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, 2021, to December 31, 2021, in compliance with paragraph 7.7.1 of the Technical Specifications issued November 1, 2010, for Facility Operating License R-37.

Sincerely,

Marshall B. Wade
Reactor Superintendent
MIT Research Reactor

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EL/st

Enclosure: As stated

A020
NRR

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

MIT RESEARCH REACTOR
NUCLEAR REACTOR LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ANNUAL REPORT

to

United States
Nuclear Regulatory Commission
for
the Period January 1, 2021 – December 31, 2021

by

REACTOR STAFF

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MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JANUARY 1, 2021 – DECEMBER 31, 2021

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-seventh annual report required by the Technical Specifications, and it covers the period from January 1, 2021, through December 31, 2021. 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-fifth 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 CY2021, 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 CY2021, the reactor averaged 102 operating hours per week, compared to 60 hours per week for CY2020, 110 hours per week for CY2019, 90 hours per week for CY2018, and 108 hours per week for CY2017. 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 CY2021 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 thirteen spent fuel elements were discharged from the core tank (reactor core plus wet-storage ring) during CY2021. *

The MITR-II fuel management program remains quite successful. During the period of CY2021, two shipments totaling 16 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.

* An additional 13th element was received from BWXT but was sent back after the on-site inspection deemed it necessary to return it. This element was not counted toward the 12 fresh and 13 discharged element totals mentioned for the year.

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. In-core experiments operated in all four reactor operating cycles of CY2021 from a combination of National Scientific User Facilities (NSUF) clients, ARPA-E, national laboratories, and industrial entities. Several NSUF irradiations planned for CY2021 were delayed into CY2022 due to supply chain issues on the PIs' side, and some planned high temperature water loop (HTWL) use was delayed due to delays in contracting or federal funding. Irradiations and experiments conducted in CY2021 include:

a) The final cycle of the Westinghouse-led Accident Tolerant Fuel (ATF) program Phase 2b irradiation in the HTWL took place in Q1. This experiment includes SiC and coated Zircaloy cladding corrosion specimens from Toshiba, General Atomics, and Westinghouse, as well as powered sensors. Post-irradiation examination has been conducted on the irradiated specimens using the NRL hot cells. Some irradiated specimens were shipped to Westinghouse for further analysis.

b) The inert gas irradiation facility HEXA was irradiated during Q2. This was a shared facility with specimens provided from Idaho National Laboratory, Stony Brook University, the NASA Space Nuclear Propulsion Program, and several MIT faculty members including Professors Koroush Shirvan and Ju Li from the Department of Nuclear Science and Engineering (NSE). The experiment train was composed of six capsules each with a different target temperature or thermal gradient and a total of over 200 specimens. This experiment built on experience from the previous-year's TEGI irradiation to achieve a wide range of specimen temperatures from 150-650°C.

c) The second cycle of the NSUF-supported irradiation, TEGI (Thermo-Electric Generators Irradiation), was installed into the reactor in Q3. This project investigates the real-time performance of TEG devices under neutron and gamma irradiation. This design aimed to eliminate the possible sources of thermal drift observed in their first cycle of irradiation by eliminating the graphite thermal sinks and spring loading from the design, and allowing the two TEGs to be more securely attached at INL and by the PI at the University of Notre Dame before being sent to MIT. This facility successfully operated for the full cycle with the reactor at full power.

d) The ARPA-E funded irradiation NETL (project PI is National Energy Technology Laboratory with MIT co-PI Professor Koroush Shirvan of NSE) was installed at the start of the Q4 cycle and operated through the whole cycle. This experiment investigates the performance of state-of-the-art sapphire-based optical fibers for temperature and strain measurement, and consists of four lead-out fibers with thermocouples for instrumentation operating at 450°C. The fibers are actively interrogated during operation by laser equipment provided by NETL. There is also a second static capsule with LWR structure steel specimens from UNIST of Korea operating at ~325°C.

e) A half-cycle HTWL irradiation was installed mid-way through Q4 to irradiate two sets of specimens, SiC fiber composite coupons from Free Form Fibers and zirconium crystals from Idaho National Laboratory. Both samples are dry (not in contact with the HTWL water flow) but take advantage of the isothermal conditions within the loop at its normal PWR operating condition of 565°F. The HTWL operated with these capsules through the end of the Q4 reactor operating cycle.

