MIT RESEARCH REACTOR

ANNUAL REPORT

TO

UNITED STATES NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JULY 1, 1986 - JUNE 30, 1987

BY

REACTOR STAFF

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Introduction

This report has been prepared by the staff of the Massachusetts Institute of Technology Research Reactor for submission to the Administrator of Region 1, 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 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 undermoderated 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 14th, 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.

This is the twelfth annual report required by the Technical Specifications, and it covers the period July 1, 1986 through June 30, 1987. 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 tenth 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 the requirements of reactor users.

A summary of operating experience and other activities and related statistical data are provided in the following Sections A-H of this report.

A. SUMMARY OF OPERATING EXPERIENCE

1. General

During the period covered by this report (July 1, 1986 - June 30, 1987), the MIT Research Reactor, MITR-II, was operated on a routine, five days per week schedule, normally at a nominal 5MW. It was the tenth full year of normal operation for MITR-II.

The reactor averaged 80.1 hours per week at full power compared to 75.4 hours per week for the previous year and 86.3 hours per week two years ago. The reactor is normally at power 90-100 hours/week, but holidays, major maintenance, long experiment changes, waste shipping, etc., reduce the average. During the past year it was reduced more than usual as the result of two week-long shutdowns for major maintenance activities (described later), one of them occurring at New Year's and one later in April. The reactor routinely operates from late Monday afternoon until late Friday afternoon, with maintenance scheduled for Mondays and, as necessary, for Saturdays.

The reactor was operated throughout the year with 25 elements in the core. The remaining positions were occupied by irradiation facilities used for materials testing and the production of medical isotopes and/or by a solid aluminum dummy. Compensation for reactivity lost due to burnup was achieved through seven refuelings of several elements each. The first of these entailed the introduction of three low burnup elements to the core's intermediate fuel ring (the B-ring). The others involved a continuation of the practice begun in previous years in which partially spent elements that had been originally removed from the B-ring were gradually introduced to the C-ring to replace fully spent elements. These procedures were combined with many element rotations/inversions, the objective of which was to minimize the effects of radial/axial flux gradients and thus achieve higher average burnups. An additional refueling was performed for removal of the one inch in-core facility so as to facilitate the design and installation of a new loop research project.

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 average overall burnup for the discharged elements was 42%. The maximum overall burnup achieved was 48%. Thirty-six of the newer, higher loaded elements (506 grams U-235) have been introduced to the core. Of them, three have attained the maximum allowed fission density. However, these may be reused if that limit is increased as would seem warranted based on metallurgical studies by DOE. As for the other thirty-three new elements, they are either currently in the reactor core or have been partially depleted and are awaiting reuse in the C-ring.

The availability of a licensed spent fuel shipping cask from DOE is again delayed this year. Although the cask is expected to be licensed later on this year, the delay has thus far caused our total fuel inventory to approach the authorized possession limit and continues to force us to deviate from our normal fuel management practice in that:

(1) The inventory of partially spent elements is now substantially below normal. This is making it difficult to convert from one core configuration to another.

(2) Inability to bring in fresh fuel and to place it in the A and B-Rings of the core may necessitate premature C-Ring refuelings in order to obtain sufficient reactivity for continued operation. This will result in lower overall burnups and ultimately increase our need for additional fuel.

Finally, it should be recognized that if casks continue to be unavailable, we will have to request a reinstatement of part or all of our previous license limit for possession of U-235 in order to continue operation.

Protective system surveillance tests are conducted on Friday evenings after shutdown (about 1800), on Mondays, and on Saturdays as necessary.

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 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) Neutron diffraction spectrometer alignment and studies (3 ports). In particular, the study of the use of pendellösung oscillations in the scattering of neutrons inside perfect crystals to greatly enhance the effect of spin-orbit contribution to high-energy neutron-nuclear scattering is being carried out by the neutron diffraction group.

b) The production of Mössbauer sources by the irradiation of Gd-160 and Pt-196 for studies of nuclear relaxation of Dy-161 in Gd and for the investigation of the chemistry and structure of gold compounds.

