NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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U.S. Nuclear Regulatory Commission,
Washington, D.C. 20555

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Subject: Annual Report, Docket No. 50-20, License R-37, Technical Specification 7.13.5

Gentlemen:

Forwarded herewith is the Annual Report for the MIT Research Reactor for the period July 1, 2004 to June 30, 2005, in compliance with paragraph 7.13.5 of the Technical Specifications for Facility Operating License R-37.

Sincerely,

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MIT RESEARCH REACTOR
NUCLEAR REACTOR LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ANNUAL REPORT

to

United States
Nuclear Regulatory Commission
for
the Period July 1, 2004 – June 30, 2005

by

REACTOR STAFF

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MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JULY 1, 2004 – JUNE 30, 2005

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 7.13.5, which requires an annual report following the 30th of June of each year.

The MIT Research Reactor (MITR), as originally constructed, consisted of a core of MTR-type fuel, enriched in uranium-235 and cooled and moderated by heavy water in a four-foot diameter core tank, 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 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 fully enriched in uranium-235. Much of the original facility, e.g., graphite reflector, biological and thermal shields, secondary cooling systems, containment, etc., has been retained.

After Construction Permit No. CPRR-118 was issued by the former U.S. Atomic Energy Commission in April 1973, major components for the modified reactor were procured and the MITR-I completed its mission on May 24, 1974, having logged 250,445 megawatt hours during nearly 16 years of operation.

The old core tank, associated piping, top shielding, control rods and drives, and some experimental facilities were disassembled, removed, and subsequently replaced with new equipment. After preoperational tests were conducted on all systems, the

U.S. Nuclear Regulatory Commission issued Amendment No. 10 to Facility Operating License No. R-37 on July 23, 1975. After initial criticality for MITR-II on August 14, 1975, and several months of startup testing, power was raised to 2.5 MW in December. Routine 5-MW operation was achieved in December 1976. Three shift operations, Monday through Friday, was continued through 1995 when a gradual transition to continuous operation (24 hours per day, 7 days per week with a shutdown for maintenance every 4-5 weeks) was initiated. The current operating mode is continuous operation at full power.

In July 1999, an application to relicense the reactor for twenty years and to upgrade its power level to 6 MW was submitted to the U.S. Nuclear Regulatory Commission. That request is now being processed. In December 2000, a fission converter medical facility was commissioned. This facility generates the best epithermal beam in the world for use in the treatment of certain types of cancer.

This is the thirtieth annual report required by the Technical Specifications, and it covers the period July 1, 2004 through June 30, 2005. 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 twenty-eighth full year of routine reactor operation at the 5-MW licensed power level. It was another year in which the safety and reliability of reactor operation met and exceeded requirements and expectations.

A summary of operating experience and other activities and related statistical data are provided in Sections A through I of this report.

A. SUMMARY OF OPERATING EXPERIENCE

1. General

The MIT Research Reactor, MITR-II, is operated to facilitate experiments and research including in-core irradiations and experiments, medical studies, and neutron activation analyses. It is also used for student laboratory exercises and student operator training, and accommodates the medical program on boron neutron capture therapy for cancer-treatment studies. When operating, the reactor is normally maintained at a nominal 5 MW. For this reporting period, the nominal full power operating cycle continued to be four weeks at a time, followed by a shutdown lasting half a day to five days, for reactor and experiment maintenance and other necessary outage activities. The reactor would then be re-started to full power and maintained there for another four to five weeks. The period covered by this report is the twenty-eighth full year of normal operation for MITR-II.

The reactor averaged 135 hours per week at power compared to 94 hours per week for the previous year and 129 hours per week two years ago.

The reactor was operated throughout the year with 24 elements in the core. The remaining three positions were occupied by solid aluminum dummies or in-core experiments. During FY2005, compensation for reactivity lost due to burnup was provided by three refuelings. These followed standard MITR practice which is to introduce fresh fuel to the inner portion of the core (the A- and B-Rings) where peaking is least and to place partially spent fuel in the outer portion of the core (the C-Ring). In addition, elements were inverted and rotated so as to achieve more uniform burnup gradients in those elements. Nine new elements were introduced into the reactor core during FY2005.

The MITR-II fuel management program remains quite successful. All of the original MITR-II elements (445 grams U-235) have been permanently discharged. The overall burnup for the discharged elements was 42%. (Note: One element was removed prematurely because of excess out-gassing.) The maximum overall burnup achieved was 48%. A total of one hundred sixty of the newer, MITR-II elements (506 grams U-235) have been introduced to the core. Of these, ninety have attained the maximum allowed fission density and were discharged. However, some of these may be reused if that limit is increased as would seem warranted based on metallurgical studies by DOE. Seven elements have been identified as showing excess out-gassing and two are suspected of this. All nine have been removed from service and returned to an off-site DOE storage facility. The other sixty-one are either currently in the reactor core, in the fission converter tank, or have been partially depleted and are in the wet storage ring awaiting reuse. During the period of FY2005, twenty-four spent elements were returned to an off-site DOE facility.

Protective system surveillance tests are conducted whenever the reactor is scheduled to be shut down.

As in previous years, the reactor was operated throughout the period without the fixed hafnium absorbers, which were designed to achieve a maximum peaking of the thermal neutron flux in the heavy water reflector beneath the core. These had been removed in November 1976 in order to gain the reactivity necessary to support more in-core experiment facilities.

2. Experiments

The MITR-II was used throughout the year for experiments and irradiations in support of research, training and education programs at MIT and elsewhere.

