NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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U.S. Nuclear Regulatory Commission,
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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, 2000 to June 30, 2001, in compliance with paragraph 7.13.5 of the Technical Specifications for Facility Operating License R-37.

Sincerely,

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FRSSB/DRSS

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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, 2000 – June 30, 2001

by

REACTOR STAFF

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MIT RESEARCH REACTOR

ANNUAL REPORT TO

U. S. NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JULY 1, 2000 - JUNE 30, 2001

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, fully 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 was shut down 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-sixth annual report required by the Technical Specifications, and it covers the period July 1, 2000 through June 30, 2001. 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-fourth 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 bulk material irradiation damage studies, neutron activation analysis, student laboratory exercises, and student operator training. It also 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. It was then started up to full power and was maintained there for another four to five weeks. The period covered by this report is the twenty-fourth full year of normal operation for MITR-II.

The reactor averaged 140.1 hours per week at full power compared to 101.8 hours per week for the previous year and 110.4 hours per week two years ago. The higher number of average full power hours per week for FY2001 was because the scheduled reactor downtime of previous years for replacement of the reactor's cooling tower and installation of the Fission Converter Medical Facility was no longer required.

The reactor was operated throughout the year with 24 elements in the core. The remaining three positions were occupied by either solid aluminum dummies or an in-core experiment. During FY2001, compensation for reactivity lost due to burnup was provided by six 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. Twelve new elements were introduced into the reactor core during FY2001. One of the six refuelings involved only flipping and rotation of partially spent elements.

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 twenty-eight of the newer, higher loaded elements (506 grams U-235) have been introduced to the core. Of these, sixty-three 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-six 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 FY2001, eight spent elements were returned to an off-site DOE facility. Details regarding shipment of spent fuel are discussed in section A.7 of this report.

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 and training programs at MIT and elsewhere.

Experiments and irradiations of the following types were conducted:

a) Prompt gamma activation analysis for the determination of boron-10 concentration in blood and tissue. This is being performed the reactor's 4DH1 and 4DH3 beam tubes. These analyses support neutron capture therapy and studies of radiation synovectomy for treatment of arthritis.

b) Gallium nitride semiconductor wafers were irradiated to study transmutation doping characteristics.

c) Neutron activation of scintillator detection medium in support of national projects on neutrino measurements.

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

e) Irradiation of archaeological, environmental, engineering materials, biological, geological, oceanographic, and medical specimens for neutron activation analysis purposes.

f) Production of copper-64, iodine-125, and gold-198 for medical research, diagnostic, and therapeutic purposes.

g) Use of neutron activation analysis to identify plutonium in bone from populations in the former Soviet Union. This also includes irradiation of tissue specimens on particle track detectors for plutonium radiobiology. These experiments are part of a major bio-toxicity study by the University of Utah.

h) Use of the facility for reactor operator and nuclear engineering training.

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

j) Use of trace analysis techniques to identify and monitor sources of acid deposition (acid rain).

k) Operation of an in-core loop to evaluate the behavior of candidate ceramics for use as fuel cladding material.

l) Measurements of the energy spectrum of leakage neutrons using a mechanical chopper in a radial beam port (4DH1). Measurements of the neutron wavelength by Bragg reflection then permits demonstration of the DeBroglie relationship for physics courses at MIT and other universities.

m) Gamma irradiation of seeds and vegetation for demonstration of radiation effects for high school science project students.

n) Use of beam tubes and the medical beams for testing and calibration of prototype neutron detectors and for characterization of beam spectra.

o) Neutron activation analysis to determine iron oxide contamination in aluminum specimens.

p) Use of neutron activation analysis to determine the pattern of mercury oxide deposition in fluorescent light tubes.

q) Irradiation of cultured cells carrying a boron-containing drug (BPA) for micro-dosimetry studies.

r) Gamma irradiation of PLGA-coated alumina fibers for medical research and applications.

s) Neutron activation of uranium samples for detector calibration at the Los Alamos National Laboratories, New Mexico.

t) Neutron activation of germanium semiconductor wafers for calibration experiments at Lawrence Berkeley National Laboratory. This is part of an international effort to detect different kinds of solar neutrinos.

u) Gamma irradiation of resins for stability analysis.

v) Gamma irradiation of regional wood specimens for hardening studies.

w) Experimental studies of the role of metallic and organo-metallic groups in the properties of polymers.

x) Use of neutron activation analysis to determine the concentrations of heavy metals in sludge from sewage treatment plants.

