NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Reactor Operations

138 Albany Street, Cambridge, MA 02139-4296
Telefax No. (617) 253-7300
Tel. No. (617) 253-4211

Activation Analysis
Coolant Chemistry
Nuclear Medicine
Reactor Engineering

November 14, 2003

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 7.13.5

Gentlemen:

Forwarded herewith is the Annual Report for the MIT Research Reactor for the period July 1, 2002 to June 30, 2003, in compliance with paragraph 7.13.5 of the Technical Specifications for Facility Operating License R-37.

Sincerely,

Thomas H. Newton, Jr., PE
Acting Director of Reactor Operations
MIT Research Reactor

Edward S. Lau, NE
Superintendent
MIT Research Reactor

John A. Bernard, Ph.D., PE, CHP
Principal Research Engineer
MIT Research Reactor

JAB/gw

Enclosure: As stated

cc: USNRC – Senior Project Manager,
NRR/ONDD

USNRC – Region I - Project Scientist,
Effluents Radiation Protection Section (ERPS)
FRSSB/DRSS

A020

MIT RESEARCH REACTOR
NUCLEAR REACTOR LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ANNUAL REPORT

to

United States Nuclear Regulatory Commission

for the Period July 1, 2002 – June 30, 2003

by

REACTOR STAFF

Table of Contents

Section		Page
Introduction		1
A.	Summary of Operating Experience	3
B.	Reactor Operation	10
C.	Shutdowns and Scrams	11
D.	Major Maintenance	13
E.	Section 50.59 Changes, Tests, and Experiments	16
F.	Environmental Surveys	20
G.	Radiation Exposures and Surveys Within the Facility	21
H.	Radioactive Effluents	22
I.	Summary of Use of Medical Facility for Human Therapy	26

MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JULY 1, 2002 – JUNE 30, 2003

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 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. 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 twenty-eighth annual report required by the Technical Specifications, and it covers the period July 1, 2002 through June 30, 2003. 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-sixth 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 medical studies and clinical trials, bulk material irradiation damage studies, and neutron activation analysis. 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 much of this reporting period, the reactor was maintained at full power almost continuously (168 hours/week) for four weeks. It was then shut down for half a day to five days for maintenance and other necessary outage activities, and then started up to full power and maintained there for another four to five weeks. The period covered by this report is the twenty-fifth full year of normal operation for MITR-II.

The reactor averaged 129.0 hours per week at power compared to 133.0 hours per week for the previous year and 140.1 hours per week two years ago. The lower number of average full power hours per week for FY2003 and FY2002 was because of various non-recurring maintenance activities.

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 FY2003, compensation for reactivity lost due to burnup was provided by five 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. Six new elements were introduced into the reactor core during FY2003.

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 outgassing.) The maximum overall burnup achieved was 48%. A total of one hundred forty-two of the newer, MITR-II elements (506 grams U-235) have been introduced to the core. Of these, eighty-one have attained the maximum allowed fission density and were discharged from the reactor core to the spent fuel storage pool. 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 outgassing and two are suspected of this. All nine have been removed from service and returned to an off-site DOE storage facility. The other fifty-two 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 FY2003, no 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 human clinical trials funded by NIH to treat glioblastoma and melanoma cancer tumors in collaboration with the Beth Israel Deaconess Medical Center.

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

c) Production of gold-198 and copper-64 seeds for DOE and NIH clinical trials / medical research at the Boston Children's Hospital.

d) 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.

e) 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.

f) High sensitivity neutron activation analyses of scintillator detection medium in support of U.S. and international projects on neutrino mass measurement (partially funded by DOE).

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

h) Gamma activation of ammonium hydroxide solutions for polymerization studies by General Electric.

i) Use of the 4DH4 spectrometer facility to develop methods for quantum computation study.

j) Use of reactor floor Hot Cell and other radioactive sample handling areas to perform fission chamber detector leakage studies for Thermo-GammaMetrics and a nuclear power industry consortium.

k) Activation of micro-scandium particles for internal radiotherapy studies at Washington University at St. Louis.

l) Autism studies using neutron activation analysis to detect trace levels of mercury in human hair, brain tissue and common food samples.

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

n) 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 Engineering Department.

o) Gamma irradiation of seeds and perishable foods for demonstration of radiation effects on plants and organic substances.

p) Microdosimetry study using the Thermal Beam Facility on cultured cells, and to determine radiation effects on organs.

q) Gamma irradiation of PLGA-coated alumina fibers and vascular grafts for medical research and applications at the Beth Israel Deaconess Medical Center.

r) Neutron activation of bismuth shot for nuclear engineering actinide research.

s) Gamma irradiation of cyanate ester resins for stability analyses of materials used as thermal insulator in plasma fusion machine high-power magnets.

t) 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.

u) Neutron activation analysis of sludge-mud samples taken from regional sewage treatment plants to determine contents and re-concentration of heavy metals.

v) Irradiation of geological materials to determine quantities and distribution of fissile materials using solid state nuclear track detectors.