f) A new flibe salt experimental facility was operated in the 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 obtained 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.

g) The neutron diffractometer/neutron imaging beamline is operational. This instrument has been used to conduct neutron imaging and tomography measurements of batteries and fuel cells to support users from NIST Center of Neutron Research whose experiments were cancelled due to the long shutdown of the NIST reactor. These measurements involved an MIT UROP student. The instrument is also used to certify control blades for the MITR. A new project funded by DOE in CY2021 would utilize this instrument to demonstrate a novel polychromatic diffractometer. In addition, we are conducting feasibility studies of a small-angle neutron scattering (SANS) facility installed at this beamline. The SANS facility has a very strong MIT faculty support. The feasibility study was the focus of the NSE Senior Design class (22.033) in the Fall 2021 semester.

h) The MIT graphite exponential pile (MGEP) 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.

i) Additionally, reactor staff conducted a series of lectures and a remote demonstration of operation of the MGEP. The demonstration included operational characteristics of the MGEP as a subcritical facility, a walkthrough of experimental procedures for student lab work, and an overview of an ongoing DOE project to explore first-of-a-kind autonomous control systems utilizing machine learning and neural networks..

j) The student spectrometer (4DH1) has been used throughout the year to support remote teaching and demonstration of neutron properties. NSE students are using it during 22.09/22.90 course. In addition, it is used for demonstrations for Course 16 (Aero/Astro).

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. Analyses were performed on various samples for the MIT NSE 22.01 class.

l) Activation of uranium foils in the 3GV6 facility 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) Activation of polymer samples and standard reference materials for further NAA studies for University of Alabama.

o) Activation and NAA of tungsten boride for Specialty Materials.

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

q) Activation of cell culture media and BNCT compounds irradiations in the Thermal Neutron Beam for the MIT Chemistry Department .

r) Researchers from CF Technologies, Inc. (Hyde Park, MA) and the NRL have conducted initial work and safety reviews in a Phase II US-DOE SBIR to develop a new technology for the purification of the medical isotope ^{177}Lu. The process will be carried out on a neutron-irradiated target of ytterbium enriched in ^{176}Y. Extensive testing of the purification equipment and techniques has been conducted using a non-radioactive mixture of ytterbium and lutetium. The ^{176}Y irradiations and separations of ^{177}Lu are planned to begin in early CY2022.

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 have continued 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 Transformational Challenge Reactor (TCR). Bare and coated uranium nitride (UN) fuel kernels are irradiated, and then the fission gas release is quantified via gas sampling and gamma spectroscopy. A series of five irradiations of TCR fuel compacts was conducted in 3GV6 throughout CY2021, each with three SiC matrix compacts with 7% enriched UN TRISO particles and utilizing the new 3GV6 shutter and cask system. These irradiations occurred over temperatures from 350-750°C for 24 hours each. One set of samples irradiated at 350°C showed evidence of fission gas being released from the TRISO particles. This set of compacts was already shipped back to ORNL for urgent analysis. An additional two 3GV6 irradiations are planned for this test series.

u) A series of irradiations continued in 2PH1 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 hydrogen gas. 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. The recently commissioned reactor simulator was used to demonstrate reactor power changes for and the MIT nuclear engineering classes (course 22.01 "Introduction to Nuclear Engineering and Ionizing Radiation", course 22.011 "Seminar in Nuclear Science and Engineering").

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 fifty-three elements fabricated by BWXT have been received, thirty-nine of which remain in use. One has been removed because of suspected excess out-gassing, another because it was dropped, and one was returned to BWXT without being placed in-core due to not meeting on-site quality assurance inspection criteria. Two hundred eleven 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 CY2021.