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

d) Production of gold-198, dysprosium-165, and holmium-166 for medical research, diagnostic and therapeutic purposes.

e) Irradiation of tissue specimens on particle track detectors for plutonium radiobiology.

f) Irradiation of semi-conductors to determine resistance to high doses of fast neutrons.

g) Use of the facility for reactor operator training.

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

i) Fault detection analysis of the output of control and process channels from the MIT Reactor as part of a study leading to control of reactors by use of fault-tolerant, digital computers. This effort recently resulted in the demonstration of techniques for reconfigurable control.

j) Closed-loop direct digital control of reactor power using a shim blade as well as the regulating rod during some steady-state and transient conditions. A new relation, the alternate dynamic period equation, was developed and used as the basis of a reactor controller.

k) Experimental studies of various closed-loop control techniques including rule-based control and the use of reactivity constraints.

l) Development and experimental evaluation of several new techniques for the measurement of reactivity.

m) 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.

o) Detection of trace quantities of fissile nuclides in geological material using a delayed neutron detector.

Two research projects that will make major use of the reactor in the next and subsequent years have been funded and are in various stages of design and development. They did not actually make use of the reactor during the year, although reactor support services, e.g., electrical power supply, were augmented in preparation for installation of experiments on the reactor in the coming year. The first project is a dose reduction study for the light water reactor industry which will involve the installation of pressurized loops in the reactor core to investigate the chemistry of corrosion and the transport of radioactive crud with systems that simulate PWR's and BWR's. The second project is an extension of previous research to develop the boron neutron capture method of therapy for brain cancer (glioblastoma). This is a collaborative effort with the Tufts University New England Medical Center.

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 by the Atomics International Division of Rockwell International, Canoga Park, California). With the exception of five elements 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, and 50-20/86-2.) 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 41 of the more highly loaded elements in 1982, 36 of which have been used to some degree. Three with about 37% burnup were in operation in the core starting in January 1980 and were discharged in 1985, since they had attained the burnup limit. Additional elements are now being fabricated by Babcock & Wilcox, Navy Nuclear Fuel Division, Lynchburg, Virginia. Three of these have been received at MIT and are scheduled for use early in the coming year.

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.

5. Changes in Operating Procedures Related to Safety

There were no amendments to the Facility Operating License during the last year.

Quality Assurance Program Approval for Radioactive Material Packages No. 164, Rev. 1, was renewed on June 20, 1986 (Rev. 3). This Approval is required for the shipment of (1) Type B quantities of radioactive material and (2) fissile material above exempt quantities. In order to renew the Approval, it was necessary to update SAR Chapter 11, "Quality Assurance Program", which supports Approval No. 164. The changes to Chapter 11 were minor and were described in last year's Annual Report. Chapter 11, as revised, was submitted to USNRC on April 7, 1987 as Safety Analysis Report Revision No. 33 for the purpose of updating that document.

With respect to operating procedures subject only to MITR internal review and approval, a summary of those related to safety is given below:

a) Evacuation maps for the reactor office building (NW12) were updated and improved to include clearer and more direct evacuation paths as well as a description of the sound of evacuation signals. (SR #0-85-24)

b) In an effort to improve scheduling and bookkeeping of routine preventive maintenance, a set of thirteen checklists were established to cover the routine maintenance performed year round. The weekly checklist covers items that need to be checked frequently and the twelve monthly checklists cover items that need to be serviced at a longer but regular interval (SR #0-86-10)

c) Procedure 4.4.5.1, "Instructions for Use of Utility Room Emergency Gauges", was revised to change the valve designation prefix from XTV to XV. This was done to simplify the valve numbers as well as matching those on the valve tags. (SR #0-86-12)

d) Procedures 4.4.4.3, "Reactor Fire", 5.7.8, "Smoke Detector System", and 6.6.2.2, "Self-Contained Breathing Devices", were revised to reflect recent changes to OSHA requirements. OSHA regulations (CPL2-2.20A) prohibit the use of the ten minute sling self-contained breathing devices for entry to a building. Accordingly, the storage location of the MITR's self-contained breathing devices were changed so that the thirty minute units are outside the reactor containment for reentry purposes and the ten minute units are kept in the containment for use in exiting. (SR #0-86-14)