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

x) Use of in-core irradiation location for shadow corrosion studies.

y) Neutron activation study and long-term irradiation effect study on wax samples with an array of colors and heavy metal contents to determine temperature sensitivity of wax used in detector designs for the MIT Chemical Engineering Department and Draper Laboratory.

z) Neutron activation of thorium foils to study neutron transmutation properties of long-lived radioactive waste.

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

bb) 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. 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 growth, 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 for cladding of power reactor fuel, with post-irradiation study performed at the reactor facility during 2001. In early 2003, a shadow corrosion experiment operated in-core for a month using this thimble.

Another major research effort that was ongoing during the period of FY2003 is the Fission Converter Project. This project is making extensive use of the reactor's fission converter facility for FDA Phase I / II boron neutron capture therapy (BNCT) clinical trials for treatment of glioblastoma (brain cancer) and melanoma (skin cancer). Funding for these clinical trials is currently provided by the National Institute of Health. The fission converter facility was funded by DOE, and construction by NRL personnel was completed 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 studies were performed as preparation for the BNCT clinical trials. The clinical trials are a collaborative effort with the Beth Israel-Deaconess Medical Center which is affiliated with the Harvard Medical School.

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, much continued effort was made to complete installation of Ricorad shielding along the inner wall of this facility adjacent to the reactor's equipment room, in order to improve shielding 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 is now completed and is fully operational. It replaces the original beam control panel. New lighting was installed inside the medical room.

See Section I for more details on the BNCT clinical trial program.

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 outgassing 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 outgassing and two were removed because of suspected excess outgassing. One hundred two elements fabricated by BWXT have been received, fifty-two of which remain in use. One has been removed because of suspected excess outgassing and forty-nine 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 those 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 7.4.4.8, "General Preparation for Work in the Core Tank, " established a procedure codifying the general guidelines and precautions for foreign material exclusion while performing work in or over the core tank. (SR#-0-02-4)

b) "Withdraw Permit Cuircuit Line Voltage Monitoring" provided for temporary connections to the withdraw permit circuit of an isolated data acquisition module designed to locate the source of spurious scram signals. Analysis showed the operation of the safety system would be unaffected. (SR#-E-03-1)

6. Surveillance Tests and Inspections

There are many written procedures in use for surveillance tests and inspections required by the Technical Specifications. These procedures provide a detailed method for conducting each test or inspection and specify an acceptance criterion which must be met in order for the equipment or system to comply with the requirements of the Technical Specifications. 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

Pursuant to Amendment No. 29 to Facility Operating License No. R-37, paragraph 2.B.(2) subparagraph (b), reported herewith is the status of the establishment of a shipping capability for spent fuel and other activities relevant to the temporary increase in the possession limit. (Note: Amendment No. 29 expired on August 8, 1999. The MITR is in compliance with the original possession limit.)

In FY2003, no shipments were completed, because of the inability of MIT to meet the requirements of the shipping interim compensatory measures issued by NRC October 3, 2002. MIT is awaiting resolution of issues concerning this by the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission.

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 FY2003) (normally at 4.9 MW)	258.8	341.4	302.3	306.5	1209.0
b) MITR-II (MIT FY1976-2002)					22,666.4
c) MITR-I (MIT FY1959-1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					34,310.6
2. MITR-II Operation (hours): (MIT FY2003)					
a) At Power (>0.5-MW) for Research	1317.1	1976.6	1507.7	1605.2	6406.6
b) Low Power (<0.5-MW) for Training[1] and Test	120.1	37.0	12.1	37.8	207.0
c) Total Critical	1437.2	2013.6	1519.8	1643.0	6613.6

[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 18 inadvertent scrams and 26 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)	High level power channel (#4, #5, #6) trip as result of overly conservative setting by operator error.	4
b)	High level Channel #4 trip as result of electronic component or connection failure.	3
c)	Channel #3 trip at low power from noise from work on chassis.	1
	Subtotal	8
2.	Process System Scrams	
a)	High temp. MTS-1A trip from vibration from work nearby.	2
b)	High temp. MTS-1A trip as result of overly conservative setting by operator error.	1
c)	Low flow secondary trip upon failure of cooling tower sump level controller.	1
d)	Low flow secondary trip from contractor activity at cooling tower.	1
e)	Low flow primary trip upon failure of recorder's internal lamp.	1
f)	Low flow primary recorder trip on operator error changing chart.	1
g)	Fission converter / thermal beam trip on experimenter test error.	2
	Subtotal	9