Experiments and irradiations of the following types were conducted:

a) Use of the Fission Converter facility for animal and drug studies funded by the U.S. DOE Innovation in Nuclear Infrastructure and Education program as part of the Boron Neutron Capture Therapy research effort to treat cancer tumors.

b) Use of the Thermal Neutron Beam for irradiation of tumor-bearing animals for imaging study of tumor progression, characterization of mechanisms of vascular damage to the gastro-intestinal system as a result of radiation exposure, and evaluation of methods to characterize new boron delivery compounds in cells.

c) Activation of gold foils and iron wires for thermal neutron flux calibration for MITR's pneumatic tubes and 3GV beam ports.

d) Activation of yttrium foils for an on-going DOE clinical trial at the Massachusetts General Hospital for spinal cord cancer removal therapy.

e) Production of gold-198 for brachytherapy.

f) Production of iodine-125 seeds in xenated silicon chips and vascular stents with activated iridium-192 for DOE clinical trials at the Massachusetts General Hospital for medical research.

g) Study of BPA drug uptake and distribution pattern in live animals using the reactor's 4DH1, 4DH3, Fission Converter, and Thermal Beam facilities. These analyses support neutron capture therapy and studies of radiation synovectomy for treatment of arthritis.

h) High sensitivity neutron activation analyses of liquid scintillator and cryogenic detection medium in support of U.S. and international projects on double-beta decay research (partially funded by DOE).

i) Activation of uranium foils for detector calibration at the Los Alamos National Laboratories, New Mexico, and other national DOE facilities.

j) Autism studies using neutron activation analysis to measure mercury and other trace elements in human hair and biopsy-derived brain tissues.

k) Neutron activation of thulium on nucleopore filters for marine biology and oceanic sediment studies at the Woods Hole Oceanographic Institute.

l) Measurements of leakage neutron energy spectrum to determine reactor temperature using a mechanical chopper in the 4DH1 radial beam port facility. Measurement of neutron wavelength by Bragg reflection permits demonstration of the DeBroglie relationship for physics courses at MIT and other universities. Time-of-flight measurements are also performed by students from the MIT Nuclear Science and Engineering Department.

m) Neutron activation of aluminum and tin specimens to determine iron oxide contamination for geological studies at Harvard University.

n) Irradiation of germanium wafers to be used in low temperature germanium-resistance thermometers, which have high sensitivity down to 0.001K.

o) Use of the reactor's 3GV facility at low power to perform track-etch analyses of brain tissues treated with a boron-containing drug for microdosimetry study.

p) Neutron activation analysis to evaluate Kr-79 gas production for refinery tracer study.

q) Irradiation of red oak tree samples in a study of toxic trace elements in vegetation from Superfund sites.

r) Use of the reactor's 3GV facility to activate geological samples for earth, atmospheric and planetary studies.

s) Irradiation of filtration beads for pilot study of the environmental effects of these beads when used for farming.

t) Neutron activation analysis of carbon nano-tubes to determine impurities in the sample content.

u) Use of the reactor facility for training of MIT student reactor operators and for nuclear engineering classes (22.09/22.104 – Principles of Nuclear Radiation Measurement and Protection, and 22.06 – Engineering of Nuclear Systems), and a Junior Physics lab course (8.13/8.14).

In addition to the above list, the MIT reactor has been used to provide fission-spectrum neutron irradiation in the core for dose reduction studies for the light-water nuclear power industry. Beginning in 1989, after much planning and out-of-core evaluation, the MIT reactor has designed and operated nine in-core experiments. These studies entail installing experimental cooling loops in the reactor core to investigate the chemistry of corrosion and the transport of radioactive crud. Loops that replicate both pressurized (PWR) and boiling water reactors (BWR) were built. The PWR loop has been operational since August 1989. The BWR loop became operational in October 1990. A third loop, one for the study of irradiation-assisted stress corrosion cracking (IASCC), became operational in June 1994. A fourth one, also for the study of crack propagation (SENSOR), began operation in April 1995.

An experiment using the IASCC thimble was installed in-core in February 1999 to study cross-corrosion behaviors of various metal specimens placed in close proximity (shadowing). The first of these experiments was successfully completed in June 1999. Another in-core experiment re-using the IASCC thimble was conducted throughout September and October 2000, irradiating and investigating behavior of new materials (ceramic fiber composites) for cladding of PWR power reactor fuel, with post-irradiation study performed at the reactor facility during 2001. In early 2003, another shadow corrosion experiment operated in-core for a month using this thimble.

A second phase of this shadow corrosion experiment began in early 2004 and was successfully completed in May 2004. A third phase was also successfully completed from May to August 2004, measuring electro-chemical potential difference between Zircaloy and Inconel specimens under neutron and gamma irradiation conditions, to evaluate effects that could reduce shadow corrosion.

In February 2004, a new type of in-core experiment was installed to test performance of innovative annular fuel designs as a part of the Generation-IV power reactor research effort by the MIT Nuclear Engineering Department. This experiment continued into FY2005. It is the first irradiation of a fueled test capsule at the MIT reactor, and one of very few undertaken at any university reactor.

Another major research effort ongoing during FY2005 is the Boron Neutron Capture Therapy (BNCT) project. This project is making extensive use of the reactor's fission converter facility, the prompt gamma facility, and the thermal neutron beam facility for drug testing and characterization using cell culture, tissues, and lab mice. Funding for these clinical trials is provided by the National Institute of Health. Construction of the fission converter facility was funded by DOE and completed by NRL staff in autumn 2000. Major peripheral equipment installation was completed in FY2001. In FY2002 and FY2003, it was used primarily for beam and drug studies by national and international groups. Many of the beam and drug studies were performed as preparation for BNCT clinical trials. The clinical trials at MIT were a collaborative effort with the Beth Israel-Deaconess Medical Center which is affiliated with the Harvard Medical School. See Section I for more details on the BNCT clinical trial program.