e) A new combustible gas meter was purchased to replace an old unit which was used for detection of hydrogren buildup in both the medical water shutter system and the air space on top of the core tank under the lid (core purge), and deuterium buildup in the heavy water reflector system in the event of isolation in any of these systems. Procedures 6.5.20.1, "Calibration of Combustible Gas Meter", and 6.5.20.2, "Combustible Gas Meter Use", were modified to incorporate changes pertinent to the use of this new meter. Calibration and conversion charts were included in the procedures to preclude any ambiguity on interpretation of the meter readings. (SR #0-86-15)

f) The administrative procedures, Chapter 1 of the Procedure Manual, were revised to update the lists of names and committee memberships. This does not involve any change to the procedures. (SR #0-87-1)

g) Procedure 6.3.4, "Fan Interlocks and Alarms", was revised to include separate steps for opening the auxiliary dampers and stack base damper, and for starting the auxiliary fans and pneumatic blower. This change refined the existing procedure by making explicit several steps that had previously been implicitly assumed by the original procedure. (SR #0-87-2)

h) Procedures 3.1.1.1, "Full Power Startup Checklist - Mechanical", 3.1.1.2, "Full Power Startup Checklist - Instrumentation", 3.1.1.3, "Full Power Startup Checklist - Cooling Tower Operation", 3.2.1, "Shutdown from Operation at Power", 3.5, "Surveillance Check for Continuous Operation", were updated to incorporate changes to various systems. Mode of operation is changed from using all three heat-exchangers simultaneously to using two at a time. Provisions are incorporated to alternate the two on-line heat exchangers so as to preclude fouling resulting from stagnation of water. This new mode of operation provides better flow characteristics and standby assurance of a heat exchanger. (SR #0-87-3)

i) Procedures 1.16.2, "MITR Operations Qualification Program for Senior Operators/Shift Supervisors", and 1.16.3, "MITR Operations Qualification Program for Operators", were updated to reflect format changes of the page layout and correction of typographical errors. There were no changes to the procedure. (SR #0-87-4)

j) The graphite stringers in the graphite region of the reactor have been in use since startup of the original reactor, MITR-I. As a means of inspecting the conditions of the graphite reflector region and the outside surface of the reflector tank, three procedures were developed. The first procedure 7.6.1, "Special Procedure for Graphite Region Inspection", outlines the steps necessary for removal of a vertical irradiation facility (3GV2) in the graphite region, insertion of a periscope for visual inspection, acquisition of graphite specimens from the high flux region, acquisition of helium samples from the graphite region, and finally reassembly of the irradiation facility. The second procedure 7.6.2, "Measurement of Wigner Stored Energy in Graphite", outlines the steps necessary for determination of the Wigner stored energy, if any, in the specimens taken from the graphite reflector. The third procedure, 7.6.3, "Graphite Combustion Test", outlines a procedure for conducting combustion tests on samples of irradiated and unirradiated graphite. Precautionary information was incorporated whenever appropriate throughout these procedures. (SR # 0-87-5 and 0-87-6)

k) Procedures 3.2.4, "Response to Weekend Alarms", 3.7.1, "Weekly Security Checklist", 3.7.2, "Daily Security Checklist", were revised to reflect the installation of a remote surveillance system for the control room and remote indication panel for alarms and radiation levels. The daily and weekly security checklists were updated to implement new procedure to control access to the parking lot after normal business hours. (SR #0-87-7)

l) Procedures 5.6.1, "High Radiation Set-Up Area Vault", 5.6.4, "Trouble NW12 Gamma Monitor", were updated to reflect the location change of the reactor fuel vault which is no longer the small vault in the set-up area in NW12. (SR #0-87-8)

m) Nine sets of boron stainless steel control blades were procured in FY 1987. As part of the quality assurance program requirements, neutron transmission tests were necessary for final verification of the materials used for fabrication. Procedure 7.6.4, "Shim Blade Neutron Transmission Tests", was established for this purpose. This procedure represents a consolidation of all previously used procedures as documented by individual memos to the appropriate Q/A files. (SR #0-87-9)

n) The "Waste Storage Tank Dump Procedure", procedure 3.6, was revised (1) to add a step to require verification of the operability of the sewer monitor prior to use, (2) to add RRPO form 2005 which shows the details of the effluent calculation. This form had been in use since July 1985 and is incorporated here as part of the procedure. (SR #0-87-10)

