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, 2019, to December 31, 2019, in compliance with paragraph 7.7.1 of the Technical Specifications issued November 1, 2010, for Facility Operating License R-37.

Sincerely,

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

EL/st

Enclosure: As stated

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

USNRC – Senior Reactor Inspector
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Division of Licensing Projects
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, 2019 – December 31, 2019

by

REACTOR STAFF

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MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JANUARY 1, 2019 – DECEMBER 31, 2019

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-fifth annual report required by the Technical Specifications, and it covers the period from January 1, 2019, through December 31, 2019. 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-third 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 CY2019, the nominal full power was 5.7 MW, with an operating period of up to eleven weeks at a time, followed by a scheduled outage lasting about two weeks or more 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 operating period.

Throughout CY2019, the reactor averaged 110 operating hours per week, compared to 90 hours per week for CY2018, 108 hours per week for CY2017, 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 either solid aluminum dummies or in-core experiments. During CY2019, 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 where peaking is least (normally the B-Ring) and to place partially spent fuel into the other portions of the core. In addition, fuel elements were inverted and rotated so as to achieve more uniform burnup gradients in them. Twelve new fuel elements were introduced into the reactor core and nine spent fuel elements were discharged from the core during CY2019.

The MITR-II fuel management program remains quite successful. During the period of CY2019, eight 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 CY2019 include:

a) The third irradiation campaign for Phase 2 of a major Accident-Tolerant Fuel program by Westinghouse Electric Company (WATF by WEC), supported by DOE, was underway, with irradiations for each reactor cycle from January to December 2019 using the experimental pressurized water loop facility. A variety of SiC composite materials, some with end plugs and experimental coatings and coated Zircaloy tubing and plates made up the sample matrix located in the loop in in-core, above-core, and outside-core-tank positions. Several samples were previously irradiated in the Phase 1 program. Several prototype test units for an in-core wireless fuel temperature sensor under development by WEC, and additive manufactured Zircaloys for advanced fuel spacer grids were also included in the irradiation. Following irradiation some samples and sensors were moved to the hot cells for examination, and four samples and one sensor were shipped to Westinghouse's lab in Pittsburgh for additional analysis. These irradiations will continue into CY2020.

b) The first part of an irradiation sponsored by the National Scientific User Facility (NSUF) was conducted using the experimental In-Core Sample Assembly (ICSA) from January to April 2019. This facility was used to irradiate a capsule containing various fiber optic cables with one end in-core at 650°C in inert gas, and the other end connected to interrogation equipment on the reactor floor visitor-accessible space. Students and a professor from the University of Pittsburgh visited to help configure the fiber sensors and collect data during the irradiation. After the irradiation concluded, the assembly was transferred to the NRL hot cells for disassembly and extraction of the fiber cables. These fiber cables, along with fiber cables extracted from a different in-reactor irradiation from CY2018 were then packaged by NRL staff and shipped to Westinghouse's lab in Pittsburgh for analysis. The second stage of this irradiation will occur in Q1 CY2020.

c) A two-cycle irradiation, also sponsored by the NSUF, was conducted in the ICSA facility from April to October 2019. This project, led by a PI from Notre Dame University, consists of several dozen miniature printed electrical resistivity/thermal conductivity sensors, irradiated in-core at 350-400°C in inert gas. Due to the sensitivity of these printed sensors, close collaboration was needed between the Notre Dame faculty and students and NRL research staff in the design and construction of the irradiation experiment. After irradiation the capsule was transferred to the NRL hot cells for extraction of the sensors, which will be shipped out for interrogation.

d) A single depleted uranium nitride fuel microparticle was irradiated using the 2PH1 pneumatic rabbit system as part of the ongoing Advanced Manufacturing Fuel Irradiation project between NRL and Oak Ridge National Laboratory