As part of the BNCT project, the epithermal neutron beam at the reactor basement's original medical facility was converted into a thermal beam during FY2002. In FY2003, Ricorad shielding was installed along the thermal beam medical room's inner wall adjacent to the reactor's equipment room, in order to minimize radiation interference in the thermal beam room during operation of the fission converter facility. Construction of a full-size control console away from the outer wall of the thermal beam facility was completed, replacing the original beam control panel. In FY 2004 and FY2005, new lighting, wall surfaces and a new floor were installed inside the medical room. In FY2005, additional Ricorad shielding was installed at the medical room's inner wall, and then the final inner wall surface was mounted in place. Extensive instrumentation rewiring for shutter operation from the new control console was also completed in FY2005.

3. Changes to Facility Design

Except for minor changes reported in Section E, no changes in the facility design were made during the year. As indicated in past reports the uranium loading of MITR-II fuel was increased from 29.7 grams of U-235 per plate and 445 grams per element (as made by Gulf United Nuclear Fuels, Inc., Connecticut) to a nominal 34 and 510 grams respectively (made originally by the Atomics International Division of Rockwell International, California, now by BWX Technologies, Inc., Virginia). With the exception of seven elements (one Gulf, six AI) that were found to be out-gassing excessively, performance of these fuel elements has been good. (Please see Reportable Occurrence Reports Nos. 50-20/79-4, 50-20/83-2, 50-20/85-2, 50-20/86-1, 50-20/86-2, 50-20/88-1, and 50-20/91-1.) The heavier loading results in 41.2 w/o U in the core, based on 7% voids, and corresponds to the maximum loading in Advanced Test Reactor (ATR) fuel. Atomics International completed the production of forty-one of the more highly loaded elements in 1982. Of the forty elements that were used to some degree, thirty-two with about 40% burnup have been discharged because they have attained the fission density limit. Of the other eight, six were, as previously reported to the U.S. Nuclear Regulatory Commission, removed from service because of excess out-gassing and two were removed because of suspected excess out-gassing. One hundred twenty elements fabricated by BWXT have been received, sixty-one of which remain in use. One has been removed because of suspected excess out-gassing and fifty-eight have been discharged because they have attained the fission density limit.

The MITR staff has been following with interest the work of the Reduced Enrichment for Research and Test Reactors (RERTR) Program at Argonne National Laboratory, particularly the development of advanced fuels that will permit uranium loadings up to several times the recent upper limit of 1.6 grams total uranium/cubic centimeter. Consideration of the thermal-hydraulics and reactor physics of the MITR-II core design show that conversion of MITR-II fuel to lower enrichment must await the successful demonstration of the proposed advanced fuels.

4. Changes in Performance Characteristics

Performance characteristics of the MITR-II were reported in the "MITR-II Startup Report." Minor changes have been described in previous reports. There were no changes during the past year. Performance characteristics of the Fission Converter Facility were reported in the "Fission Converter Facility Startup Report".

5. Changes in Operating Procedures

With respect to operating procedures subject only to MITR internal review and approval, a summary is given below of changes implemented during the past year. Those changes related to safety and subject to additional review and approval are discussed in Section E of this report.

a) PM 1.9, "Bypass of Safety Functions", modified the bypass procedure to require that all bypass installations, not just certain jumper bypasses, be checked by two responsible persons. (SR#-0-04-8)

b) PM 1.12, "Radiological Training and Dosimetry Classification", updated an administrative procedure to reflect the current transition to computer-based training on radiological controls. (SR#-0-04-17)

c) "Fuel Management Codes – PC", modified the mainframe computer programs used in fuel management to run on a PC. (SR#-0-04-16)

d) PM 5.4.4, "Low Flow HM-1 or HM-1A", converted the low flow secondary coolant scrams to loss of flow alarms, and revised the related response procedure accordingly. (SR#-0-05-4)

e) PM 5.4.14, "Loss of City Water Pressure", created a response procedure to accompany the installation of a sensor and annunciator alarm that monitor the city water supply line to the reactor secondary coolant and emergency core cooling systems for loss of pressure. (SR#-0-05-3)

f) PM 6.1.3.14, "Determination of Low-Range Amplifier Calibration Points", revised an instrument calibration procedure for more detailed data points and use with the current low range nuclear safety channel hardware. (SR#-0-05-8)

g) PM 7.3.6, "Procedure for Change-out of MITR-II Heavy Water", updated the procedure used in 1991 to reflect current tritium activity, additional work planned for the heavy water reflector system while it was drained, and use of a new digital scale to measure drum contents during filling. (SR#-0-04-15)

h) PM 7.4.4.2, "In-Service Inspection of Primary Core Tank and Fuel, and Spent Fuel Storage Pool", re-ordered a surveillance checklist for ease of use, added several checks, and added inspection of the spent fuel pool for cleanliness, and for integrity of the fuel racks and the stored elements. (SR#-0-02-5)

6. Surveillance Tests and Inspections

There are many written procedures in use for surveillance tests and inspections required by the Technical Specifications. These procedures provide a detailed method for conducting each test or inspection and specify an acceptance criterion which must be met in order for the equipment or system to comply with the requirements of the Technical Specifications. The tests and inspections are scheduled throughout the year with a frequency at least equal to that required by the Technical Specifications. Thirty such tests and calibrations are conducted on an annual, semi-annual, or quarterly basis.

Other surveillance tests are done each time before startup of the reactor if shut down for more than 16 hours, before startup if a channel has been repaired or de-energized, and at least monthly; a few are on different schedules. Procedures for such surveillance are incorporated into daily or weekly startup, shutdown or other checklists.

During the reporting period, the surveillance frequency has been at least equal to that required by the Technical Specification, 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 FY2005, three shipments were completed, reducing the inventory of spent fuel at MIT to less than a full shipment of eight elements. The U.S. Department of Energy has indicated further shipments may be available in FY2006 for future fuel discharges.