o) Procedures 6.5.9.1, "Area Monitor Calibration Procedure", and 6.5.9.3, "Calibration Procedure for Fuel Vault Monitor", were revised to reflect the following changes: (1) the log N-16 monitor is no longer in use (because of the existence of the linear N-16 monitor which provides the same functions) and thus deleted from the procedure, (2) the new auxiliary core purge monitor has been installed and is added to the procedure, (3) the distances at which the calibration measurements are taken were changed to give better results. (SR #0-87-12)

p) The equipment room sump tank was replaced by a stainless unit. An "Equipment Room Sump Tank" procedure was established to outline the necessary steps in removing the old unit and installing and plumbing in the new one. (SR #M-86-1)

q) The checklist used for procedure 6.1.2.1, "Building Pressure Test", was revised to reflect the fact that the leak on the outer door of the truck lock had been repaired, and that both doors should be tested independently. (QA #0-87-1)

r) Miscellaneous minor changes to operating procedures and to equipment were approved and implemented throughout the year.

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. Twenty-seven 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 Specifications, and the results of tests and inspections were satisfactory throughout the year for Facility Operating License No. R-37.

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 FY87) (normally at 4.9 MW)	190.1	185.9	203.4	182.6	762.0
b) MITR-II (MIT FY76-86)					8,430.8
c) MITR-I (MIT FY59-74)					10,435.2
d) Cumulative, MITR-I & MITR-II					19,628.0
2. Hours of MITR-II Operation (MIT FY87)					
a) At Power (>0.5 MW) for research	1,097.7	1,000.5	1,087.7	977.0	4,162.9
b) Low Power (<0.5 MW) for training[1] and test	56.9	30.4	19.8	30.9	138.0
c) Total critical	1,154.6	1,030.9	1,107.5	1,007.9	4,300.9

[1] Note: 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. SHUTDOWN AND SCRAMS

During the period of this report there were 10 inadvertent scrams and 11 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 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.

I. Nuclear Safety System Scrams

		Total
a)	Channel 3 noise resulting from technician failure to adequately secure chassis in rack	1
b)	Channel 3 due to faulty coaxial connector	1
c)	Channel 3 noise due to cold solder joint	1
d)	Low voltage on detector power supply due to failure of the A.C. constant voltage power supply	1
	Subtotal	4

II. Process System Scrams

a)	Primary pump circuit breaker opened on thermal overload due to a defective heater	2
b)	High temperature reactor outlet scram due to operator inadvertently slamming closed the door of temperature indicator	1
c)	High temperature reactor outlet scram due to technician investigating sticky recorder	1
d)	Low flow secondary coolant due to operator tripping pump by mistake	1
e)	Simultaneous deflation of both gaskets on main personnel lock due to trainee error	1
	Subtotal	6

III. Unscheduled Shutdowns or Power Reductions

a) Shutdowns due to Electric Company power loss — 5

b) Operator shut reactor down due to:

i)	High plenum particulate activity resulting from trainee failure to secure core purge filter housing adequately	1
ii)	Low oil pressure in exhaust damper due to hydraulic pump failure	1
iii)	Oil leak in intake damper	1
iv)	Winds greater than 60 mph	1

c) Operator lowered power to investigate:

i)	Low pressure in the helium supply at an irradiation thimble	1
ii)	Tripping of a cooling tower fan due to vibration switch	1

Subtotal 11

Total 21

Experience during recent years has been as follows for scrams and unscheduled shutdowns:

Fiscal Year	Number
83	25
84	19
85	10
86	27
87	21

D. MAJOR MAINTENANCE

Major maintenance projects during FY87, including the effect, if any, on safe operation of the reactor are described in this section.

Many major maintenance items were performed in FY87 in anticipation of supporting the necessary requirements of the upcoming dose reduction project for light water reactors. In order to support the projected electrical loads for the loop experiments, a new three phase electrical penetration through the containment shell was installed and leak tested. Appropriately sized electrical cables were installed to bring the power from the penetration to the motor control center in the equipment room where the main switch gear is located. Additional cables were brought from this location to the reactor top where the instrumentation for the experiment is located. This new three phase system with a neutral ground is designed to operate at 480 V with a peak current of 400 A.