(ORNL). ORNL requires testing of the performance of a new fuel form for their under-development gas-cooled reactor prototype. The fuel for this reactor will use millions of ceramic-encapsulated micro fuel particles contained in additively-manufactured compacts. The NRL is irradiating these particles to determine how the new manufacturing process might affect their ability to retain volatile radioactive gasses. This incremental test program will scale from single depleted particles to enriched fuel compacts using multiple MITR irradiation facilities and the NRL gamma spectroscopy lab to perform all gas analysis. The single particle was successfully packaged, irradiated, and quantitatively evaluated, all using NRL facilities, accomplishing an important baseline benchmark step for this project.

e) Extraction and post-irradiation examination (PIE) of samples from the first three fluoride salt irradiations continued during CY2019. The major activities were microstructure examination of the samples at MIT and INL, and measurement of trapped tritium and tritium-trapping mechanisms in graphite which was part of the components in the irradiations.

f) The subcritical Graphite Exponential Pile supported two MIT undergraduate senior theses, which were successfully completed in June 2019. A new research proposal was awarded DOE funding. This three-year project started in October 2019 and focuses on utilizing the graphite pile to demonstrate an autonomous reactor operation framework, using movable detectors for big-data collection and a machine-learning algorithm for real-time high-fidelity prediction.

g) 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"), 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.

h) Measurements at the 4DH4 Neutron Diffractometer were conducted for testing neutron scintillators for Radiation Monitoring Devices, Inc.

i) NRL Seed Program (4DH4): Measurements were conducted at the 4DH4 Neutron Diffractometer: neutron computed tomography of 3D-printed parts in collaboration with Professor John Hart (MIT MechE); neutron-based mapping of hydrogen diffusion during plasticity in collaboration with Professor Cem Tasan and graduate student Haoxue Yan (MIT DMSE), and radiographic examinations of uranium fuel slugs used in the MIT graphite exponential pile.

j) NRL Seed Program (Other Facilities): Irradiations in 2PH1 pneumatic facility and 3GV6 irradiation facility of germanium wafers for research scientist Anuradha Agarwal (MIT Materials Research Laboratory); and irradiations in 1PH1 pneumatic facility of GaAs/AlAs superlattice for Professor Mingda Li (MIT Nuclear Science & Engineering Department).

k) Elemental analyses were performed using neutron activation analysis (NAA) on samples of the in-core components to be used in the WATF-2b and NSUF irradiation experiments described above. 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.

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

m) Activation of ytterbium-168 pellets for medical therapy study for Source Production and Equipment Co.

n) Elemental analyses were performed using NAA on alumina and silicon nitride samples used in the project sponsored by the NSUF in conjunction with Notre Dame ICSA irradiation experiment described above.

o) Activation of sapphire and polyethylene cable samples for further NAA studies for University of Alabama.

p) Activation and NAA of various samples in support of MIT course 22.01 "Introduction to Nuclear Engineering and Ionizing Radiation".

q) Activations of dysprosium source for use in MIT Junior Physics Lab.

r) Activation of copper disc samples for MIT Physics Department.

s) Activation of gold-198 seeds for medical brachytherapy.

t) A radiation dose study was conducted in the 3GV6 beam port with the reactor shut down in support of Argonne National Labs imaging project.

u) 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"). Additionally a group from Intercontinental Nuclear Institute (INI) in conjunction with University of Massachusetts Lowell conducted various experiments, power manipulations, and a tour of the reactor facility.

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 starting 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 thirty-four elements fabricated by BWXT have been received, forty-five of which remain in use. One has been removed because of suspected excess out-gassing, another because it was dropped, and one hundred eighty-seven have been discharged because they have attained the fission density limit.

The MITR is actively involved in studies for future 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 October 2018, NRC accepted a report entitled "Low Enriched Uranium (LEU) Conversion Preliminary Safety Analysis Report for the MIT Research Reactor (MITR)" supporting 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 tank. The tank will remain unfueled pending resumption of epithermal beam research. In CY2013, the D_2O coolant was removed from the fission converter system 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, and not covered in Section E of this report, a summary is given below of changes implemented during CY2019.