3. Unscheduled Shutdowns

a)	Shutdown due to loss of offsite electricity.	4
b)	Shutdown due to drops of shim blades (#2, #4, #5, #6).	10
c)	Shutdown to repair shield coolant leak.	1
d)	Shutdown to repair pinhole leak in primary blowout patch.	1
e)	Shutdown due to circuit L21/L22 voltage transients.[1]	10
	Subtotal	26
	Total	43

Note (1): The circuit L21/L22 voltage transients were caused by a fault in the cooling tower fan circuitry, and by a vibration susceptibility in the fission converter circuitry, which interacted with the withdraw permit circuit. These transients all occurred very fast and took substantial time to isolate and correct. As a result there were a number of these shutdowns; however they had no safety significance.

4. Experience during recent years has been as follows:

Fiscal Year	Scrams
1999	11
2000	18
2001	17
2002	8
2003	17

D. MAJOR MAINTENANCE

Major maintenance projects performed during FY2003 are described in this Section. Much maintenance was performed to continue the safe, reliable and efficient operation of the MIT Research Reactor, to complete conversion of the basement medical room epithermal neutron beam into a thermal beam facility for advanced BNCT drug studies and certain types of BNCT human clinical trials, and to systematically replace the reactor neutron absorber blades, and their drive mechanisms and shim blade magnets.

The repair and maintenance of machinery and computer control and monitoring software and hardware for neutron transmutation doping of silicon (NTD Si) also required continued 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, electronics, and associated microprocessor-based controllers and computer tracking systems. It was constantly operating whenever the reactor was at power throughout this fiscal year.

Major maintenance items performed in FY2003 were as follows:

1) Shim blade #2, #4, #5 and #6 magnets were replaced as a preventive maintenance measure. Shim blade #2, #4 and #5 drive mechanisms were rebuilt during FY2003. The regulating rod drive was also rebuilt.

2) Four prototype shim blade magnets were designed and fabricated to improve water-tightness and electro-magnetic performance.

3) Neutron transmission tests and other necessary test and calibrations were performed on 18 spare shim blades for future use in the reactor.

4) A new intercom system was installed and phased in for all 24 locations external to the reactor containment building for a period of pre-operational testing. Of these, 13 locations are new sites where communication needs have grown over the years. This system was funded by the DOE Instrumentation Grant.

5) A new leak detection system and alarm panel was installed to replace the previous system. Replacement parts for maintenance of the previous alarm system were no longer manufactured. The new system improves maintainability and reliability of leak detection. It also allows three times more leak tape locations than the previous system. This system was funded by the DOE Instrumentation Grant.

6) Hot Cell #1 on the reactor floor was refurbished and cleaned in preparation for the shadow corrosion in-core experiment. Internal lighting was improved. The air flow ΔP manometer was replaced. Both manipulator arms were rebuilt with salvageable parts from the Hot Cell #2 manipulator arms. Hot Cell #2 was used to store the experimental lead shutters and other activated components from the Fission Converter project.

7) A new stainless steel hot box was assembled at the reactor floor. It is now refurbished with internal lighting, fire warning and suppression system and new internal electrical feeds. This work is performed in anticipation of hot box needs for the annular fuel experiment and other in-core experiments. It is funded by the DOE INIE Program. (The current location of the hot box is the former in-core loop experiment disassembly area. This corral was disassembled and its area asbestos floor tiles were replaced in preparation for the hot box installation work. Three large shield walls from the disassembly corral were core-drill sampled and were disposed. Two were reused for other reactor shielding needs.)

8) The 1PH and 2PH1 pneumatic tube systems were cleaned up and their system filters replaced. This restored full air flow through the systems and improved pneumatic and cooling performance of the systems. The 2PH1 pneumatic system was also visually inspected with a fiberscope.

9) A double door and three fire-proof reinforced steel doors (Fleming, Series H) were installed at various entrance locations to NW12 as a new entry control measure for the reactor administrative areas. These doors were introduced with consultation from the MIT Safety Office, the MIT Police and the Massachusetts State fire inspectors.

10) The reactor emergency battery bank was cleaned with acid neutralizer.

11) Stack blowers #1 and #2 were replaced. The equipment room air-sampler pump and flow lines and the plenum blower air flow lines were replaced. The air flow monitor was also adjusted.

12) A radio-repeater unit by Comtronics was installed to facilitate two-way radio-communication from within the reactor containment building to off-site agencies.