In addition to enhancing the high voltage electrical service capability, heat removal capability was also increased by installation of a new heat exchanger for experimental coolant. This heat exchanger is capable of rejecting 50 kW of heat at 120°F. This heat exchanger is located in the equipment room together with the other processing components. Piping was installed from the heat exchanger to the reactor floor where the out-of-pile experimental coolant tank will be located.

In FY87, nine sets of control blade absorbers and six electromagnets were fabricated in our own machine shop. These included the armature assembly and the pieces to form the connecting rod. All the installed control blade absorbers(6), magnets(6), and the regulating rod absorber(1) were replaced with new ones. The control rod drive mechanisms(7) were rebuilt and replaced. New calibration curves were generated with the standard calibration procedures. The old set of absorbers was in service since 1981 and had accumulated over 100,000 MWH of exposure.

The graphite region was last inspected during the modification in 1974 and 1975. A procedure and tools were developed to inspect the conditions of the graphite stringers in the graphite reflector. Access was gained by the removal of a graphite vertical facility (3GV2). A periscope was inserted into the graphite region and inspected both the graphite stringers in the vicinity and the surface of the reflector tank. Graphite samples were taken and tests were performed to determine their stored Wigner energy and combustibility. The results showed no signs of any stored energy in the graphite nor any ability to support combustion, even at temperatures in excess of 1200°C. The physical appearance of the graphite stringers was the same as when installed. A film presumably oxides, however, was found on the reflector tank. A subsequent visual inspection is scheduled to be performed early in the coming year.

The equipment room sump tank and pumps were replaced because of excessive corrosion accumulated over the years. The new sump tank was made of stainless steel so as to inhibit oxidation of the tank. The two old submersible pumps were replaced by a self-priming gear pump which has more than the combined capacity of the two submersible pumps.

The leak on the truck lock outer door was found and repaired. It passed the annual containment pressure test with adequate margin. An old PCB transformer, which developed a very small leak, was removed and disposed of in accordance with the environmental safety requirements. The transformer had been used for operating the helium refrigeration plant for the cryogenic system. This experiment has not been active for many years and will be dismantled; therefore the transformer need not be replaced.

Two new electrodes for cathodic protection of the steel containment shell were installed to increase protection coverage near the truck lock and cooling tower area where the secondary pipes are located. These two additional electrodes replenish the decrease of electrical potential in the soil due to deterioration of the older units. The condensers in the air conditioning units for the containment building were completely flushed and cleaned. Good size leaks in the cooling coils in the intake plenum were found and repaired. This restored the capacities of these two units.

The leak checking on one of the main heat exchangers, HE-1A, is still in progress. Various methods of locating leaks in the approximately 1000 tubes have been tried. The helium leak detection method was found to be the most sensitive and is being used. One of the cooling tower booster pumps developed a leak on the shaft seal which was subsequently replaced.

To provide improved surveillance of reactor status prior to entry under emergency conditions, a TV camera system complete with pan and tilt capabilities was installed in the control room for remote monitoring the reactor instrumentation. The TV monitor and the movement controls for the camera are located in the operation office. A remote zoom lens allows reading of almost all indications in the control room from the operations office. An annunciator alarm on the alarm panel in the control room is actuated whenever the remote viewing system is turned on.

Facility security has been enhanced by the installation of additional closed circuit surveillance equipment.

Many other routine maintenance and preventive maintenance jobs were performed throughout the 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 will be forwarded to the Director, Standardization and Non-Power Reactor Project Directorate, Office of Nuclear Reactor Regulation, 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".

In recent annual reports, the only facility changes and experiments carried out under Section 50.59 were in connection with the digital closed-loop computer control project. No change made in FY87 in connection with this experiment involves an unreviewed safety question. The current status of this computer control project and the tests performed during the reporting period are as follows:

Digital Computer Control of Reactors Under Steady-State and Transient Conditions

SR#-M-81-3 (11/17/81), M-81-4 (12/10/81), E-82-2 (01/08/82), E-82-3 (02/24/82), E-82-4 (03/03/82), E-82-5 (04/14/82), E-82-6 (07/13/82), 0-83-5 (02/03/83), E-83-1 (02/08/83), 0-83-12 (04/23/83), 0-83-20 (07/20/83), 0-84-11 (06/25/84), 0-84-12 (07/12/84), 0-84-16 (12/6/84), 0-84-21 (11/1/84), 0-85-11 (5/9/85), 0-85-13 (6/28/85), 0-85-16 (7/12/85), 0-85-20 (8/16/85), 0-85-25 (12/1/85), 0-85-26 12/1/85), 0-86-11 (10/17/86), 0-86-13 (11/28/86).