a) The PM 1.16.3 & PM 1.16.4 Reactor Operator & Senior Reactor Operator / Shift Supervisor initial qualification cards were updated to reflect current equipment and the expected areas and levels of knowledge and experience. The revision improved layout and removed references to equipment no longer in service. (SR #2016-25)

b) AOP 5.8.21 "Sabotage or Theft of SNM or Threat of Sabotage or Theft" was updated to assure compliance with the notification requirements of 10 CFR 73.71(a)(1) and 10 CFR 73.71(b)(1). The time limit for the notification to the NRC Operations Center was specified, using the language of the regulations, to be "within one hour of discovery" of safeguards events. Additional updates were made to reflect current terminology, equipment, and means of contact. All changes were administrative in nature. (SR #2016-26)

c) PM 6.1.3.1A "Pulse Channel Discriminator Setpoint Test" was updated with minor formatting changes and clarifications on adjusting the settings of the pulse channels. There were no changes to human-machine interfaces and no cyber security issues. (SR #2018-10)

d) PM 6.5.5 "Backup Reactor Steam Supply Availability" was updated to refer to the new Building NW12 boiler and its indications, which differ from those of the prior boiler. Place-keeping was added to the format of the procedure, and the caution statements were moved to precede the step to which they applied. (SR #2018-27)

e) PM 6.5.19 "Calibration of Test Equipment" was established to ensure that reactor test equipment and tools are calibrated annually by an accredited calibration laboratory in compliance with ANSI/ANS 15.8-1995. (SR #2019-2)

f) PM 3.1.10 "Placing Channels In and Out of Commission" was updated to align with current procedure formatting. Steps were added to bypass the associated low voltage scram on the common power supply unit when a channel is placed out of service, and to restore the scram when the channel is placed in service. This update did not change the original intent of the procedure. (SR #2019-3)

g) PM 6.1.4.6 "Electromagnet Coil Resistance Measurement" was updated to align with current procedure formatting. A data sheet and signature blocks were added. This update incorporated current best practices and did not change the original intent of the procedure. (SR #2019-4)

h) PM 6.1.4.4 "Primary Coolant Flow Scram Time" was updated to align with current procedure formatting, add signature blocks and spaces for recording time measurements, and add clarification on the operation of equipment. The added directions ensure proper operation of the system and proper return of the system to normal configuration after performance of the procedure. (SR #2019-8)

i) PM 1.15 "Refueling" & PM 1.15.1 "Removal of Spent Fuel" was revised to add a signature line for the Reactor Engineer in the section for Refueling Verification, which previously had only the signature line for "Senior Reactor Operator (w/5 yrs. Experience)". The section of the core map for fuel elements in the fission converter was removed, as the fission converter is no longer fueled. The requirement for cooling time prior to spent element removal was modified to "not been operated at >100 kW for at least four days" to match with Technical Specification 5.4.4, rather than specifying the element's location as the fuel storage ring. (SR #2019-20)

j) PM 1.14.4 "Industrial Safety Needs Assessment Checklist" was reformatted to fit on a single page, so that it could be printed on the reverse side of a Job Workbook entry form, ensuring that it would always be attached to the form without taking up extra space. The content of the checklist remained unchanged. (SR #2019-21)

k) PM 6.6.2.4 "Inventory of Emergency Supplies and Equipment" was updated to align with current procedure formatting and for ease of use. New sections were added for eyewash station inventory, first aid kit check, and check of decontamination and deluge showers. (SR #2019-22)

l) PM 1.14.5 "Valve Position Log" was implemented for use by operators and maintenance personnel for valve position changes that are to be reversed after a maintenance activity is complete, for cases where a lock-out / tag-out is not needed and restoration is not otherwise controlled by a procedure. The new procedure and log form improved safety by ensuring that any changes to a system will be reversed after completion of the work and by providing documentation to help resolve any discrepancies that may arise afterwards. (SR #2019-28)

m) PM 1.8 "Reactor Operating Logs" was updated to align with current best practices for use of the electronic console log book and the associated electronic "turnover items" page. This update was determined to have minimal impact on safety, being entirely administrative in nature. (SR #2019-30)

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 by Reactor Operations on an annual, semi-annual, or quarterly basis.