13) Gamma dose in the spent fuel storage pool was optimized by new placement of elements. The axial and radial gamma fields were characterized for irradiations.

14) Additional lead shielding was constructed to the north corner of Hot Cell #1 to improve shielding for the reactor floor area.

15) D_2O helium cover gas fill valves (GV-38, diaphragm solenoid), bypass valves, pressure relief valve and isolation valves were replaced for improved maintainability and reliability. The existing fill-valve replacement components are no longer manufactured. The CO_2 graphite cover gas supply system fill valve (SV-3) was of the same type and was also replaced at about the same time.

16) Temperature probes DT-5 and DT-6 for the D_2O reflector system were replaced and tested. The D_2O recombiner filter unit and associated piping was also replaced.

17) A new elevated concrete pad was installed immediately outside the back engineering lab garage door to prevent in-leakage of rain water to flood the waste storage area. In addition, a heavy gauge gasket dust guard was replaced for the garage door to improve dust control for the back engineering lab.

18) Plumbing for the waste tank recirculation system was upgraded to replace older valves and to improve system piping maintainability.

19) Key valves and pressure sensing switches were replaced to upgrade the reactor instrument compressed air system.

20) Helium gas supply lines at the reactor top for all six shim blade drives were replaced with copper tubing to improve durability and leak tightness. Th previously-used poly lines were removed. In addition, a supply line was extended to provide helium purge gas for the fission chamber in 3GV4 for the new Gamma-Metrics nuclear safety system.

21) Reactor shield coolant piping and valves in associated with PV-9 in the equipment room were replaced to improve maintainability and leak tightness.

22) City water make-up to the reactor secondary coolant system was modified for remote operation from the Control Room. Previously, entry into the Equipment Room Near area was required to perform the city water feed.

23) The reactor's radiochemistry clean laboratory (NW13-226) was refurbished to improve cleanliness, maintainability, and lighting. Another clean laboratory (NW13-223) equipped with a chemistry hood was also refurbished for animal and human tissue handling. New floor tiles were installed for both labs. Room and hood lighting was improved. The filters for the chemistry hood were replaced.

24) Service and high-pressure spray cleaning was performed on all water cascade honeycombs in the reactor cooling towers to maintain cooling efficiency.

25) 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.

26) Fan belts for the core purge blower, the D_2O helium recombiner blower, and the primary chemistry room hood blower were replaced.

27) The primary coolant cleanup system and spent fuel pool cleanup system ion columns and filters were replaced. All core purge system filters were replaced. Primary and D_2O storage tank blow-out patches were also replaced.

Many other routine maintenance and preventive maintenance items were scheduled and completed throughout the fiscal year. Major effort was also made towards physical security improvements at the facility.

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)

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, 2003, 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)

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.

In-Core Irradiation of Fissile Materials
SR#0-01-11, #0-01-12, #0-02-8 (Pending)

Technical Specifications for fueled experiments were approved by the U.S. Nuclear Regulatory Commission on April 16, 2003. A safety evaluation report has been prepared for the first such experiment. It is currently being reviewed by the MITR Staff.

Zircaloy Corrosion Loop
SR#0-02-6 (02/26/03), SR#0-03-1 (02/26/03)

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 is expected to be in use again in late 2003 / early 2004.

Operation with Foreign Object in Core Tank
SR#0-02-3 (07/26/02)

A small object fell into the core tank while maintenance was being performed on July 17, 2002. The object became lodged below a natural circulation valve where it did not affect reactor coolant flow. It was not possible to remove the object until specialized equipment (a fiberscope capable of withstanding high radiation fields) was designed and built by a vendor. Safety analyses were therefore performed to show that even if the object became dislodged it would not adversely affect reactor operation. The object was successfully removed on February 6, 2003.

New Sampling Station
SR#M-03-1 (06/05/03)

A new reactor coolant sampling station was installed in the newly refurbished hood at the basement level of the reactor building. The station allows recirculation and collection of shield (new capability), primary, and D_2O coolant samples in a well-lighted, ventilated and spill-controlled hood enclosure in a low background dose area Also new in the sampling station is an ability to sample from the primary cleanup loop.

