MIT NUCLEAR REACTOR LABORATORY

AN MIT INTERDEPARTMENTAL CENTER

Edward S. Lau
Assistant Director
Reactor Operations

Mail Stop: NW12-122
138 Albany Street
Cambridge, MA 02139

Phone: 617 253-4211
Fax: 617 324-0042
Email: eslau@mit.edu

March 31, 2021

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, 2020, to December 31, 2020, 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
Research and Test Reactors Oversight Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

A020
NRR

MIT RESEARCH REACTOR
NUCLEAR REACTOR LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ANNUAL REPORT

to

United States Nuclear Regulatory Commission

for

the Period January 1, 2020 – December 31, 2020

by

REACTOR STAFF

Table of Contents

MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JANUARY 1, 2020 – DECEMBER 31, 2020

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.

On December 4, 2019, NRC approved the licensing of a new digital nuclear safety system. After an NRC-approved postponement due to the nationwide COVID-19 public health emergency, implementation was completed in September 2020. The reactor was returned to full power on September 16, 2020, with the new system in service.

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-sixth annual report required by the Technical Specifications, and it covers the period from January 1, 2020, through December 31, 2020. 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-fourth 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 at the MIT Nuclear Reactor Laboratory (NRL) 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 CY2020, 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 CY2020, the reactor averaged 60 operating hours per week, compared to 110 hours per week for CY2019, 90 hours per week for CY2018, 108 hours per week for CY2017, and 112 hours per week for CY2016. The lower average for CY2020 was the result of extended shutdowns for the nationwide COVID-19 public health emergency, and for installation of the new digital nuclear safety system in the control room.

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 CY2020 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. Six new fuel elements were introduced into the reactor core and eleven spent fuel elements were discharged from the core during CY2020.

The MITR-II fuel management program remains quite successful. During the period of CY2020, 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. Despite significant disruption to the reactor operating schedule in CY2020, several irradiations were successfully completed serving a variety of users. Irradiations and experiments conducted in CY2020 include:

a) In-core irradiations continued for "Phase 2b" of the Westinghouse-led Accident Tolerant Fuel (ATF) program over 3 cycles in the HTWL. This experiment includes SiC and coated Zircaloy cladding corrosion specimens from Toshiba, GA, and Westinghouse, as well as powered sensors. Post-irradiation examination has been conducted on the irradiated specimens using the NRL hot cells. Some specimens were returned to the reactor while others, including sensors, were shipped to Westinghouse for further analysis.

b) An NSUF-supported in-core irradiation of optical fibers, PFOX2, completed its second cycle of irradiation in Q1 in the ICSA. The PI from University of Pittsburgh collected real-time data from the fibers to make distributed temperature measurements along the length of the irradiation capsule. After irradiation the optical fibers were removed from their protective metal guide tubes in the hot cell and shipped to Westinghouse for analysis.

c) A second NSUF-supported in-core irradiation, TEGI (Thermo-Electric Generators Irradiation), was installed into the reactor in Q4. This is the first of two cycles of irradiation for this project investigating the real-time performance of TEG devices under neutron irradiation. In order to accommodate the low temperature (<100°C) requirement, a dry irradiation facility substantially similar to the FS-2/FS-3 design was used. While initially after reaching full power the temperatures were as-predicted, the TEG temperatures continued to increase. Over the next week reactor power had to be repeatedly reduced to maintain the requested temperature profile within the experiment. After consultation with NSUF management and the PI, the reactor was then returned to full power for the remainder of the cycle. Despite the higher temperatures, the TEGs have continued to operate and generate data. A second irradiation of a next generation of these devices is scheduled for Q3 2021.

d) Within the same irradiation vehicle as the TEGI is a capsule of passive high-temperature metal-graphite diffusion couples provided by Westinghouse as part of their eVinci micro reactor development program. With the reactor at full power these have been held at a constant 800°C, and will be removed for initial PIE in the NRL hot cells and then shipping back to Westinghouse after the end of the Q4 cycle.