Other surveillance tests are done each time before startup of the reactor if shutdown exceeds 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 CY2019, there was one shipment made, reducing the inventory of spent fuel at MIT. These shipments are made using the BEA Research Reactor (BRR) package. The U.S. Department of Energy has indicated that further shipments may be feasible in CY2020 for future fuel discharges.

B. REACTOR OPERATION

Information on energy generated and on reactor operating hours is tabulated as follows:

	Calendar Quarter 1	2	3	4	Total
1. Energy Generated (MWD):					
a) MITR-II (MIT CY2019) (normally at 5.7 MW)	325.6	408.2	340.4	221.3	1,295.5
b) MITR-II (MIT FY1976-CY2018)					39,532.8
c) MITR-I (MIT FY1959-FY1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					51,263.5
2. MITR-II Operation (hours): (MIT CY2019)					
a) At Power (≥ 0.5-MW) for Research	1,350	1,729	1,522	963	5,564
b) Low Power (< 0.5-MW) for Training[1] and Test	46	39	38	33	156
c) Total Critical	1,396	1,768	1,560	996	5,720

(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 were three inadvertent automatic scrams and four other unscheduled shutdowns.

The term "inadvertent automatic scram" in this section refers to shutting down of the reactor through protective system (nuclear safety or process system) automatic engineered action when the reactor is at power or at least critical; the reactor operator is not involved in the scram action.

The term "other unscheduled shutdown" typically refers to an unscheduled power reduction to subcritical initiated manually by the reactor operator in response to an abnormal condition indication. For such shutdowns, the reactor operator may manually use a "minor scram" (fast control blade insertion by gravity) or a "major scram" (fast control blade insertion plus reflector dump and containment building isolation), among other possible actions. An example of another type of "other unscheduled shutdown" is a reactor shutdown due to loss of off-site electrical power, because the reactor protective system action was not the cause of the shutdown. Incidental control blade drops are likewise considered "other unscheduled shutdowns", because such drops lower the reactor power rapidly, and require the console operator to manually shut down the reactor.

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

		Total
1.	Nuclear Safety System Scrams	
a)	Trip on Channel #3 from NIM bin connector problem.	1
b)	Trip on Channel #6 from a transistor failure.	1
c)	Trip on Channel #6 when the use of non-equilibrium data resulted in an overly conservative scram setting.	1
	Subtotal	3
2.	Process System Scrams	
a)	None.	0
	Subtotal	0

3. Other Unscheduled Shutdowns

a)	Shutdown caused by fluctuation of off-site electrical power.	1
b)	Minor scram initiated by operator upon observation of smoke rising near the reactor top, later traced to failure of a small power transformer for a 12-volt spotlight.	1
c)	Shutdown for repair of the Bernoulli filters, which were fouled by a sudden large release of scale from the cooling towers into the secondary system.	1
d)	Shutdown for repair of the automatic controller for the regulating rod.	1
	Subtotal	4
	Total	**7**

4. Experience during recent years has been as follows:

Calendar Year	Nuclear Safety and Process System Scrams
2019	3
2018	1
2017	1
2016	4
2015	8
2014	13
2013	4
2012	6
2011	9

D. MAJOR MAINTENANCE

Major reactor maintenance projects performed during CY2019 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 CY2019 are summarized as follows:

1. Instrumentation engineers added extra EMI shielding on the detector cabling routes for DWK 250 Channels #3 and #4, both at the reactor top and also inside the 4IH1 port access, reducing interference from outside EMI sources. (1/3-4)

2. The motors and right-angle gearboxes for shim blade drives #2, #3 and #4 were replaced, along with the wiring for the two shim blade drives, and a capacitor for shim blade drive #2. (1/10, 1/14)

3. Major repairs were made to the secondary system's Bernoulli Filters A and B in the equipment room. The pneumatic cylinder assembly was replaced on both of the filters. (1/28)

4. The primary pressure switch MPS-4 was replaced, which is used for the High Pressure Reactor Inlet alarm. (3/5)

5. A cooling jacket leak at the 3GV6 vertical sample thimble was repaired. The cooling jacket was completely removed from 3GV6 and placed next to Hot Cell #1 for repair and inspection. A spare cooling jacket was installed in 3GV6 instead. (4/4)