B. REACTOR OPERATION

Information on energy generated and on reactor operating hours is tabulated below:

	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
1. Energy Generated (MWD):					
a) MITR-II (MIT FY2005) (normally at 4.9 MW)	270.2	272.2	347.1	258.6	1148.1
b) MITR-II (MIT FY1976-2004)					24,669.8
c) MITR-I (MIT FY1959-1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					36,253.1
2. MITR-II Operation (hours): (MIT FY2004)					
a) At Power (>0.5-MW) for Research	1753.6	1766.5	2160.9	1476.1	7157.1
b) Low Power (<0.5-MW) for Training[1] and Test	41.5	13.9	32.0	43.1	130.5
c) Total Critical	1795.1	1780.4	2192.9	1519.2	7287.6

[1] These hours do not include reactor operator and other training conducted while the reactor is at full power for research purposes (spectrometer, etc.) or for isotope production. Such hours are included in the previous line.

C. SHUTDOWNS AND SCRAMS

During the period of this report there were 6 inadvertent scrams and 9 unscheduled shutdowns.

The term "scram" refers to shutting down of the reactor through protective system action when the reactor is at power or at least critical, while the term "shutdown" refers to an unscheduled power reduction to subcritical by the reactor operator in response to an abnormal condition indication. Rod drops and electric power loss without protective system action are included in unscheduled shutdowns.

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

		Total
1. Nuclear Safety System Scrams		
a)	Trip on Channel #5 as result of internal electronic component failure.	1
b)	High power level trip on Channel #6 as result of operator error while performing a reshim.	1
c)	Fission Converter trip on spurious electronic noise during Fission Converter operation.	1
	Subtotal	3
2. Process System Scrams		
a)	High temperature trip of Withdraw Permit Circuit as result of noise spike on MT-5A recorder.	2
b)	Low flow primary coolant trip as result of fault in primary flow recorder fluorescent light.	1
	Subtotal	3

3. Unscheduled Shutdowns

a)	Shutdown due to loss of offsite electricity.	5
b)	Shutdown due to drops of shim blade (#6).	1
c)	Shutdown due to leak into the primary coolant of CO_2 cover gas from the AFTR in-core experiment.	1
d)	Shutdown due to automatic ventilation isolation resulting from failure of a sample under irradiation in the 2PH1 pneumatic tube facility.	1
e)	Shutdown due to loss of city water supply pressure.	1
	Subtotal	9
	Total	19

4. Experience during recent years has been as follows:

Fiscal Year	Scrams
2005	6
2004	9
2003	17
2002	8
2001	17

D. MAJOR MAINTENANCE

Major maintenance projects performed during FY2004 are described in this Section. Much maintenance was performed to continue the safe, reliable and efficient operation of the MIT Research Reactor, to systematically replace the reactor neutron absorber shim blades, and their drive mechanisms and shim blade magnets, and as preventive effort to upgrade reactor equipment and instrumentation before major degradation. Other maintenance and upgrade effort was made to support in-core experiments and other reactor uses:

(a) Annular Fuel Test Rig (AFTR) – Reactor staff supported its safety reviews, installation, operation of the experiment, repair, cover gas sampling procedure and implementation, removal, underwater dose measurement of the irradiated AFTR fuel capsules for dose assessment and shielding designs, and transfer to special storage. Many new procedures were developed and safety reviewed for these operations.

(b) High Temperature Irradiation Facility (HTIF) – Reactor staff supported its pre-installation reactivity assessment by measuring reactivity worth of its proposed tungsten in-core experiment holder at low power. Four special low power startups were performed for the measurement. New procedures were initiated and safety reviewed for these measurements. Additionally, reactor staff assisted experimenters in the installation of experiment equipment at the reactor top and floor.

(c) EPRI Electro-Chemical Potential Loop (ECP) – Reactor staff supported its full-power operation, its removal from the core, and transfer of irradiated specimens into Hot Cell #1 for post-irradiation analyses.

(d) Thermal Neutron Beam Room Renovation – The Thermal Neutron Beam facility was completely renovated not only for aesthetics but for significant reduction of neutron and gamma background doses due to operation of the Fission Converter facility. This facility has primarily been utilized this fiscal year for advanced BNCT drug studies by research teams from the MIT Nuclear Science and Engineering Department, Ohio State University, and University of Connecticut.

(e) Neutron Phase Contrast Imaging Project (NPCI) – Reactor staff replaced the port plug for the 6SH2 radial beam port facility with one equipped with a special neutron beam collimator. Additionally, a rotator drum spectrometer was installed and carefully aligned as an extended component for the facility. A high-density concrete corral was also installed around the new spectrometer to provide extra shielding against radiation streaming. A safety review was completed beforehand to develop a special written procedure for the installation. Several practice runs were also conducted with RRPO to optimize the procedure before the start of this evolution.

The repair and maintenance of machinery and computer control and monitoring software and hardware for neutron transmutation doping of silicon (NTD Si) continues to require staff support. This machinery, installed in two of the reactor through-ports, includes two twenty-foot tubes for each port, rotating and pushing mechanisms, billet handling and storage conveyors, electronic sensors, and associated microprocessor-based controllers and computer tracking systems. It was constantly operating whenever the reactor was at power. For this fiscal year, additional effort was put into initiating a large number of surveillance procedures for the NTD Si system by the reactor staff for application for an ISO 9001 Certification for the program.