The project involving computer analysis, signal validation of data from reactor instruments, and closed-loop control of the MIT Reactor by digital computer was continued. A non-linear supervisory algorithm has been developed and demonstrated. It functions by restricting the net reactivity so that the reactor period can be rapidly made infinite by reversing the direction of control rod motion. It, combined with the signal validation procedures, insures that there will not be any challenge to the reactor safety system while testing closed-loop control methods. Several such methods, including decision analysis, rule-based control, and modern control theory, continue to be experimentally evaluated. The eventual goal of this program is to use fault-tolerant computers coupled with closed-loop digital control and signal validation methods to demonstrate the improvements that can be achieved in reactor control.

Each new step in the program is evaluated for safety in accordance with standard review procedures (Safety Review numbers listed above) and approved as necessary by the MIT Reactor Safeguards Committee.

Initial tests of this digital closed-loop controller were conducted in 1983-1984 using the facility's regulating rod which was of relatively low reactivity worth (0.2% $\Delta K/K$). Following the successful completion of these tests, facility operating license amendment No. 24 was obtained from NRC (April 2, 1985). It permits:

(1) closed-loop control of one or more shim blades and/or the regulating rod provided that no more than 1.8% $\Delta K/K$ could be inserted were all the connected control elements to be withdrawn,

(2) closed-loop control of one or more shim blades and/or the regulating rod provided that the overall controller is designed so that reactivity is constrained sufficiently to permit control of reactor power within desired or authorized limits.

A successful experimentation program is now continuing under the provisions of this license amendment. A protocol is observed in which this controller is used to monitor, and if necessary override, other novel controllers that are still in development. Tests performed during this reporting period include:

a) Completion of the tests in which one of the reactor's shim blades was moved at half-speed. (Note: The initiation of these tests was described in last year's report.) The timing-chain sprocket of the blade used for these tests has now been returned to its normal configuration.

b) Tests of a controller designed using state analysis methods.

In addition, the MIT Reactor Safeguards Committee approved use of reactivity constraints derived from the alternate dynamic period equation as satisfying the provisions of Technical Specification #6.4. This approval did not involve an unreviewed safety question because the alternate constraints are always bounded by the standard ones on which the reactivity constraint concept was originally based.

F. ENVIRONMENTAL SURVEYS

Environmental surveys, outside the facility, were performed using area monitors. The systems (located approximately in a 1/4-mile radius from the reactor site) consist of calibrated G.M. detectors with associated electronics and recorders.

The detectable radiation levels due to argon-41 are listed below:

Site	July 1, 1986 - June 30, 1987
North	0.4 mR/year
South	0.7 mR/year
East	4.3 mR/year
West	0.3 mR/year
Green (East)	0.2 mR/year

Fiscal Yearly Averages:

1978	1.9 mR/year
1979	1.5 mR/year
1980	1.9 mR/year
1981	1.9 mR/year
1982	2.5 mR/year
1983	2.3 mR/tear
1984	2.1 mR/year
1985	2.2 mR/year
1986	1.8 mR/year
1987	1.2 mR/year

G. RADIATION EXPOSURES AND SURVEYS WITHIN THE FACILITY

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

Period 7/01/86 - 6/30/87

Whole Body Exposure Range (Rems)	No. of Personnel
No Measurable	31
Measurable - Exposure less than 0.1	91
0.1 - 0.25	9
0.25 - 0.5	7
0.5 - 0.75	6
0.75 - 1.0	1
Total Personnel = 145	Total Man Rem = 11.4

Summary of the results of radiation and contamination surveys from July 1986 to June 1987:

During the 1986-1987 period, the Reactor Radiation Protection Office continued to provide radiation protection services necessary for full-power (5 megawatt) operation of the reactor. Such services (performed on a daily, weekly, or monthly schedule) include, but are not limited to, the following:

1. Collection and analysis of air samples taken within the containment shell, and in the exhaust-ventilation system.

2. Collection and analysis of air samples taken from the cooling towers, D_2O system, waste storage tanks, shield coolant, heat exchangers, fuel storage facility, and the primary system.