6. Reactor staff coordinated with engineers from Infinite Cooling, Inc., to work on installing a plume abatement structure at the cooling towers. (4/4-5)

7. The primary and D_2O ion columns were replaced. (4/8)

8. The stack base and reactor top intercom units were restored. (4/8)

9. Various connectors for control room data recorders were upgraded. (4/8)

10. The shim blade drop timer was repaired. (4/8)

11. Various leak tapes in the equipment room were repaired or replaced. (4/8)

12. Reactivity worth measurements were completed for the regulating rod and six shim blades. (4/9)

13. Ion chamber plateau tests were performed for Channels #1, #3, and N-16, and all four DWK 250 channels. (4/10)

14. Reactor staff coordinated with MIT Emergency Management to install a new automated external defibrillator (AED) unit at the reactor floor next to the main airlock. (4/16)

15. Reactor staff coordinated with MIT Facilities contractors to replace an access manhole cover and the associated framing for an underground electrical vault in the backyard. (5/2-3)

16. The safety amplifier for Channel #3 was bench-tested and its NIM bin connector at the back of the chassis was replaced. The heat sink capability for transistors Q7 and Q8 on the circuit board was also upgraded. (6/10)

17. The NRL's second automated external defibrillator (AED) was installed by the north door of the Operations Office. (6/17)

18. The annual Charcoal Filter Efficiency Test was completed by reactor staff and reactor radiation protection staff. (7/2)

19. The stack radiation monitor flow meters were upgraded. (7/3)

20. Flow testing for the LEU conversion project was performed to investigate flow characteristics of the primary system, especially for higher flows up to 2500 gpm. (7/1-5)

21. Reactor staff coordinated with the MIT Central Machine Shop to install new pipe connection hardware at the cooling tower cleanup system. (7/8)

22. Reactor staff coordinated with MIT Facilities and contractors to cut a trench adjacent to the cooling towers and install foundation footers for a new cooling tower plume abatement system. (7/15)

23. Control blade #3, its electromagnet, and drive were all replaced. (7/17)

24. The gasket between the reactor's upper shield ring and the upper shield access ring was repaired. (7/19)

25. Reactivity worth measurements for the newly installed control blade (#3) were completed. (7/23)

26. Reactor staff coordinated with MIT Facilities contractors to install grounding wires and the foundation footer concrete for the cooling tower plume abatement system. (7/30-31)

27. Reactor staff coordinated with MIT Facilities pipe-fitters to install new chilled water piping in the lab area for cooling the hydraulic pump for a new Instron machine for experiments and testing. (7/31 – 9/20)

28. Reactor staff coordinated with MIT Facilities contractors to re-grade the floor in the back lab area and coat the entire floor with hard epoxy paint. (7/31 – 8/20)

29. Reactor staff coordinated with MIT Facilities contractors to replace the steam preheat coil in the containment building ventilation intake air handler (AHU-4). (10/7-10)

30. The cooling tower filtration system was replaced by reactor staff. (10/7-25)

31. Reactor staff coordinated with MIT Facilities and contractors to upgrade a 480-volt electric meter panel in the Utility Room with a digital display unit which will eventually provide telemetry for monitoring energy use in NW12. (10/10)

32. The metal frame structure for the cooling tower plume abatement system was installed. (10/14-21)

33. The primary ion column was replaced. (10/12)

34. The PF-12A shield system flow meter was replaced. (10/25)

35. The water loop experiment's high-pressure charging pump was replaced. (12/2)

36. The 6" rotating tube for the NTD silicon irradiation program was replaced. (11/23 – 12/13)

37. The D_2O ion column was repacked and replaced. (12/14-20)

38. The primary ion column was replaced. (12/19)

39. Reactor staff coordinated with MIT Facilities to replace the filter rack within the containment building ventilation intake air handler (AHU-4). (12/23-27)

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".

Advanced 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), SR #2017-20 (4/01/2019)

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 2017 through December 2019, it was used for WATF Phase 2 and Exelon experiments.