Dose reduction studies for the light water reactor industry began use of the reactor on a regular basis in 1989. (Planning and out-of-core evaluations had been in progress for several years.) These studies entail installing loops in the reactor core to investigate the chemistry of corrosion and the transport of radioactive crud. Loops that replicate both pressurized and boiling water reactors have been 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. The first of these experiments was successfully completed in June 1999. Another in-core experiment using the IASCC thimble was conducted throughout September and October 2000, irradiating and investigating behavior of new materials for cladding of power reactor fuel.

A major research project that is now making and will continue to make extensive use of the reactor for medical applications is a program called the Fission Converter Project which entailed building a new facility for the treatment of glioblastoma (brain cancer) and melanoma (skin cancer) using neutron capture therapy. This is a collaborative effort with the Beth Israel-Deaconess Medical Center which is affiliated with the Harvard Medical School. Throughout the period of FY2001, there was a major effort for final installation of all components of the Fission Converter Facility.

Modification began on the existing medical facility at the reactor basement to create a thermal beam for the Boron-Neutron-Capture Therapy (BNCT) project, primarily for non-clinical research. 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., New Haven, Connecticut) to a nominal 34 and 510 grams respectively (made originally by the Atomics International Division of Rockwell International, Canoga Park, California). With the exception of seven elements (one Gulf, six AI) that were found to be outgassing excessively, performance 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, forty of which have been 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. Additional elements are now being fabricated by Babcock & Wilcox, Naval Nuclear Fuel Division, Lynchburg, Virginia. Eighty-eight of these have been received at MIT, fifty-five of which remain in use. One has been removed because of suspected excess outgassing and thirty-two 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. <u>Changes in Performance Characteristics</u>

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. <u>Changes in Operating Procedures</u>

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 3.7.1, "Weekly Security Checklist," was updated for use with current equipment, structures, and MIT Police information. (SR#-0-00-8, SR#-0-01-4)

b) AOP 5.7.15, "IASCC Irradiation Facility," was update for use with the Ceramic Fiber-wrapped Composite Clad (CFCC) experimental loop, which functions within the design envelope of the Irradiation-Assisted Stress Corrosion Cracking (IASCC) experiment. The changes primarily reflect the CFCC's lower operating pressure. (SR#-0-00-11)

c) PM 3.7.2, "Daily Security Checklist," was updated to specify more explicitly its time of use and circumstance of locking the parking lot. A step was added to verify proper location of the back airlock handle, and the former drafting room was renamed to its room number. (SR#-0-00-12)

d) "Airlock Bypass Instructions" were established detailing the method for mechanically bypassing each containment building airlock when it is necessary to have both doors of the airlock open at the same time. (SR#-0-00-13)

e) "CFCC Removal Procedure" was established for transfer of the CFCC in-core loop components to the reactor floor hot cell or to the spent fuel storage pool. (SR#-0-00-14)

f) PM 3.15.1, PM 3.15.3, PM 6.1.5.1, PM 6.1.5.2, and PM 6.1.5.3, "Fission Converter Procedures" were created or updated for the purpose of verifying proper shutdown sequence, setpoint settings, and calibrations of the fission converter in accordance with Technical Specification 6.6.3. (SR#-0-01-1)

g) PM 6.3.6, "Trouble Radiation Monitors Alarms and Interlock," was updated to reflect current system equipment, including the new effluent monitors and new flow switches for the water monitors. (SR#-0-01-3)

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 FY2001, one shipment was completed. At present, additional shipments would be needed in order to reduce the inventory of spent fuel at MIT to zero. The U.S. Department of Energy is currently allowing some shipments to proceed, and has indicated that additional shipments will be possible in calendar year 2001.