Major maintenance items performed in FY2005 were summarized as follows:

1) The reactor's D_2O reflector system was drained and refilled with fresh heavy water, reducing its tritium concentration from ~4 Ci / liter to ~1 mCi / liter. Ten 55-gallon drums of spent D_2O were returned to DOE several weeks after the replacement. They included waste D_2O collected over the last twelve years from various ion column deuterization operations and routine sampling for analyses. The fresh D_2O and all shipments were funded by the U.S. DOE University Reactor Fuel Assistance Program. Planning for this replacement was started in January 2003 and the project was completed in November 2004 with the delivery of the spent D_2O to the designated DOE storage site.

2) The main pump DM-1 of the reactor's D_2O reflector system was rebuilt, and the auxiliary pump DM-2 of the system was replaced with an upgraded model. Both pumps were carefully aligned and tested satisfactory.

3) More than 50 reflector system valve diaphragms were replaced while the D_2O was drained from the reflector system.

4) About 22 leak detection tapes at various locations in the reflector system were replaced and tested satisfactory during the D_2O replacement operations.

5) The reactor floor Hot Cell and Hot Box were equipped with new area radiation monitors and the Hot Box upgraded with lighting, electrical feeds, and new fire alarm and suppression systems. The radiation monitor and fire alarm systems will alarm in the control room to alert operators of abnormal conditions in the Hot Cell and the Hot Box.

6) Shim blade #2 was replaced, along with its guide rods, armature, and offset plates. Its drive mechanism was rebuilt, and its electromagnet was replaced as a preventive maintenance measure.

7) The reactor regulating rod was replaced with a new one. Its drive mechanism was also rebuilt.

8) The reactor's medical water shutter control diaphragm valves BV-21, BV-22 and BV-30 were all rebuilt. The shutter system level probe BL-2 was also replaced.

9) Secondary system gate valve HV-3 was replaced with a butterfly valve for upgrade and ease of operation. Secondary system quarter-turn valve HV-5 was also replaced.

10) All eight fan motors of cooling tower unit #2 were rebuilt. All eight water spray nozzles were upgraded with new rotating units for better cascade distribution. All water seals at the base of the unit were stripped and renewed.

11) Repair and maintenance effort was performed on shield and secondary pipe leaks.

12) The emergency power system transfer switch was replaced. The original switch was found to be intermittent during testing. It was repaired, cleaned and lubricated. The replacement was a preventive measure and an upgrade that allows an easier manual transfer should the automatic feature hesitate.

13) New digital display and alarm modules were installed in the control room for reactor primary core outlet temperatures MTS-1A and MT-5A.

14) The two main reactor heat exchangers were chemically cleaned (continuous flushing for 32 hours) with inhibited phosphoric acid (10% strength) mixed with anti-foaming agents and corrosion inhibitors. The cleaning of the heat exchangers improved the reactor cooling capability significantly.

15) A new pressure gage AP-8 and switch APS-1 was installed at the city water inlet to the reactor containment building in the physics lab. This allows early detection of loss of city water supply by constant monitoring of its supply pressures. It now alarms in the control room upon tripping on low pressure to notify the operator to take action for a potentially sustained loss of city water supply.

16) The main intake and exhaust ventilation dampers were cleaned, lubricated and vacuum-tested satisfactory. This is a scheduled preventive maintenance item to ensure reliable operation for containment isolation when needed.

17) The Fission Converter helium cover gas supply regulator FGV-3 was rebuilt with an upgrade. The original unit was in place since 1999 and had become intermittent later in this reporting period. This upgrade eliminated one of the major sources of process system helium loss.

18) The reactor staff identified and repaired a significant helium leak in the D_2O reflector cover gas supply line. The leak was found to be inside a narrow vertical pipe-way in the equipment room. It was due to corrosion on a section of pipe where it was in contact with the steel liner of the pipe-way. This repair and the one mentioned in the previous item helped to cut back on consumption of helium gas for reactor use by more than a factor of five. In addition to the leak repair, the helium system's automatic solenoid feed valve GV-38 was rebuilt.

19) The reactor primary coolant system low pressure sensors MP-6 and MP-6A were upgraded with remote digital displays in the control room (originally local readouts only). The control room indications will provide a warning if pressures drop below nominal values, representing a deviation from normal primary coolant flow during operations. This upgrade and the modified reactor procedures for test and calibration were recorded in safety review documents.

20) Reactor staff coordinated with a contractor to inspect the polar crane in the containment building. Repair and maintenance were performed on the main drive gear and the tethered controller box.

21) The restricted area fume hood blower was replaced. This is a large unit that is mounted on the NW12 rooftop. It was damaged when the supporting bracket collapsed due to heavy snowfall in early spring. The damage also included the associated duct work and seal. All these were either repaired or replaced. All NW12 restricted area fume hoods were tested satisfactory by MIT Environmental Health & Safety afterward.

22) Several major pressure gages in reactor coolant systems were replaced as preventive maintenance. Pressure snubbers to reduce "chattering" in MP-6 and MP-6A pressure gages were also replaced and tested.

23) Fan belts for the core purge blower, the D_2O helium recombiner blower, the reactor floor Hot Cell blower, and the primary chemistry hood blower were replaced.

24) The electrical heating systems for two of the four liquid CO_2 supply tanks failed and were replaced. They had been in service since 1995.

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

E. SECTION 50.59 CHANGES, TESTS, AND EXPERIMENTS

This section contains a description of each change to the facility or 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.

The review and approval of changes in the facility and in the procedures as described in the SAR are documented in the MITR records by means of "Safety Review Forms." These have been paraphrased for this report and are identified on the following pages for ready reference if further information should be required with regard to any item. Pertinent pages in the SAR have been or are being revised to reflect these changes, and they either have or will be forwarded to the Document Control Desk, USNRC.

The conduct of tests and experiments on the reactor are normally documented in the experiments and irradiation files. For experiments carried out under the provisions of 10 CFR 50.59, the review and approval is documented by means of the Safety Review Form. All other experiments have been done in accordance with the descriptions provided in Section 10 of the SAR, "Experimental Facilities."