e) Design and upgrade of a 3" graphite vertical neutron beam port (3GV6) progressed smoothly during CY2020. The first funded project is the Transformational Challenge Reactor (TCR) fuel particles and fuel compacts irradiations. This program aims to build a small gas-cooled reactor at Oak Ridge National Laboratory to demonstrate advanced manufacturing and fabrication technology (e.g. 3D printing) for nuclear reactor components including fuel. The contract allows for the 3GV port upgrade with electrical heating to reach ~ 700°C, cover gas control/monitoring, shielding, transfer cask, etc., for fuel irradiation and irradiated sample transfer. Other funded projects are scheduled to utilize the same facility. We are planning to develop another 3GV beam port for low- medium temperature irradiations.

f) Post-irradiation examination of specimens from the fluoride salt (FHR FS-X) in-core irradiations has continued under funding from SINAP, Kairos Power, and NSUF rapid-turnaround grants to utilize PIE facilities at NRL, Idaho National Lab, and Pacific Northwest National Lab. Post-irradiation measurements have also been completed on the TCP sensors irradiated in 2019, which will be shipped to INL later this year.

g) A new flibe salt experimental facility has been designed to use the lower neutron flux basement thermal beam (old BNCT shielded medical room). This project is funded by Kairos Power, a Fluoride salt-cooled High-temperature Reactor (FHR) startup by our UC-Berkeley collaborators. The experiments to be conducted will obtain first-of-its kind data on tritium permeation through metallic materials to support licensing of their pebble-bed FHR. Additional funding was also awarded by NSUF.

h) The neutron diffractometer/neutron imaging beamline is operational. This instrument has been used in collaboration with MIT faculty and involved UROP students. The instrument is also used to certify control blades for MITR. A new proposal would utilize this instrument to demonstrate a novel polychromatic diffractometer.

i) The subcritical graphite pile was re-started several years ago by Professor Kord Smith with the support of NRL staff and other NSE faculty members. It has since been used for teaching and research. A DOE-NE funded research project used the graphite pile to conduct experiments in support of demonstrating autonomous control of a subcritical system. The facility is an ideal testbed due to its inherent safety characteristics and modular construction. These allow in-pile instrumentation and pulley mechanisms to be installed without significantly modifications to the facility.

j) The student spectrometer (4DH1) has been used throughout the year to support remote teaching and demonstration of neutron properties. Regular NSED use of the spectrometer has been postponed to the spring semester 2021. A UROP student is currently involved in upgrade of the spectrometers' capabilities.

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) Irradiations of experimental neutron detectors and target foils in the Thermal Neutron Beam for Los Alamos National Labs

n) Elemental analyses were performed using NAA on samples of in-core experimental components prior to their use in research projects described above. Analyses were performed on various samples for the MIT NSE 22.01 class, and on Na-22 samples to measure positron Doppler broadening as part of an NSED student's research. Initial safety tests were performed for upcoming activated Sc, Sb, and Ir production, and for a Lu-177 medical isotope SBIR project.

o) Activation of Kapton tape and polymer 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) Creation of a Europium source for use in MIT Physics Department.

r) Activation of Yb-176 powder to support a Lu-177 production and separation project beginning early 2021.

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

t) A series of irradiations are being conducted in 2PH1 for the first phase of the ORNL-supported Advanced Manufactured Fuel Irradiation (AMFI) program. This project is supporting the development of the ORNL TCR Program. Bare and coated UN fuel kernels are irradiated, and then the fission gas release is quantified via gas sampling and gamma spectroscopy. This is a prelude to 3GV6 irradiations of printed fuel compacts.

u) Irradiations in 1PH1 and 2PH1 are being conducted for the first phase of the INL-supported NASA-INL-BWXT collaboration on the development of a new Space Nuclear Power (SNP) reactor. These irradiations have demonstrated our ability to irradiate small-sealed volumes of samples in H2. Both structural materials and encapsulated UCO and UN fuel kernels (TRISO particles) are being irradiated. Any released fission gasses will be measured, and then the materials will be shipped to other labs for analysis.

v) 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 forty elements fabricated by BWXT have been received, forty of which remain in use. One has been removed because of suspected excess out-gassing, and another because it was dropped. One hundred ninety-eight 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 CY2020.