a) PM 7.3.3 "D_2O Inventory" was updated to improve the formatting of the procedure and the clarity of the charts. Neither the intent nor the inventory method was changed. (SR #2016-33)

b) PM 7.4.6.4 "Spent Fuel Pool Storage Rack Cadmium Degradation Monitoring" was established in order to monitor degradation of the cadmium liner in the Spent Fuel Pool fuel storage boxes. A criticality study showed a K_{eff} of <0.95 as long as there is 1% or more of the cadmium remaining. A specification of 10% of the original cadmium levels was selected as a minimum requirement. (SR #2017-8)

c) PM 6.1.3.2 "Period Channel Verification" & PM 6.1.3.16 "Detector Linearity Check" were modified for use with the Mirion DWK 250 channels of the Nuclear Safety System. All steps of the procedures are performed per manufacturer's recommendations, reactor technical specifications, and general industry practices. (SR #2017-54)

d) PM 6.5.6.1C "Calibration of Digital Test Pressure Gauge – PSI Range" & PM 6.5.6.4B "Calibration of Digital Test Pressure Gauge – Inches of H_2O Range" were established as new variations of existing pressure gauge calibration procedures. The new procedures incorporate use of a new master test gauge which is calibrated annually. (SR #2018-28)

e) PM 6.6.1.4 "Communication Links Test" was updated to align with current formatting practices, and to provide further guidance on updating all call lists to include their exact locations in the procedure manuals. (SR #2020-7)

f) PM 6.5.19 "Calibration of Test Equipment and Tools" was updated to incorporate current equipment and tools being used and to provide a means for future annual updates as needed. (SR #2020-8)

g) PM 3.5 "Daily Surveillance Check" & several PM 3.8 Makeup Water System Checklists were revised to expand the nominal flow range for WF-4 to 0.6-1.0 gpm from the previous 0.8-1.0 gpm. WF-4 flow decreases as the water filters become spent, but the filters don't need to be changed until flow drops below 0.6 gpm. (SR #2020-9)

h) AOP 5.4.3 "Low Flow Shield Coolant" was updated to account for mechanical and electrical system changes to the actuation of the Low Flow Shield Coolant alarm. The update does not change the intent or any operator actions. (SR #2020-10)

i) PM 3.1.1.2 "Full Power Startup Checklist – Two Loop Instrumentation",
PM 3.1.3 "Startup for Less than 100 kW Operation",
PM 3.2.1 "Shutdown from Operation at Power", and
PM 3.2.2 "Shutdown from Less than 100 kW Operation"
were revised to incorporate use of the Mirion DWK 250 channels of the Nuclear Safety System. The portions of the procedures dealing with nuclear instrumentation were rewritten entirely to reflect the recently upgraded equipment. The nuclear safety channels previous designated 7, 8, and 9 were re-designated as 5, 6, and 7, respectively. There were additional changes to details including standardization of procedure formatting and improvement of consistency between the procedures where applicable. In the checklist for shutdown from operation at power, secondary system manipulations were fine-tuned to avoid the possibility of a water hammer. All changes maintained the intent of the procedures.
(SR #2020-19, SR #2020-24, SR #2020-25, and SR #2020-26)

j) PM 3.1.1.3 "Cooling Tower Operation and Full Power Checks" was updated to standardize formatting and to reflect the new nuclear safety system and a new cooling tower filter system. Additionally, the water monitor reading specification was changed from within 20% of previous equilibrium reading to within 200 cpm of previous equilibrium reading, in order to prevent normal conditions from being marked as out of specification. (SR #2020-23)

k) PM 7.3.9 "Charging D_2O to the Reflector" incorporates a previously-existing special procedure into the regular "PM" procedure manual. Formatting was standardized and ordering of steps was improved. Instructions were added for how to handle inadvertent drum over-pressurization. The changes did not change the original intent of the procedure. (SR #2020-27)

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 CY2021, there were two 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 CY2022 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 CY2021) (normally at 5.7 MW)	368.2	308.3	266.0	285.0	1227.5
b) MITR-II (MIT FY1976-CY2020)					41,539.1
c) MITR-I (MIT FY1959-FY1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					53,201.8
2. MITR-II Operation (hours): (MIT CY2021)					
a) At Power (≥ 0.5-MW) for Research	1557	1333	1133	1212	5235
b) Low Power (< 0.5-MW) for Training(1) and Test	11	18	23	18	70
c) Total Critical	1568	1351	1156	1230	5305