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 FY2001) (normally at 4.9 MW)	365.3	363.4	357.3	364.9	1450.9
b) MITR-II (MIT FY1976-2000)					19,890.4
c) MITR-I (MIT FY1959-1974)					10,435.2
d) Cumulative, MITR-I & MITR-II					31,776.5
2. MITR-II Operation (hours): (MIT FY2001)					
a) At Power (>0.5-MW) for Research	1833.1	1819.9	1779.7	1870.3	7303.0
b) Low Power (<0.5-MW) for Training(1) and Test	37.4	14.2	13.5	67.3	132.4
c) Total Critical	1870.5	1834.1	1793.2	1937.6	7435.4

(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 19 inadvertent scrams and 33 unscheduled power reductions.

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 "reduction" or "shutdown" refers to an unscheduled power reduction to low power or 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 power reductions.

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)	Period channel level offscale trip as result of Channel #2 failure.	1
b)	High level Channel #3 trip as result of operator error.	2
c)	High level Channel #3 trip as result of electronic noise caused by new safety system installation in progress.	4
d)	High level Channel #4 trip as result of overly conservative setpoint.	3
e)	Minor scram activated as result of operator error while changing recorder chart.	1
	Subtotal	11
2.	Process System Scrams	
a)	High temperature primary trip as result of inadequate cooling tower fan speed setting.	1
b)	High temperature primary trip due to MTS-1A spiking.	1
c)	Fission converter trip as result of experimenter error while testing.	4
	Subtotal	6

3. Unscheduled Shutdowns

a)	Shutdown due to loss of offsite electricity.	6
b)	Shutdown due to drops of shim blades (#2, 5, & 6).	5
c)	Shutdown due to ventilation failure.	2
d)	NTD Silicon machine malfunctions.	2
	Subtotal	15
	Total	32

4. Experience during recent years has been as follows:

Fiscal Year	Scrams
1996	18
1997	8
1998	5
1999	11
2000	18
2001	17

D. MAJOR MAINTENANCE

Major maintenance projects performed during FY2001 are described in this Section. Much maintenance was performed to continue the safe, reliable and efficient operation of the MIT Research Reactor, and to complete installation of control instrumentation and utilities for the Fission Converter Facility on site.

The repair and maintenance of machinery and computer control and monitoring software and hardware for neutron transmutation doping of silicon (NTD Si) also required much continued support. This machinery, installed in two of the reactor throughports, 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 is used constantly during all the operating cycles in the fiscal year.

Major maintenance items performed in FY2001 were as follows:

(1) Radiation shielding at the top of the fission converter tank and around its major piping was reinforced with additional Pb and Ricorad material, and all gaps were closed with airtight sealant to reduce argon-41 buildup inside the reactor containment building.

(2) Installation of the fission converter medical room shield door and its control system were completed.

(3) Warning lights and additional signs were established within the reactor containment to warn of operation of the fission converter. These were conducted in compliance with recommendations from the MIT Reactor Safeguards Committee.

(4) A total of 1.25" thickness of lead was installed on top of a supported, eight-foot section of primary piping where it enters the equipment room from the pipe tunnel area. This reduced the nitrogen-16 gamma radiation inside the fission converter medical room by better than a factor of two.

(5) All asbestos-containing floor tiles on the reactor floor and reactor basement, except for the control room, were removed, and new tiles were installed.

(6) All conduit and wire and the controller box for the containment building intrusion alarm system were replaced.

(7) The reactor floor sink was dismantled. An upgraded version and new plumbing were re-established at a different location on the reactor floor.