a) A set of four PM 1.10.2.1.2 Pneumatic Tube Operation procedures were updated with more detailed descriptions of the tubes' equipment and operation. Safety is improved by the greater clarity and inclusion of systemic tracking. (SR #2018-13)

b) PM 1.1.2 "Nuclear Reactor Laboratory" administrative definitions were revised to add definitions for the Senior Review Board and the Reactor Engineer, and to update position descriptions/responsibilities for Director of Reactor Operations (DRO) and Assistant DRO. The description for the Director of Research and Services was removed, as the position was no longer applicable in this document. (SR #2019-16)

c) AOP 5.8.23 "Cooling Tower Plume Catcher Trouble" was established in conjunction with the installation of an experimental electrostatic plume-catcher (QA #2019-19) above the cooling towers. Availability of this procedure improves safety by providing instructions for responding to abnormalities with the system, including how to shut down the high voltage supply if needed. (SR #2019-19A)

d) PM 6.4.18 "Smoke Detector System Surveillance" integrated two previously-existing procedures, PM 6.4.18 "Smoke Detectors - Freon and Circuitry Tests" and PM 6.4.19 "Detector Sensitivity Tests", as well as providing updates for clarity, current equipment, and best practices, particularly for interaction with fuses. The updates did not alter the original intent of the procedures. (SR #2019-36)

e) PM 6.5.6.3 "System Pressure Gauge Calibration" was updated to clarify that two independent calibrations must be performed and to include specific instructions on how to connect the test rig to each pressure gage to be tested and how to return the systems to proper alignment after the calibration. A combined data table was added, and signature lines were added for each step of the procedure. The update did not alter the original intent of the procedure. (SR #2020-1)

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. There was one exception. – Because of the extended facility lockdown for the COVID-19 public health emergency, the neutron detector plateau test procedure was not completed until after the due date. Reactor staff notified NRC of this in advance, and initiated a license amendment request to allow deferral of certain surveillance requirements when the reactor is shutdown. The application was accepted for technical review, and is currently under evaluation by NRC.

7. Status of Spent Fuel Shipment

In CY2020, there were no shipments made to reduce 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 will be feasible in CY2021 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 CY2020) (normally at 5.7 MW)	314.9	3.4	84.4	308.1	710.8
b) MITR-II (MIT FY1976-CY2019)					40,828.3
c) MITR-I (MIT FY1959-FY1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					51,974.3
2. MITR-II Operation (hours): (MIT CY2020)					
a) At Power (≥ 0.5-MW) for Research	1348	15	359	1357	3079
b) Low Power (< 0.5-MW) for Training(1) and Test	29	18	1	28	76
c) Total Critical	1377	33	360	1385	3155

(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 two 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 from console key switch mechanical sensitivity.	1
b)	Trip on Channel #6 from an overly conservative scram setting.	1
	Subtotal	2
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)	Shutdown because of failure of air compressor CM-1.	2
c)	Shutdown on insufficient secondary system flow due to malfunction of cooling tower sump level sensor.	1
	Subtotal	4
	Total	**6**

4. Experience during recent years has been as follows:

Calendar Year	Nuclear Safety and Process System Scrams
2020	2
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 CY2020 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 CY2020 are summarized as follows:

Date	Maintenance Description
1/2/2020	American Crane & Hoist technicians performed maintenance work on the containment's polar crane: replaced the crane's electrical collector shoes, lubricated and adjusted the collectors, wire-brushed the power rails that they could reach with the lift, inspected and lubricated the side of the crane that cannot be reached from the crane bridge, and tightened the wooden planks on the bridge.
1/6/2020	Primary system valve MV-35 repaired (Job #M-1286)
1/6/2020	High Temperature Water Loop (HTWL) removed (Core 234B)
1/7/2020	Heat Exchanger HE-D2 was replaced (QA #2019-32)
1/7/2020	Emergency Core Cooling System (ECCS) piping was rerouted to accommodate 3GV6 loader
1/8/2020	Primary and D_2O Ion Columns replaced
1/9/2020	Annual ECCS test and calibration completed
1/13/2020	New 3GV6 cask mounted and tested
1/14/2020	Annual inspection of in-core components and fuel
1/14/2020	HTWL WATF2b-4 and ICSA-PFOX2 loaded into core (Core 235A)