(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 three 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 failure of UPS that was supplying electrical power for Nuclear Safety System DWK 250 Channels #3 and #4.	1
	Subtotal	1
2.	Process System Scrams	
	a) Trip from the Low Flow Core Purge timer scram when a problem with the main intake fan caused a sustained loss of containment building ventilation.	1
	Subtotal	1

3. Other Unscheduled Shutdowns

a)	Minor scram initiated by operator upon Shim Blade #4 dropping from its magnet.	2
b)	Shutdown because of primary coolant piping flange leak.	1
	Subtotal	3
	Total	**5**

4. Experience during recent years has been as follows:

Calendar Year	Nuclear Safety and Process System Scrams
2021	2
2020	2
2019	3
2018	1
2017	1
2016	4
2015	8
2014	13
2013	4
2012	6

D. MAJOR MAINTENANCE

Major reactor maintenance projects performed during CY2021 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 CY2021 are summarized as follows:

Date	Maintenance Description
1/5/2021- 1/7/2021	Replaced Regulating Rod Drive and Absorber
1/6/2021	Replaced Shim Blade 5 'Blade In' proximity switch (Job #E-3462)
1/7/2021	Annual ECCS test and calibration completed
1/8/2021	Shim Blade 5 Drive repaired
1/8/2021	Annual inspection of in-core components and fuel
1/11/2021	Primary System and D_2O Reflector System ion columns replaced
1/11/2021- 1/13/2021	Installed remote timer controller for MV-101 operation
1/13/2021	Primary System vibration analysis up to 2550 gpm flowrate
1/19/2021	Repairs on polar crane by American Crane and Hoist
2/9/2021	Spent Fuel Pool storage rack checked for Cadmium degradation (required every 5 years)
2/16/2021	Installed HTWL-WATF2b-8 in-core experiment (Core #238A)
2/26/2021	Repairs made to Shim Blade Drop Timer (Job #E-3475)

3/4/2021	Replaced failed piston on Bernoulli Filter C (Job #M-1366)
4/5/2021	Removed HTWL-WATF2b-8 in-core experiment (Core #238B)
4/6/2021	Shim Blade 4 absorber and drive replaced (Job #M-1356)
4/8/2021	Removed old Linear Flux Channel #5 ion chamber in 3GV4
4/9/2021	Installed new breaker in MCC-1 for future battery charger
4/9/2021	Replaced Primary System ion column
4/12/2021-4/16/2021	Upgraded Security System and performed system-wide security test by Siemens.
4/12/2021-4/16/2021	Replaced and aligned MM-1 and HM-B motors
4/12/2021	Installed 3GV6 cooling jacket flowmeter
4/12/2021	Installed new Linear Flux Channel #5 ion chamber in 3GV4
4/13/2021	Deconstructed Fission Converter Water Shutter
4/14/2021	Sections of leaking Secondary System piping removed for off-site repairs. Secondary System partially drained.
4/21/2021	Installed repaired Secondary System piping and refilled sections of Secondary System which had been drained.
5/5/2021	4" Silicon load cell pusher and 4" Silicon pusher switch replaced (Job #M-1371)
5/6/2021-5/10/2021	Replaced and aligned DM-1 motor
5/10/2021	Installed HEXA in-core experiment (Core #239A)
5/17/2021	Upgraded security system biometric scanners
5/27/2021	Temporary CO_2 supply installed in Receiving Room for upcoming CO_2 tank replacement.
6/4/2021	Replaced backyard CO_2 tanks replaced
6/18/2021	Replaced Cooling Tower #1 Fan Controller (Job #E-3408)
7/6/2021	Removed HEXA in-core experiment (Core #239B)