(8) The Hot Shop hood was decontaminated and refurbished. Its ventilation filters and lighting were replaced. This was needed in order to accommodate increased radioactive sample handling.

(9) The reactor containment building Cathodic Protection System and its instrumentation were completely replaced. All electrodes were replaced with a new type, and there are additional electrodes installed at new locations.

(10) Lead paint removal was finally completed at the northwest face of the reactor containment building after a storage shed at that location was dismantled. New paint was applied at that area.

(11) The airtight seal for Hot Cell #2 was replaced in its entirety. The Hot Cell was decontaminated and its internal lighting was improved. A remote fire alarm test pushbutton was also installed for the Hot Cell to facilitate testing of its fire warning system.

(12) Twelve new shim blades were fabricated. They are made of 1.29% boron-10 impregnated stainless steel. Their support guide rods and offset plates were also fabricated. Six of the new set will be used in next year's replacement of all existing shim blades. The other six will be used as spares.

(13) Ten new shim blade magnets were fabricated according to a new specification. Choice of coil and construction materials were revised and improved for reduction of corrosion and for better electromagnetic performance.

(14) The secondary water monitor flow switches and plumbing were completely replaced.

(15) The main airlock outer door gasket was replaced. The airlock was then leak-tested according to established procedures.

(16) The main airlock inner door mechanical system was rebuilt.

(17) The control room intake ventilation air blower was replaced. This blower supplies fresh air to the control room from the main intake ventilation duct at the reactor floor, and maintains a positive air pressure differential in the control room relative to the rest of the containment building.

(18) All protective covers on the reactor's emergency batteries in the Utility Room were replaced with new ones.

(19) All original and unused ventilation and piping systems for the reactor basement medical room were completely removed.

(20) The weekend auto-caller system for paging on-call licensed personnel was completely replaced with updated equipment and software. Its associated signal cables were also replaced.

(21) Much of the interior of the reactor building and the interior of the attached office building were cleaned and repainted with new colors. This was to improve the working environment and facility appearance, as demand for use, teaching, and tours increased.

(22) The Core Purge blower and the D_2O helium recombiner blower fan belts were replaced. The fan belt for the primary chemistry room hood blower was also replaced.

(23) The neutron chopper motor for the student spectrometer facility, its helium-3 detection system, and its data acquisition system, software, and computer were replaced.

(24) The primary coolant cleanup system ion column and filters were replaced. The Core Purge system filter was replaced. Primary and D_2O storage tank blow-out patches were replaced.

Many other routine maintenance and preventive maintenance items were performed 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."

<u>Experiments Related to Neutron Capture Therapy</u>

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 (Pending)

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 beam are now anticipated to start in early 2002 under the auspices of the National Institutes of Health.

Ceramic Fiber Composite Clad Loop
SR#0-00-10 (09/07/00), #0-00-11 (09/07/00), #0-00-14 (10/26/00)

A Ceramic Fiber Composite Clad (CFCC) loop was successfully installed in October 2000. This loop's design was within the envelope of the previously approved Irradiation Assisted Stress Corrosion Cracking Loop (IASCC). The purpose of the CFCC Loop was to investigate the performance of ceramic materials that are candidates for use as clads for fuel elements in power-production reactors. Ceramic clads offer improved safety through the avoidance of a steam-zirconium reaction that can lead to hydrogen production. Several other in-core loops are now in the planning stage. Safety reviews will be prepared for each.

Shim Blade #1 and #6 Drive Controls
SR#0-01-2 (01/22/01)

An error was identified in the wiring diagram for the shim blade #1 and #6 control circuits. It would allow the outward motion relays of shim blade motors #1 and #6 to energize if a scram occurred while simultaneously shimming outward on any drive. The error in wiring at the corresponding utility shelf locations was corrected, and a comprehensive test procedure was performed to verify satisfactory function of the circuits.

