8 mrem
2013	0.2 mrem
2012	0.3 mrem
2011	0.3 mrem
2010	0.1 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, 2017 - December 31, 2017

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	51
Measurable – < 0.1	26
0.1 – 0.25	6
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 = 1.8 Total Number of Personnel = 84

From January 1, 2017, through December 31, 2017, 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 10,690,205 liters discharged during CY2017 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 1.17E-5 Ci for CY2017. The total tritium was 2.15E-1 Ci. The total effluent water volume was 10,712,824 liters, giving an average tritium concentration of 1.73E-5 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 2400.36 Ci of Ar-41 was released at an average concentration of 3.73E-10 μCi/ml. This represents 3.73% of EC (Effluent Concentration (1E-08 μCi/ml)).

3. Solid Waste

One shipment of solid waste was made during the calendar year. The information pertaining to this shipment is provided in Table H-2.

TABLE H-1

ARGON-41 STACK RELEASES

CALENDAR YEAR 2017

	Ar-41 Discharged (Curies)	Average Concentration[1] (µCi/ml)
January 2017	34.15	7.14 E-11
February	239.40	4.01 E-10
March	62.31	1.04 E-10
April	29.27	6.12 E-11
May	179.33	3.00 E-10
June	199.42	4.17 E-10
July	188.59	3.95 E-10
August	242.05	4.05 E-10
September	121.75	2.55 E-10
October	280.12	4.69 E-10
November	183.46	3.84 E-10
December	189.87	3.18 E-10
Totals (12 Months)[2]	**1949.71**	**2.98 E-10**
EC (Table II, Column I)		1×10^{-8}
% EC		**2.98%**

(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 2017

Description	
Volume	49 ft^3
Weight	995 lbs.
Activity	11 mCi
Date of shipment	April 5, 2017
Disposition to licensees for burial	Energy Solutions, Clive, UT, and Toxco Material Management Center, Oak Ridge, TN
Waste broker	Ecology Services Inc., Columbia, MD

TABLE H-3

LIQUID EFFLUENT DISCHARGES
CALENDAR YEAR 2017

	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. 2017	NDA(2)	.0205	584,225	.0351
Feb.	1.34	26.5	967,631	27.4
Mar.	NDA(2)	.0253	1,323,151	.0191
Apr.	NDA(2)	.0216	385,107	.0561
May	4.14	32.8	1,027,252	31.9
June	NDA(2)	72.4	1,150,965	62.9
July	NDA(2)	.00673	133,682	.0504
Aug.	2.58	29.2	1,021,875	28.6
Sept.	NDA(2)	.161	1,084,781	.148
Oct.	1.48	23.8	936,698	25.4
Nov.	0.335	8.66	1,173,450	7.38
Dec.	1.81	21.7	924,007	23.5
12 months	11.7	215	10,712,824	17.3

(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.