7/12/2021	Replaced Primary System ion column
7/15/2021	Fission Converter skid relocated from Fission Converter top to mezzanine by D_2O Gasholder.
7/19/2021-7/21/2021	Chemical cleaning of HE-1 to remove scale.
7/21/2021	Replaced HV-79 (HP-4 isolation valve) (Job #M-1357)
7/22/2021-7/29/2021	Replaced and aligned MM-1A and HM-A motors.
7/26/2021	Replaced Shim Blade 2 magnet and drive mechanism (Job #E-3502)
7/27/2021	Replaced Shim Blade 5 absorber
8/9/2021	Installed TEGI-2 in-core experiment (Core #240A)
8/10/2021	Primary System vibration analysis
10/4/2021	Removed TEGI-2 in-core experiment (Core #240B)
10/7/2021	Replaced Primary System ion column
10/7/2021-10/19/2021	Replaced Emergency Battery System battery bank, charger, and monitoring system. Performed Emergency Battery Discharge Test.
10/14/2021-10/15/2021	Chemical cleaning of Auxiliary Heat Exchangers
10/20/2021	Replaced Shim Blade 2 absorber
10/20/2021	Replaced Shim Blade 5 'Blade In' proximity switch and tube (Job #E-3519)
10/21/2021	Installed NETL in-core experiment (Core #241)
11/5/2021	Replaced NZ12.21 display on TK 250 module of DWK 250 Channel #2
11/22/2021	Installed HTWL-Boone in-core experiment (Core #241A)

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) \ High Temperature 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 the first quarter of 2021, it was used for WATF Phase 2 and Exelon experiments. Later in 2021, it saw dry samples – SiC fiber composite coupons from Free Form Fibers and zirconium crystals from Idaho National Laboratory.

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 CY2021 for in-core experiments and irradiations. – See section A.2 (Experiments and Utilization), items (b), (c), and (d).

Physical Security Plan Revisions
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), SR #2021-2 (01/25/2021) SR #2021-2A (04/12/2021), SR #2021-2C (04/28/2021)

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 CY2020, planning began for conversion from the C*CURE security management system to the Genetec system being adopted throughout the MIT campus. In CY2021, the conversion took place. It included, for compatibility with the new system, replacement of the iris readers with other biometric readers, with a corresponding Physical Security Plan revision sent to NRC in April 2021, shortly after the completion of the upgrade. Other security devices were either replaced or retrofitted with external interfaces to make them compatible with the new system.

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 through CY2021, this newly-installed system continued to operate in parallel with the existing stack effluent and water monitoring systems.

Emergency Plan & Procedure Revisions
SR #2019-33 (12/14/2020 – 06/16/2021)

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. The updates were approved by the MIT Reactor Safeguards Committee in December 2020 and were implemented in the second quarter of CY2021, with a corresponding Emergency Plan & Procedure revision sent to NRC in June 2021.

Shim Blade Electromagnets
SR #2017-12 (07/22/2019 – 05/04/2021)

The design of the MITR safety magnets was improved to ensure electrical isolation from the coil to the magnet case. The main design changes were the addition of a counter-bore and radius on the wire entrance to the magnet top flange, a wider channel and radius on the magnet core top, and the movement of the coil wire to magnet wire electrical connections to inside of the epoxy potted magnet coil. Additional modifications were made to improve the manufacturing process. These included the addition of concentric mating surfaces to the magnet core/bottom plate assembly for precise part location during welding, the pre-potting of the magnet coil in epoxy to hermetically seal the connection inside the coil itself, and the utilization of a YAG Laser for the final assembly weld. All modifications were evaluated to improve functionality and reliability, therefore increasing safety.

License Amendment Request for Emergency Battery Surveillances
SR #2020-32 (03/02/2021 – 08/30/2021), SR #2021-28 (10/19/2021)

The NRL proposed to upgrade the batteries in the reactor's emergency electrical power systems from flooded lead-acid batteries to absorbent glass mat (AGM) valve-regulated lead-acid (VRLA) batteries. In March 2021, the NRL submitted a corresponding license amendment request for Technical Specification 4.6, modifying the emergency battery surveillance requirements to be appropriate for use with the AGM VRLA batteries. The batteries would be assured to continue to meet all requirements for providing emergency electrical power to reactor equipment following a loss of normal electrical power to the reactor facility. After the NRL submitted refinements and responses to NRC's Request for Additional Information, Technical Specification Amendment No. 46 was approved by NRC on August 30, 2021.

Replacement of all 60 batteries, along with installation of their new battery charger and battery monitoring system, took place in October 2021. The subsequent operating test and performance test on the system satisfactorily certified the system as in full compliance with the new Technical Specifications.