Period Channel Level Offscale Circuit
SR#E-01-1 (05/03/01)

Damage from a short circuit disabled portions of the integrated circuit modules for the Channel 1 level offscale trip signals. No replacement modules were available. The trip outputs were rewired to operate using spare contacts on the undamaged portions of the modules in concert with new external relays. The new circuitry produces no interactions with other parts of the safety system.

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 (Pending)

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. Accordingly, the fission converter design is not discussed as part of this report.

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 (07/01/00 – 06/30/01)
North	0.46 mrem
East	0.25 mrem
South	0.75 mrem
West	0.37 mrem
Green (east)	0.13 mrem

Fiscal Year Averages

2001	0.4 mrem
2000	0.2 mrem
1999	0.2 mrem
1998	0.4 mrem
1997	0.2 mrem
1996	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, 2000 - June 30, 2001

Whole Body Exposure Range (rems)	Number of Personnel
No measurable	81
Measurable – < 0.1	52
0.1 – 0.25	22
0.25 – 0.5	7
0.5 – 0.75	3
0.75 – 1.00	1
1.00 – 1.25	2

Total Person Rem = 11.66 Total Number of Personnel = 168

From July 1, 2000 through June 30, 2001, 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 21,479,955 liters discharged during FY2001 from the cooling towers. (Other large quantities of non-radioactive waste water are discharged to the sanitary sewer system by other parts of MIT, but no credit for such dilution is taken because the volume is not routinely measured.)

Total activity less tritium in the liquid effluents (cooling tower blowdown, waste storage tank discharges, and engineering lab sink discharges) amounted to 3.73 E-5 Ci for FY2001. The total tritium was 1.23 E-1 Ci. The total effluent water volume was 21,526,095 liters, giving an average tritium concentration of 5.71 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 2171.68 Ci of Ar-41 was released at an average concentration of 5.78 E-9 μCi/ml. This represents 57.8% 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 2001

	Ar-41 Discharged (Curies)	Average Concentration[1] (μCi/ml)
July 2000	135.30	4.66 E-9
August	130.55	3.60 E-9
September	100.75	3.47 E-9
October	140.87	4.86 E-9
November	238.30	6.57 E-9
December	198.99	6.86 E-9
January 2001	213.97	7.38 E-9
February	132.81	4.58 E-9
March	165.40	4.56 E-9
April	292.96	1.01 E-8
May	256.81	7.08 E-9
June	164.97	5.69 E-9
Totals (12 Months)	2,171.68	5.78 E-9
EC (Table II, Column I)		1×10^{-8}
% EC		57.8%

(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 2001

Description	Shipment 1
Volume	0 ft^3
Weight	0 lbs. (0 kg)
Activity(1)	0 Ci (0 MBq)
Date of shipment	N/A
Disposition to licensee for burial	N/A
Waste broker	N/A

No shipments of solid radioactive waste were made for Fiscal Year 2001.

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 2001

	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 2000	12.6	10.8	181.1	5.96
Aug.	2.28	5.09	201.6	2.52
Sept.	NDA	9.62	355.4	2.71
Oct.	NDA	2.94	197.3	1.49
Nov.	12.0	8.71	205.3	4.24
Dec.	NDA	0.355	126.3	.281
Jan. 2001	NDA	1.71	95.4	1.79
Feb.	1.62	1.86	57.3	3.25
Mar.	NDA	.411	206.5	.199
Apr.	NDA	7.65	260.6	2.94
May	2.16	3.81	213.4	1.79
June	6.71	70.3	52.2	1.35
12 months	37.37	123.26	2,152.40	5.73

(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.

(3) Figure reflects absence of diluent because of cooling tower shutdown.

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 FY2001, the major BNCT effort was on the continuation of Phase I trials for glioblastoma as well as final completion and pre-operational tests of the Fission Converter Facility for future clinical trials. 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 performed. Each is summarized in the following.

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 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. During this reporting period, no subjects were irradiated.

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 and new Phase I / Phase II trials (melanoma and glioblastoma) are now being planned for use with that beam.