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 (07/01/02 – 06/30/03)
North	0.16 mrem
East	0.14 mrem
South	0.41 mrem
West	0.28 mrem
Green (east)	0.20 mrem

Fiscal Year Averages

2003	0.2 mrem
2002	0.3 mrem
2001	0.4 mrem
2000	0.2 mrem
1999	0.2 mrem
1998	0.4 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, 2002 - June 30, 2003

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	113
Measurable – < 0.1	40
0.1 – 0.25	14
0.25 – 0.5	7
0.5 – 0.75	1
0.75 – 1.00	2
1.00 – 1.25	0

Total Person Rem = 8.60   Total Number of Personnel = 177

From July 1, 2002 through June 30, 2003, 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 24,727,638 liters discharged during FY2003 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 2.44 E-5 Ci for FY2003. The total tritium was 1.10 E-1 Ci. The total effluent water volume was 24,745,479 liters, giving an average tritium concentration of 4.45 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 1,538.38 Ci of Ar-41 was released at an average concentration of 4.00 E-9 μCi/ml. This represents 40.0% of EC (Effluent Concentration (1×10^{-8} μCi/ml)).

3. Solid Waste

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

TABLE H-1

ARGON-41 STACK RELEASES

FISCAL YEAR 2003

	Ar-41 Discharged (Curies)	Average Concentration(1) (μCi/ml)
July 2002	128.80	4.49 E-9
August	25.59	7.14 E-10
September	105.00	3.66 E-9
October	171.36	5.98 E-9
November	148.45	4.14 E-9
December	117.29	4.09 E-9
January 2003	253.26	8.83 E-9
February	188.63	6.58 E-9
March	74.67	2.08 E-9
April	112.69	3.93 E-9
May	124.41	3.47 E-9
June	88.23	3.08 E-9
Totals (12 Months)	1,538.38	4.00 E-9
EC (Table II, Column I)		1×10^{-8}
% EC		40.0%

(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 2003

Description	Shipment 1
Volume	1809 ft^3 (51.23 m^3)
Weight	90,031 lbs. (40,874 kg)
Activity(1)	2.65 Ci (9.80E4 MBq)
Date of shipment	6/23/03
Disposition to licensee for burial	Envirocare of Utah, Inc. Clive Disposal Site Interstate 80, Exit 49 Clive, VT 84029
Waste broker	N/A

One shipments of solid radioactive waste was made for Fiscal Year 2003.

Notes: (1) Radioactive waste includes dry active waste comprised of contaminated and/or irradiated items and dewatered resin. The principal radionuclides are activation and fission products such as ^{60}Co, ^{58}Co, ^{51}Cr, ^{65}Zn, ^{187}W, ^{125}Sb, ^{95}Zr, ^{95}Nb, ^{3}H, ^{46}Sc, ^{103}Ru, ^{137}Cs, ^{55}Fe, ^{63}Ni, ^{129}I, ^{99}Tc, ^{14}C, ^{110m}Ag, ^{54}Mn, ^{144}Ce and ^{141}Ce.

TABLE H-3

LIQUID EFFLUENT DISCHARGES
FISCAL YEAR 2003

	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 2002	0.13	3.82	161.8	2.36
Aug.	0.11	4.28	49.5	8.65
Sept.	NDA[2]	6.23	345.8	1.80
Oct.	0.115	19.5	430.4	4.53
Nov.	NDA	12.4	685.4	1.81
Dec.	NDA	6.43	452.6	1.42
Jan. 2003	NDA	4.25	122.3	3.48
Feb.	NDA	44.9	170.0	26.4
Mar.	NDA	1.56	14.7	10.6
Apr.	NDA	4.60	14.2	32.4
May	NDA	1.41	15.8	8.92
June	NDA	0.431	12.0	3.59
12 months	0.355	109.81	24,745,479	4.44

(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

During FY2003, the major BNCT effort was on the first Phase I/II trials for glioblastoma as well as melanoma using the new 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

During this reporting period, one subject was irradiated at a total skin dose of 2000 RBE-cGy:

Subject 2003-1 51 year old male, irradiation date 10/24/02.
Location of irradiation: right knee, right hip.

Subject irradiations are continuing under this Phase II protocol.

e) Phase I / Phase II Glioblastoma Study with BIDMC

During this reporting period, five subjects were irradiated: three at an average brain dose of 700 RBE-cGy each, and two at 770 RBE-cGy each. Summary of these irradiations is as follows:

Subject 2003-2 63 year old male, irradiation dates 11/04/02 and 11/05/02.
Location of irradiation: cranium.

Subject 2003-3 51 year old male, irradiation dates 03/20/03 and 03/21/03.
Location of irradiation: cranium.

Subject 2003-4 51 year old male, irradiation dates 05/08/03 and 05/09/03.
Location of irradiation: cranium.

Subject 2003-5 57 year old female, irradiation dates 05/15/03 and 05/16/03.
Location of irradiation: cranium.

Subject 2003-6 67 year old male, irradiation dates 06/17/03 and 06/18/03.
Location of irradiation: cranium.

Subject irradiations are continuing 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.