Experiments Related to Neutron Capture Therapy

SR#0-89-4 (01/23/89), #0-89-8 (03/01/89), #0-91-7 (05/06/91), #0-91-17 (03/06/92), #0-92-3 (03/06/92), #0-92-4 (03/02/92), #M-92-2 (05/14/92), #0-93-5 (05/28/93), #0-93-9 (07/13/93), #0-93-20 (11/30/93), #0-94-19 (12/02/94), #0-96-5 (05/03/96), #0-97-2 (02/18/97), #0-97-11 (08/14/97), #0-97-13 (09/23/97), #0-97-14 (10/03/97), #M-98-1 (01/30/98), #0-98-5 (06/24/99) #0-99-7 (02/02/00), #M-00-1 (03/29/00), #0-00-7 (07/28/00), #0-01-1 (02/16/01), #M-01-1 (03/28/01), #0-01-8 (03/25/03), #0-02-1 (10/22/02), #0-02-2 (02/01/02), #0-04-7 (05/06/04)

In conjunction with the Tufts – New England Medical Center (NEMC) and with the support of the U.S. Department of Energy, MIT has designed an epithermal neutron beam for the treatment of brain cancer (glioblastoma). Thermal beams have been used successfully for this treatment in Japan. The reason for designing an epithermal beam is to allow tumor treatment without having to subject the patient to surgery involving removal of a portion of the skull. Also, an epithermal beam gives greater penetration. In October 1991, MIT hosted an international workshop for the purpose of reviewing proposed beam designs and dosimetry. Subsequent to the receipt of advice from the workshop panel members, a final design was selected for the epithermal filter for the MIT Research Reactor's Medical Therapy Facility beam. Approvals of the protocol for the conduct of patient trials were received from all requisite MIT and NEMC Committees as well as from the U.S. Food and Drug Administration. Also, a license amendment and quality management plan for use of the MIT Research Reactor's Medical Therapy Facility was issued by the U.S. Nuclear Regulatory Commission as License Amendment No. 27 on February 16, 1993.

Subsequent to the receipt of that license amendment and a similar one in August 1993 for our medical partner, the Tufts – New England Medical Center, procedures for performing BNCT and a preoperational test package were prepared. The latter was completed during FY94.

Patient trials were initiated in September 1994 as part of a Phase I effort that is required by the FDA. In December 1994, changes were issued to certain of the procedures that had been prepared for conduct of the irradiations. These changes were intended to reduce the signature burden on senior personnel during the trials so that their full attention could be given to the human subject.

Three subjects were irradiated in FY95. One more was done in FY96 in conjunction with NEMC. A change of medical partners then occurred, after which a second irradiation was done in FY96. The new program was a joint effort between MIT and the New England Deaconess Hospital (NEDH), which was affiliated with the Harvard Medical School. This change necessitated an amendment to the NEDH's license for radioactive materials and their use, as well as to the various internal approvals. Subsequent to receipt of these licenses/approvals, the Phase I trial for melanoma was continued. Also, a separate Phase I protocol for glioblastoma multiforme was approved. Patient trials under that protocol were initiated in July

1996. In FY97, New England Deaconess Hospital merged with the Beth Israel Hospital. The resulting organization is Beth Israel – Deaconess Medical Center, which is now also a major teaching hospital for the Harvard Medical School. Under the new partnership, a total of twenty-two human subjects were irradiated through April 1999 up to a dose level of 1420 RBE-cGy.

Technical Specification #6.5, "Generation of Medical Therapy Facility Beam for Human Therapy," and its associated BNCT Quality Management Program were updated in FY97. The change was purely administrative in nature. No substantive changes of any type resulted. The language update in the two documents was to reflect transition from NRC regulation to State regulation of medical use licensees, and thereby to prevent any possible subsequent disruption of the ongoing BNCT research program due to such administrative shift. The change allows MIT to conduct BNCT on human subjects from both NRC and Agreement State (the Commonwealth of Massachusetts) medical use licensees whose licenses contain BNCT-specific conditions and commitments for BNCT clinical trials on human subjects conducted at the MIT reactor. The change was approved by the NRC on April 3, 1997.

On October 3, 1997, a Safety Evaluation Report and associated Technical Specifications were submitted to NRC for the design and construction of a new Medical Therapy Facility utilizing a Fission Converter. Approval for operation of the new facility was received in December 1999. Fuel was loaded into the facility in April 2000 and startup testing was completed by August 2000. This new facility provides MIT with the best epithermal neutron beam for BNCT in the world. Approval to use this beam for patient irradiations was received from the U.S. Nuclear Regulatory Commission on April 2, 2001. Clinical trials of BNCT for both deep-seated melanoma and glioblastoma that use the new fission converter beam began in October 2002 under the auspices of the National Institutes of Health. As of June 30, 2005, one patient with deep-seated melanoma and six patients with glioblastoma multiforme have been irradiated with this beam.

Fission Converter
SR#0-97-14 (10/03/97), #M-98-1 (01/30/98), #0-98-5 (06/24/99), #0-99-7 (02/02/00), #M-00-1 (03/29/00), #0-00-7 (07/28/00), #0-01-1 (02/16/01), #M-01-1 (03/28/01), #0-01-8 (03/25/03), #0-02-1 (10/22/02), #0-02-2 (02/01/02), #0-04-7 (05/06/04)

The safety evaluation report and technical specifications for the fission converter were submitted to the U.S. Nuclear Regulatory Commission on October 3, 1997. Approval was received on 21 December 1999. A startup report was submitted on 1 September 2000. Requests for minor changes to some of the test and calibrations of the associated process systems are were approved in March 2003. A lithium metal filter was installed in May 2004 for the purpose of further optimizing the energy spectrum of the neutron beam. This filter is sealed in an aluminum frame and, when not in use, is stored in a protective case outside the fission converter facility. It is tested periodically to verify the absence of leakage. Precautions are in place should there be any leakage.