1/14/2020	Intake air manifold (AHU-4) temperature sensor unit repairs by MIT Facilities / Medford Wellington
1/16/2020	Q7 and Q8 transistors replaced on Channel 5 magnet current supply (Job #E-3433)
2/24/2020	Replaced DWK 250 Channel #4 pre-amplifier
2/24/2020	Repaired 4" Silicon Tube
3/2/2020	Cooling Tower Sump Level Probe heater replaced (Job #E-3429)
3/16/2020 – 6/15/2020	Reactor shutdown / extended outage for COVID-19 pandemic lockdown
3/18/2020	HTWL2b-4 removed (Core 235B)
6/18/2020	ICSA-PFOX2 removed (Core 235C)
6/23/2020	Shim Blade and Regulating Rod Calibrations performed
6/24/2020	Withdraw Permit Circuit transformer replaced (Job #E-3442)
6/29/2020 – 6/30/2020	Containment Building Pressure Test performed
7/2/2020	Primary Ion Column replaced
7/6/2020	Relay replaced in Keithley for Nuclear Instrument Channel #3
7/13/2020	Nuclear Instrument detector repairs for Channels #5 and #8 in 3GV4
7/21/2020	Nuclear Safety System calibrations performed in advance of implementation of new system
7/24/2020	Final shutdown with legacy Nuclear Safety System
7/27/2020 – 9/15/2020	New Nuclear Safety System implementation, pre-operational testing, and training
9/16/2020	Initial startup with new Nuclear Safety System
9/21/2020	HTWL WATF2b-6 loaded into core (Core 236)
9/26/2020	Replaced hydraulic pump and motor assembly for Main Ventilation Exhaust Damper
10/13/2020	HTWL WATF2b-6 removed (Core 236A)

10/15/2020	Repair of secondary coolant system pump HM-A
10/21/2020	All Krohne Rack key switches replaced with new type of selector switches
10/21/2020 – 10/22/2020	HTWL WATF2b-7 and ICSA TEGI loaded into core (Core 237)
12/18/2020	Replaced Hot Cell Blower and all associated wiring.

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.

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 2020, 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 CY2020 for in-core experiments and irradiations. – See section A.2 (Experiments and Utilization), items (b), (c), and (d).

Nuclear Safety System Upgrade with Digital DWK 250 Wide Range Monitors
SR #0-12-21 (10/19/2012), SR #0-13-22 (07/11/2013), SR #0-13-27 (11/08/2013)
SR #2017-17 (05/25/2017), SR #2017-18 (09/15/2020), SR #2017-51 (12/07/2017)
SR #2017-52 (10/04/2017), SR #2020-15 (07/27/2020), SR #2020-21 (09/16/2020)

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. Throughout CY2018 and CY2019, the integrated system operated in parallel in the control room, but was not connected to the existing reactor scram circuits. 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 allowed 180 days to complete the upgrade.

In response to the COVID-19 public health emergency, the reactor building was closed from mid-March 2020 through mid-June 2020. Reactor staff submitted a request to NRC for postponement of implementation. NRC issued Amendment No. 43, extending the effective implementation deadline to 12/31/2020. Between late June and late July 2020, the reactor operated a few more times with its original nuclear safety system, in order to complete required calibration procedures and to collect final operating data. After that, the reactor was shut down for decommissioning of its original nuclear safety system and installation of the new nuclear safety system. After satisfactory completion of quality assurance checks and initial operating tests, the reactor was started up on 9/16/2020 with the new digital nuclear safety system operating. The system has been in service without trouble since then.

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.

One shipment was scheduled in CY2020, but was cancelled because of the COVID-19 public health emergency, which severely restricted travel by government personnel needed for the shipments.

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 and CY2020, this newly-installed system continued to operate in parallel with the existing stack effluent and water monitoring systems.

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.

In CY 2020, planning began for conversion from the existing C*CURE security management system to a Genetec system. This will include, for compatibility with the new system, replacement of the iris readers with other biometric readers, with a corresponding Physical Security Plan revision.

Standard Operating Plan for Fuel Handling
SR #2019-31 (10/28/2019), SR #2019-31A (02/26/2020)

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, and implemented in early CY2020.

Technical Specification Amendment for NRL Management Restructuring
SR #2019-29 (07/24/2020)

In March 2020, the NRL submitted a license amendment request for several places in of the reactor's Technical Specifications, modifying the title of the Level 1 staff member from "Director" of the NRL to "Managing Director for Operations" at the NRL. Amendment No. 44 was approved by NRC on July 24, 2020.