MCODE Isotope Extract Script Package
SR #2021-30 (12/03/2021)

A new computer script was written, using Python 3, to increase the accuracy of uranium-235 isotope tracking throughout the refueling calculation process. The new script still interacts with MCODE files but saves several hours of computation time by avoiding an unnecessary MCNP calculation via use of information already available. The script does not alter the input to MCODE and therefore has no effect on safety limit calculations, depletion modeling, or fission density tracking.

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 (01/01/2021 – 12/31/2021)
North	0.25 mrem
East	0.17 mrem
South	0.23 mrem
West	0.17 mrem
Green (east)	0.01 mrem

Calendar Year Average

2021	0.2 mrem
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, 2021 - December 31, 2021

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	74
Measurable – < 0.1	26
0.1 – 0.25	9
0.25 – 0.50	2
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 = 2.736 Total Number of Personnel = 111

From January 1, 2021, through December 31, 2021, 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 8,857,256 liters discharged during CY2021 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 3.48E-5 Ci for CY2021. The total tritium was 6.79E-2 Ci. The total effluent water volume was 8,879,463 liters, giving an average tritium concentration of 1.55E-5 μCi/ml.

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

All releases were in accordance with Technical Specification 3.7.2.1, 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 2569.86 Ci of Ar-41 was released at an average concentration of 3.98E-10 μCi/ml. This represents 3.98% of EC (Effluent Concentration (1E-08 μCi/ml)).

3. Solid Waste

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

TABLE H-1

ARGON-41 STACK RELEASES

CALENDAR YEAR 2021

	Ar-41 Discharged (Curies)	Average Concentration(1) (μCi/ml)
January 2021	332.43	5.42 E-10
February	202.74	4.13 E-10
March	242.37	4.94 E-10
April	212.24	3.46 E-10
May	265.74	5.42 E-10
June	202.10	4.12 E-10
July	11.60	1.90 E-11
August	204.14	4.19 E-10
September	388.26	6.37 E-10
October	79.38	1.63 E-10
November	203.29	4.17 E-10
December	225.57	3.70 E-10
Totals (12 Months)(2)	**2569.86**	**3.98 E-10**
EC (Table II, Column I)		1×10^{-8}
% EC		**3.98%**

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

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

TABLE H-2

SUMMARY OF MITR-II RADIOACTIVE SOLID WASTE SHIPMENTS

CALENDAR YEAR 2021

Descriptions

Volume	72 ft^3
Weight	1269 lbs.
Activity	42 mCi
Date of shipment	February 17, 2021
Waste processor	Toxco Material Management Center, Oak Ridge, TN
Waste broker	Ecology Services Inc., Columbia, MD
Disposition to licensees for burial	Energy Solutions, Clive, UT

Volume	94.8 ft^3
Weight	2430 lbs.
Activity	1350 mCi
Date of shipment	June 15, 2021
Waste processor	Toxco Material Management Center, Oak Ridge, TN
Waste broker	Ecology Services Inc., Columbia, MD
Disposition to licensees for burial	Energy Solutions, Clive, UT

Volume	138 ft^3
Weight	959 lbs.
Activity	392 mCi
Date of shipment	December 8, 2021
Waste processor	Toxco Material Management Center, Oak Ridge, TN
Waste broker	Ecology Services Inc., Columbia, MD
Disposition to licensees for burial	Energy Solutions, Clive, UT

TABLE H-3

LIQUID EFFLUENT DISCHARGES
CALENDAR YEAR 2021

	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. 2021	1.862	26.8	501508	53.495
Feb.	1.617	12.3	594944	20.730
Mar.	1.478	7.50	789654	9.502
Apr.	NDA(2)	0.002	360457	0.006
May	12.216	6.33	641109	9.881
June	NDA(2)	0.003	819587	0.003
July	7.489	5.96	72789	81.880
Aug.	NDA(2)	0.002	379404	0.006
Sept.	NDA(2)	0.002	1753278	0.001
Oct.	5.276	2.74	495087	5.531
Nov.	NDA(2)	2.01E-7	1172358	0.00
Dec.	4.868	6.24	1299289	4.800
12 months	34.805	67.9	8879463	15.486

(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.