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), SR #2017-6 (7/02/2019), SR #2017-6A (05/03/2017)

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 CY2019 for in-core experiments and irradiations. – See section A.2 (Experiments and Utilization), item (b).

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 2019.

DWK 250 Wide Range Monitors and Mirion Fission Chamber Detectors
SR #0-12-21 (10/19/2012), SR #0-13-22 (07/11/2013), SR #0-13-27 (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. Throughout CY2018, reactor staff recorded crucial parameters from the system as part of the hourly logs whenever the reactor was at power, and performed routine calibration procedures about once a month.

In CY2018, reactor staff docketed three rounds of responses (4/20, 5/3, and 11/7/2018) to NRC Requests for Additional Information (RAI). Any response that involved revising a proposed Technical Specification was reviewed and approved by the MITRSC Standing Subcommittee prior to docketing. Response to the initial RAI, which was based on an NRC Onsite Regulatory Audit visit in July 2017, had been docketed on 12/14/2017. Reactor staff also met with NRC by conference call in a formal Public Meeting on 4/19/2018 regarding the grounds for modifying one of the relevant Technical Specifications. In CY2019, upon NRC request, one more round of supplemental information was submitted to NRC on 2/27/2019.

On 12/04/2019, NRC issued Amendment No. 42 to Renewed Facility Operating License No. R-37, authorizing implementation of the new Nuclear Safety System, including its digital components, and use of the system as an input to the reactor protection system. The Amendment allows 180 days to complete the upgrade.

Procedures Governing Shipment of Spent Fuel

SR #0-12-22 (03/21/2013), SR #0-13-2 (03/28/2013), SR #0-13-12 (06/28/2014), SR #0-13-12A (07/03/2014), SR #0-13-12B (07/22/2015), SR #2015-22 (08/26/2015), SR #2017-29 (08/30/2017), SR #2018-15 (07/25/2018), SR 2019-17 (09/30/2019)

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. In 2017, all the procedures were revised to maintain verbatim agreement with the BRR cask's Safety Analysis Report (Revision 10). In 2018 and again in 2019, the Supervisory Checklist was overhauled to ensure better preparation prior to a shipment, and to improve clarity for transportation compliance. Many other spent fuel shipping procedures were also reviewed and revised to improve clarity. Of particular note in 2019, new steps were inserted for operation and handling of a new canopy that DOE deployed to cover the BRR package during highway transport. Accuracy and clarity of the procedures was maintained, as was verbatim compliance with the cask's Safety Analysis Report.

Physical Security Plan Revision

SR #0-13-16 (05/12/2014), SR #0-13-30 (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), SR #2019-7 (06/11/2019), SR #2019-9 (09/27/2019)

MITRSC approval for the revised Plan was granted per the Security Subcommittee meeting of 6/6/2013. It was then submitted to NRC as a License Amendment Request, and approved by NRC in 2014. 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 (RAI) 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. In 2018, further modifications to the Plan were proposed as a followup to the RAI, and were reviewed and approved by the MITRSC in October 2018. These proposed modifications were discussed with NRC during a routine inspection in December 2018.

In May 2019, all proposed modifications to the Plan and associated security procedures were presented to the MITRSC Security Subcommittee, including proposed changes to AOP 5.8.22 "Loss or Degradation of a Security System", in accordance with new regulatory guidelines that were incorporated into the Security Plan. The Subcommittee approved the modifications, and the Plan was submitted to NRC on 6/11/2019. On 7/29/2019, NRC was satisfied with the update as being in compliance with 10 CFR 73 and incorporating all of the site-specific compensatory measures to which MIT had committed. NRC then closed Confirmatory Action Letter (CAL) No. NRR-02-005 which had been issued in 2002 in response to the 9/11 national emergency.

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), SR #2015-30E (04/21/2017)

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 CY2019, this newly-installed system continued to operate in parallel with the existing stack effluent and water monitoring systems.

TREAT Core Instrumentation Low Power Experiment
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 first 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. The planned tests were completed from the latter half of CY2017 through the early part of CY2018.