Emergency Plan & Procedure Revisions
SR #2019-33 (12/14/2020)

The Emergency Plan and Emergency Operating Procedures were updated to change all mentions of MIT's "Security and Emergency Management Office" to "MIT Emergency Management". Some procedure steps were broken down into multiple steps, and in all procedures, signature lines were added for each step. References to the three Emergency Support Centers were made consistent. The changes were determined to be mostly administrative in nature, and to cause no reduction to effectiveness. The Emergency Plan was also reviewed to the latest guidance per ANSI/ANS 15.16-2015 and Regulatory Guide 2.6, Rev 2, 2017, and found to be in compliance.

3GV6 Loader and Emergency Core Cooling System (ECCS) Re-Piping
SR #2020-2 (10/27/2020), SR #2020-2A (01/07/2020)

A sample-loader and cask assembly was installed in CY2020 for sample insertion and retrieval at the 3GV6 irradiation facility. This system is comprised of loading hardware, transition tube, port shutter, bottom port plug, and shielded sample cask with top cap, and replaces individual components that precluded experimental movement while the reactor was at power. The new system was evaluated as suitable for operation and testing with the reactor at low power, up to 0.5 MW. A small section of ECCS piping was re-routed to accommodate cask docking, introducing minimal form losses. ECCS flow was then tested satisfactorily prior to reactor startup.

MM-1/1A Disconnect Switch
SR #2020-3 (01/08/2020), SR #2020-3A (01/17/2020)

A disconnect switch was installed for the control power for the main primary coolant pumps MM-1 and MM-1A, such that the pumps could be secured during refuelings without operating their 480V breakers. Corresponding changes were made in the PM 2.7 Standard Operating Plan and in several operational checklists used for refuelings. These changes improve safety by reducing the risk of arc flash injury to personnel operating the equipment.

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 (01/01/2020 – 12/31/2020)
North	0.13 mrem
East	0.25 mrem
South	0.13 mrem
West	0.25 mrem
Green (east)	0.01 mrem

Calendar Year Average

2020	0.2 mrem
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, 2020 - December 31, 2020

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	79
Measurable – < 0.1	21
0.1 – 0.25	1
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 = 0.82 Total Number of Personnel = 102

From January 1, 2020, through December 31, 2020, 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 4,236,304 liters discharged during CY2020 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 5.72E-6 Ci for CY2020. The total tritium was 6.56E-2 Ci. The total effluent water volume was 4,246,313 liters, giving an average tritium concentration of 1.10E-4 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 1748.11 Ci of Ar-41 was released at an average concentration of 2.63E-10 μCi/ml. This represents 2.63% of EC (Effluent Concentration (1E-08 μCi/ml)).

3. Solid Waste

No 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 2020

	Ar-41 Discharged (Curies)	Average Concentration[(1)] (µCi/ml)
January 2020	213.72	3.45 E-10
February	404.63	8.17 E-10
March	179.30	2.90 E-10
April	0.00	0.00 E-00
May	0.00	0.00 E-00
June	21.41	4.32 E-11
July	68.10	1.10 E-10
August	0.00	0.00 E-00
September	150.20	3.03 E-10
October	270.26	4.37 E-10
November	244.67	4.94 E-10
December	195.82	3.16 E-10
Totals (12 Months)[(2)]	**1748.11**	**2.63 E-10**
EC (Table II, Column I)		1×10^{-8}
% EC		**2.63%**

(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 2020

Descriptions

Volume	--- ft^3
Weight	--- lbs.
Activity	--- mCi
Date of shipment	---------
Disposition to licensees for burial	--------
Waste broker	--------

There was no waste shipped in CY2020.

TABLE H-3

LIQUID EFFLUENT DISCHARGES
CALENDAR YEAR 2020

	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. 2020	NDA(2)	·0.31	436,990	0.711
Feb.	2.42	19.4	725,045	26.7
Mar.	NDA(2)	0.13	501,219	0.267
Apr.	NDA(2)	0.01	39,802	0.190
May	NDA(2)	0.01	40,824	0.224
June	NDA(2)	0.02	76,759	0.281
July	NDA(2)	0.01	192,733	0.0464
Aug.	1.70	32.2	25,329	1270
Sept.	NDA(2)	0.21	432,628	0.478
Oct.	NDA(2)	0.12	544,155	0.213
Nov.	NDA(2)	0.02	613,250	0.0299
Dec.	1.60	13.2	617,579	21.4
12 months	5.72	65.6	4,246,313	110

(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.