In-Core Irradiation of Fissile Materials
SR#0-01-11 (04/16/03), #0-01-12 (04/16/03), #0-02-8 (02/27/04), #0-03-7 (03/02/04), #0-04-2 (03/02/04)

Technical Specifications for fueled experiments were approved by the U.S. Nuclear Regulatory Commission on April 16, 2003. A safety evaluation report was prepared for the first such experiment, which was then conducted successfully from March 2004 to September 2004.

Zircaloy Corrosion Loop / EPRI Electro-Chemical Potential Loop
SR#0-02-6 (02/26/03), #0-03-1 (02/26/03), #0-04-4 (05/17/04)

An in-core loop that replicates PWR conditions was installed for the purpose of evaluating 'shadow corrosion' in power production reactors. The design of this loop was within the envelope of previously-installed PWR-type loops. No new safety issues were raised. The loop operated in the spring of 2003 and again in spring and summer of 2004. Additional operation of this loop is planned for FY 2006.

Replacement of Primary and Secondary Pumps
SR #M-04-1 (01/14/04)

Primary pumps MM-1 and MM-1A were replaced with 60 HP variable frequency drive 6" x 4" ANSI high efficiency pumps. Secondary pumps HM-1 and HM-1A were replaced with 50 HP variable frequency drive pumps. The new pumps have greater reliability and future flexibility in operation. In FY2005 these pumps were operated at various frequency settings, to collect reactor operating data on different coolant flow rates.

High Temperature Irradiation Facility
SR #0-04-18 (12/06/04), #0-05-6 (04/07/05)

A high temperature irradiation facility was designed and fabricated under the U.S. DOE Innovation in Nuclear Infrastructure and Education program to allow testing of candidate materials for Generation-IV reactor research and development. Accomplishments through FY2005 include design and construction of the loop, as well as reactivity measurements on a tungsten prototype of the experiment's heating element. This loop is currently undergoing final ex-core certification.

Titanium Contact with Primary Coolant
SR #0-04-19 (12/01/04), #M-04-2 (12/30/04), M-05-1 (04/15/05)

A Technical Specification amendment was requested and received from the U.S. Nuclear Regulatory Commission adding titanium to the list of materials allowed to be in contact with the primary coolant. Titanium will be used in the planned redesign of the In Core Sample Assembly, and in new primary heat exchangers proposed for FY2006.

F. ENVIRONMENTAL SURVEYS

Environmental monitoring is performed using continuous radiation monitors and dosimetry devices. The radiation monitoring system consists of G-M detectors and associated electronics at each remote site with data transmitted continuously to the Reactor Radiation Protection Office and recorded on strip chart recorders. The remote sites are located within a quarter mile radius of the facility. The detectable radiation levels per sector, due primarily to Ar-41, are presented below. Units located at east and south sector were inoperable periodically during the reporting period due to site renovations. These values are adjusted for the period(s) the sites were not operational.

Site	Exposure (07/01/04 – 06/30/05)
North	0.10 mrem
East	0.12 mrem
South	0.33 mrem
West	0.15 mrem
Green (east)	0.14 mrem

Fiscal Year Averages

2005	0.2 mrem
2004	0.2 mrem
2003	0.2 mrem
2002	0.3 mrem
2001	0.4 mrem
2000	0.2 mrem

G. RADIATION EXPOSURE AND SURVEYS WITHIN THE FACILITY

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

July 1, 2004 - June 30, 2005

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	100
Measurable – < 0.1	34
0.1 – 0.25	10
0.25 – 0.5	6
0.5 – 0.75	1
0.75 – 1.00	0
1.00 – 1.25	0

Total Person Rem = 5.84 Total Number of Personnel = 151

From July 1, 2004 through June 30, 2005, the Reactor Radiation Protection Office 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, and fission converter beam installation and testing, etc.

The results of all surveys and surveillances conducted have been within the guidelines established for the facility.

H. RADIOACTIVE EFFLUENTS

This section summarizes the nature and amount of liquid, gaseous, and solid radioactive wastes released or discharged from the facility.

1. Liquid Waste

Liquid radioactive wastes generated at the facility are discharged only to the sanitary sewer serving the facility. The possible sources of such wastes during the year include cooling tower blowdown, the liquid waste storage tanks, and various sinks. All of the liquid volumes are measured, by far the largest being the 43,141,215 liters discharged during FY2005 from the cooling towers. (Other large quantities of non-radioactive waste water are discharged to the sanitary sewer system by other parts of MIT, but no credit for such dilution is taken because the volume is not routinely measured.)

Total activity less tritium in the liquid effluents (cooling tower blowdown, waste storage tank discharges, and engineering lab sink discharges) amounted to 1.59 E-4 Ci for FY2005. The total tritium was 1.9175 E-1 Ci. The total effluent water volume was 43,157,966 liters, giving an average tritium concentration of 4.443 E-6 μCi/ml.

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

All releases were in accordance with Technical Specification 3.8-1, including Part 20, Title 20, Code of Federal Regulations. All activities were substantially below the limits specified in 10 CFR 20.2003. Nevertheless, the monthly tritium releases are reported in Table H-3.

2. Gaseous Waste

Gaseous radioactivity is discharged to the atmosphere from the containment building exhaust stack. All gaseous releases likewise were in accordance with the Technical Specifications and 10 CFR 20.1302, and all nuclides were substantially below the limits after the authorized dilution factor of 3000 with the exception of Ar-41, which is reported in the following Table H-1. The 1,756.23 Ci of Ar-41 was released at an average concentration of 4.72 E-9 μCi/ml. This represents 47.2% of EC (Effluent Concentration (1×10^{-8} μCi/ml)).