4DH1 Spectrometer Improvements
SR #2017-27 (08/21/2017), SR #2017-27A (09/20/2018)

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. In 2018, the spectrometer's local manual operation was upgraded to include remote shutter actuation from the control room, and position indication there.

<u>4DH4 Diffractometer Beam Facility</u>
SR #0-12-3 (07/09/2018)

After extensive design, construction, testing, and characterization, a neutron beam facility featuring a diffractometer was placed in service at the 4DH4 beam port. Procedures were established for operation in monochromatic and polychromatic modes, and an Abnormal Operating Procedure was introduced for response to alarm conditions and for emergency shutdown of the beam. The installation includes redundant beam status indicators, and multiple personnel warning alarms active whenever the beam is on. Shielding of the diffractometer drum and the beam has been optimized for reduction of radiation levels and for experiment accessibility.

<u>Technical Specification (TS) 7.5.2.1 Experiment Review and Approval</u>
SR #2018-2 (06/12/2018), SR #2018-17 (09/17/2018)

In January 2018, the NRL submitted an amendment request for TS 7.5.2.1, modifying the procedure approval requirements for reactor experiments of a type not previously approved. While the MIT Reactor Safeguards Committee would continue to review and approve the design and safety evaluation of new experiments, review and approval of the written procedures for those experiments would shift to Reactor Operations. The amendment was approved by NRC in June 2018. A corresponding change was then made in administrative procedure PM 1.10.1, "Experiment Review and Approval". In CY2019 all experiment reviews and approvals were performed in accordance with the updated Technical Specification and administrative procedure.

<u>Replacement of Legacy Blade Drive Motors</u>
SR #2018-11 (07/02/2019)

In CY2018 – CY2019 the gear motors for reactor shim blade drives #2, 3, 4, and 5 were replaced with ¼ horsepower, single-phase, four-pole induction motors with integrated, electromagnetically released friction brakes. This was a drop-in replacement for the original gear motors, except that the output shaft runs at a nominal 36 RPM versus 50 RPM for the original gear motors. The difference in output shaft speed is adjusted by the output shaft pulley tooth count to obtain the required speed at the blade drive. The new motors have a smaller form factor with a different output shaft orientation, so an additional bracket was required to center the motor in the pipe well and to provide for a jack-shaft to extend the output shaft for pulley alignment. The new gear-motor/bracket/jackshaft assembly provides for easier belt replacement, loosening, tightening, and alignment. The larger, higher tooth count pulleys at the output shaft do not cause any space interference and will result in longer belt lifetime. The replacement entirely meets the design and function of the original motor. The improved design attributes of the new assembly do not alter the basic design or function or failure modes and simply enhance installation, maintenance and maintainability of the gear motors.

Replacement of DL-6 Level Probe
SR #2018-20 (07/02/2019)

DL-6, the D_2O reflector tank level probe, was replaced with a new one employing ultrasonic technology. It is similar to one that has been in satisfactory service in the medical water shutter system for many years. The annual calibration procedure, PM 6.1.3.8 "D_2O Reflector Level Indication – Scram, Alarm, and Calibration", was also updated accordingly. In CY2019, the new probe continued to test satisfactorily and exhibit reliable indications.

Replacement of PF-10 in Shield System
SR #2018-22 (04/01/2019)

The flow meter in the shield coolant system's clean-up loop was original reactor equipment that had developed a slow intermittent leak between its housing and the sight glass. The flow meter was replaced with a new component leak resistance 0-5 gpm variable area flow meter.

Modification of Stack Monitor Air Flow Meter System
SR #2019-18 (09/06/2019)

The 40 L/minute flow meters and integral adjusting valves for the stack effluent monitors were each replaced with a 40 L/minute flow meter without a flow adjusting valve in the inlet. At the same time, new separate adjusting valves were installed at the suction inlets of the vacuum pumps. This arrangement allowed an increase in system flowrate and reduced load on the pumps.