3. Performance of radiation and contamination surveys, radioactive waste collection, calibration of reactor radiation monitoring systems, and servicing of radiation survey meters.

4. Providing of radiation protection services for control rod removal, spent-fuel element transfers, ion column removal, etc.

The results of all surveys described above 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. There were two sources of such wastes during the year: the cooling tower blowdowns and the liquid waste storage tanks. All of the liquid volumes are measured, by far the largest being the 6,208,000 liters discharged during FY 1987 from the cooling towers. (Larger 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 since the volume is not routinely measured.)

All releases were in accordance with Technical Specification 3.8-1, including Part 20, Title 10, Code of Federal Regulations. There are no reportable radionuclides inasmuch as all activities were substantially below the limits specified in 10 CFR 20.303 and 10 CFR 20, Appendix B, Note 5.

2. Gaseous Waste

Gaseous radioactivity is discharged to the atmosphere from the containment building exhaust stack and by evaporation from the cooling towers. All gaseous releases likewise were in accordance with the Technical Specifications and Part 20, and all nuclides were below the limits of 10 CFR 20.106 after the authorized dilution factor of 3000. Also, all were substantially below the limits of 10 CFR 20, Appendix B, Note 5, with the exception of argon-41, which is reported in the following Table H-1. The 4223 Ci of Ar-41 were released at an average concentration of 1.20×10^{-8} μCi/ml for the year. This represents 30% of MPC (4×10^{-8} μCi/ml) and is slightly more than the previous year's release of 3797 Ci. The increase is due to an imbalance in one component of the reactor building ventilation system that existed for a week during December 1986.

3. Solid Waste

Only one shipment of solid waste was made during the year, information on which is provided in the following Table H-2.

TABLE H-1

ARGON-41 STACK RELEASES

FISCAL YEAR 1987

	Ar-41 Discharged (Curies)	Average Concentration(1) (μCi/ml)
July 1986	304	0.90×10^{-8}
August	320	1.16
September	203	0.75
October	329	0.96
November	313	1.13
December	663	2.40
January 1987	394	1.14
February	394	1.43
March	396	1.43
April	317	0.92
May	293	1.06
June	297	1.08
12 months	4223	1.20×10^{-8}
MPC (Table II, Column I)		4×10^{-8}
% MPC		30%

(1) Note: After authorized dilution factor (3000).

TABLE H-2

SUMMARY OF MITR RADIOACTIVE SOLID WASTE SHIPMENTS

FISCAL YEAR 1987

	Units	Shipment #1	Total
1. Solid waste packaged	Cubic Feet	112.5	112.5
2. Weight	Pounds	3489	3489
3. Total activity (irradiated components, ion exchange resins, etc.) ^{60}Co, ^{51}Cr, $^{55-59}Fe$ ^{65}Zn, etc.	Ci	0.082	0.082
4. (a) Date of shipment		06/09/87	
(b) Disposition to licensee for burial		U.S. Ecology, Inc.	

NUCLEAR REACTOR LABORATORY

AN INTERDEPARTMENTAL CENTER OF
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L. CLARK, JR.
Director of Reactor Operations

August 29, 1987

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

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

Dear Sirs:

Forwarded herewith is the Annual Report for the MIT Research Reactor for the period July 1, 1986 to June 30 1987, in compliance with paragraph 7.13.5 of the Technical Specifications for Facility Operating License R-37.

Sincerely,

Kwan S. Kwok
Assistant Superintendent,
Reactor Operations

Lincoln Clark, Jr.

Lincoln Clark, Jr.
Director of Reactor Operations

LC/gw
Enclosure: As stated

cc: MITRSC
USNRC - Region I
Chief, Reactor Projects Section 1B
USNRC - Region I
L.T. Doerflein, Project Inspector, Section 1B
USNRC - Resident Inspector, Pilgrim Nuclear Station

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