3. Solid Waste

No shipments of solid waste were made during the year. The information pertaining to these shipments is provided in Table H-2.

TABLE H-1

ARGON-41 STACK RELEASES

FISCAL YEAR 2005

	Ar-41 Discharged (Curies)	Average Concentration(1) (μCi/ml)
July 2003	99.72	3.48 E-9
August	151.01	5.27 E-9
September	140.63	3.92 E-9
October	153.67	5.36 E-9
November	149.37	4.17 E-9
December	108.85	3.80 E-9
January 2004	139.19	4.86 E-9
February	166.90	5.82 E-9
March	188.45	5.26 E-9
April	101.02	3.52 E-9
May	187.57	5.23 E-9
June	169.85	5.92 E-9
Totals (12 Months)	1,756.23	4.72 E-9
EC (Table II, Column I)		1×10^{-8}
% EC		47.2%

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

TABLE H-2

SUMMARY OF MITR-II RADIOACTIVE SOLID WASTE SHIPMENTS

FISCAL YEAR 2005

Description	
Volume	0
Weight	0
Activity(1)	0
Date of shipment	No Shipment FY-05
Disposition to licensee for burial	
Waste broker	N/A

TABLE H-3

LIQUID EFFLUENT DISCHARGES
FISCAL YEAR 2005

	Total Activity Less Tritium	Total Tritium Activity	Volume of Effluent Water(1)	Average Tritium Concentration
	($x10^{-6}$ Ci)	(mCi)	($x10^{4}$ liters)	($x10^{-6}$ μCi/ml)
July 2004	155	30.6	194.0	555.07
Aug.	NDA	18.7	183.9	480.03
Sept.	NDA	51.4	470.8	398.97
Oct.	NDA	18.5	461.9	223.00
Nov.	NDA	9.82	462.4	90.04
Dec.	NDA	9.40	214.9	39.06
Jan. 2005	NDA	11.7	290.1	27.84
Feb.	NDA	3.25	473.7	43.56
Mar.	NDA	10.1	598.9	44.56
Apr.	3.73	9.34	258.2	45.00
May	NDA	18.0	616.9	46.31
June	NDA	0.94	90.1	30.55
12 months	158.73	191.75	4315.8	4.443

(1) Volume of effluent from cooling towers, waste tanks, and NW12-139 Engineering Lab sink. Does not include other diluent from MIT estimated at 2.7 million gallons/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. 7.13.5(i).

1. Investigative Studies

In recent years, the major BNCT effort for human subjects was on continuing Phase I/II trials for glioblastoma as well as melanoma using the Fission Converter Facility. Phase I studies are required by the U.S. Food and Drug Administration. The purpose of these studies is to investigate the toxicity (or lack thereof) of a proposed therapy. No benefit is expected to those participating in these studies. Three Phase I trials have been completed, and a Phase II trial and a Phase I/II trial are underway. Each is summarized below.

a) Original Phase I Melanoma Study with Tufts New England Medical Center (NEMC)

This study began in September 1994. The approach used for this protocol implementation was for the subject to be given an oral test dose (400 mg/kg) of the boron-containing drug (BPA). Blood and punch biopsy samples were then taken in order to determine the biodistribution of the boron in both healthy tissue and tumor over time. This was necessary because the uptake of boron in tumor varies markedly from one person to another. The irradiations themselves were done in four fractions. For each, the subject was orally given 400 mg/kg of BPA and a limited number of blood/biopsy samples were taken to confirm the previously measured uptake curve. The starting point in the Phase I protocol was a total dose to healthy tissue of 1000 RBE-cGy. After the third subject, this was increased to 1250 RBE-cGy. Four subjects participated during 1994 and 1995, and a summary of their responses was given in our annual reports for FY95 and FY96.

This Phase I protocol was continued under the sponsorship of the Beth Israel – Deaconess Medical Center (BIDMC).

b) Phase I Melanoma Study with New England Deaconess Hospital (NEDH)

The protocol adopted here was the same as that used for the NEMC study except that: (i) the boronated drug (BPA) was introduced intravenously (IV) and the total dose 1250 RBE-cGy was delivered in one fraction. The use of IV BPA greatly increases boron uptake and hence dose to tumor. One subject was irradiated under this protocol, as summarized in the annual report for FY96.

NEDH became part of BIDMC in FY97.

c) Phase I Glioblastoma Study with Beth Israel – Deaconess Medical Center (BIDMC)

This protocol is similar to the NEDH melanoma study in that it uses IV BPA. The total dose is delivered in multiple fractions via calculated, intersecting beam paths. Eight subjects participated in FY97, six in FY98, and eight in FY99 as summarized in our annual reports for those years.

d) Phase II Melanoma Study with BIDMC

One subject was irradiated under this protocol, as summarized in the annual report for FY2003. During this reporting period, no subjects were irradiated.

Subject irradiations may continue under this Phase II protocol.

e) Phase I / Phase II Glioblastoma Study with BIDMC

Five subjects were irradiated in FY2003 under this protocol, and one in FY2004, as summarized in the annual reports for those years. During this reporting period, no subjects were irradiated.

Subject irradiations may continue under this Phase I/II protocol.

2. Human Therapy

None.

3. Status of Clinical Trials

The Phase I glioblastoma and melanoma trials with BIDMC have been closed because they used the original epithermal beam in the basement medical therapy room. A new beam that is superior in both flux and quality is now available from the Fission Converter Facility. New Phase I / Phase II trials (melanoma and glioblastoma) began with that beam in October 2002.