Standard Operating Plan for Fuel Handling
SR #2019-31 (10/28/2019), SR #2019-31A (pending)

SOP 2.7 "Fuel Handling" was updated to align with current best practices, and to reflect the current normal receipt path of fresh fuel and the timing of its installation. Use of the "Reactor Business Office" for reporting purposes was replaced with "Accountability Officer". Reference to PM 7.1.2 for fuel inspection was replaced with reference to new procedure PM 3.3.5 "Acceptance of New Fuel", in order to ensure that all relevant information will be located and documented in one place, and that any future changes to the fuel acceptance procedure will require a safety review under 10 CFR 50.59. This update was approved by the MIT Reactor Safeguards Committee on 10/28/2019.

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 environmental monitoring 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 (01/01/2019 – 12/31/2019)
North	0.15 mrem
East	0.43 mrem
South	0.10 mrem
West	0.43 mrem
Green (east)	0.03 mrem

Calendar Year Average

2019	0.2 mrem
2018	0.2 mrem
2017	0.4 mrem
2016	0.6 mrem
2015	0.4 mrem
2014	0.8 mrem
2013	0.2 mrem
2012	0.3 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, 2019 - December 31, 2019

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	77
Measurable – < 0.1	25
0.1 – 0.25	6
0.25 – 0.50	1
0.50 – 0.75	1
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 = 2.3   Total Number of Personnel = 110

From January 1, 2019, through December 31, 2019, 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 two on-site 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 16,123,964 liters discharged during CY2019 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 1.03E-5 Ci for CY2019. The total tritium was 1.00E-1 Ci. The total effluent water volume was 16,133,821 liters, giving an average tritium concentration of 6.23E-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 3.7.2.1, including Part 20, Title 10, Code of Federal Regulations. All activities were substantially below the limits specified in 10 CFR 20.2003 "Disposal by Release into Sanitary Sewerage". 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 2154.67 Ci of Ar-41 was released at an average concentration of 3.46E-10 μCi/ml. This represents 3.46% of EC (Effluent Concentration (1E-08 μCi/ml)).

3. Solid Waste

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

TABLE H-1

ARGON-41 STACK RELEASES

CALENDAR YEAR 2019

	Ar-41 Discharged (Curies)	Average Concentration[1] (μCi/ml)
January 2019	35.20	5.89 E-11
February	70.17	1.47 E-10
March	198.78	4.16 E-10
April	256.71	4.46 E-10
May	201.85	4.38 E-10
June	57.17	1.24 E-10
July	254.36	4.24 E-10
August	343.09	7.14 E-10
September	183.41	3.82 E-10
October	197.11	3.28 E-10
November	201.92	4.20 E-10
December	154.91	2.58 E-10
Totals (12 Months)[2]	**2154.67**	**3.46 E-10**
EC (Table II, Column I)		1×10^{-8}
% EC		**3.46%**

(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 2019

Descriptions

Volume	29.4 ft^3
Weight	852 lbs.
Activity	15 mCi
Date of shipment	May 31, 2019
Disposition to licensees for burial	Energy Solutions, Clive, UT
Waste broker	Ecology Services Inc., Columbia, MD

Volume	149 ft^3
Weight	2444 lbs.
Activity	716 mCi
Date of shipment	December 11, 2019
Disposition to licensees for burial	Energy Solutions, Clive, UT
Waste broker	Ecology Services Inc., Columbia, MD

TABLE H-3

LIQUID EFFLUENT DISCHARGES
CALENDAR YEAR 2019

	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. 2019	NDA(2)	2.92	514,360	5.67
Feb.	NDA(2)	0.00348	2,000,766	0.00174
Mar.	2.08	38.1	1,566,580	24.3
Apr.	NDA(2)	1.41	1,036,297	1.36
May	3.50	9.34	2,200,987	4.24
June	2.42	17.1	2,169,300	7.90
July	NDA(2)	0.80	236,144	3.39
Aug.	2.26	29.1	2,548,045	11.4
Sept.	NDA(2)	0.436	1,630,196	0.268
Oct.	NDA(2)	0.371	832,623	0.446
Nov.	NDA(2)	0.338	1,134,908	0.298
Dec.	NDA(2)	0.497	263,615	1.89
12 months	10.3	100.3	16,133,821	5.10

(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.