MIT RESEARCH REACTOR

ANNUAL REPORT

TO

UNITED STATES NUCLEAR REGULATORY COMMISSION

FOR THE PERIOD JULY 1, 1983 - JUNE 30, 1984

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 properational 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 ninth annual report required by the Technical Specifications, and it covers the period July 1, 1983 through June 30, 1984. 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 seventh 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 fully met the requirements of reactor users. July 21, 1983, marked the 25th anniversary of the date when the MIT Reactor first went critical.

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, 1983 - June 30, 1984), the MIT Research Reactor, MITR-II, was operated on a routine, five days per week schedule, normally at a nominal 5MW. It was the seventh full year of normal operation for MITR-II.

The reactor averaged 90.3 hours per week at full power compared to 85.2 hours per week for the previous year. The reactor is normally at power 90-100 hours/week, but holidays, major maintenance, long experiment changes, waste shipping, etc., reduce the average. 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 24 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 three refuelings of several elements each. These involved a continuation of the practice begun in previous years in which fresh fuel was introduced to the A and B-rings while 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 eliminate the effects of radial/axial flux gradients and thus achieve higher average burnups.

The MITR-II fuel management program remains quite successful. All but fifteen of the original MITR-II elements (445 grams U-235) have been permanently discharged. The average overall burnup for the discharged elements was 42%. Of the remaining fifteen elements with the 445 gram loading, fourteen will reach maximum depletion within the next six months. Thirty-three of the new (506 grams U-235) are either currently in the reactor core or have been partially depleted and are awaiting reuse in the C-ring. One of these elements had to be permanently discharged due to excessive offgassing as mentioned later in this report.

Continuation of the MITR's very successful fuel management program after June 1985 is contingent upon it being possible to ship out spent fuel. Continued delays in the availability of a licensed cask from DOE are of increasing concern.

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).

b) Installation of digital control on an inelastic scattering spectrometer for molecular dynamics studies.

c) Dosimetry measurements of the neutron beam in the medical therapy facility for improvement of the boron neutron capture technique for brain cancer.

d) Dosimetry measurements for pneumatic rabbits and other irradiation facilities.

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

f) Production of phosphorus-32, gold-198, gold-199, dysprosium-165, fluorine-18, osmium-191, and chlorine-38.

g) Irradiation (i) of tissue specimens on particle track detectors for plutonium radiobiology, (ii) of agricultural specimens and animal tissue for boron location, and (iii) of geological samples for fissile element distribution.

h) Use of the facility in reactor operator training.

i) Irradiation damage studies of candidate fusion reactor materials.

j) Studies of fatigue failure as a function of surface bombardment and bulk irradiation damage.

k) Measurement of trace uranium in computer chip substrate materials by delayed neutron detection.

l) 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.

m) Closed-loop direct digital control of reactor power using the regulating rod during some steady-state and transient conditions.

n) Experimental studies of various closed-loop control techniques including decision analysis, state-variable feedback, and the use of reactivity constraints.

o) Measurements of the energy spectrum of leakage neutrons using a mechanical chopper in a radial beam port (4DH1).

p) Detection of trace quantities of fissile nuclides using a delayed neutron detector.

3. Changes to Facility Design

As indicated in past reports the uranium loading of MITR-II fuel has been increased from 29.7 grams of U-235 per plate and 445 grams per element to a nominal 34 and 510 grams respectively. With the exception of two elements, performance has been good. (Please see Reportable Occurrence Reports Nos. 50-20/79-4 and 50-20/83-2.) 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. The most recent fuel fabricator, Atomics International Division of Rockwell International, has completed the production of 41 of the more highly loaded elements, 33 of which have been used to some degree. Three with about 33% burnup, have been in operation in the core since January 1980 and will probably be permanently discharged during the coming year, since they will have attained the burnup limit. Additional elements, scheduled for fabrication during FY 1985, will be produced by a different manufacturer.

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 current 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.

Other changes in the facility are reported in Section E.

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 year of this report.

Work continued on revising MIT's application for renewal of License No. SNM-986. This license covers kilogram quantities of slightly enriched U-235, gram quantities of Pu, normal and depleted

U. Other licenses covering smaller quantities of similar material would be combined with License SNM-986. The MIT Reactor is involved, because most of the SNM is stored on the reactor site, and much of it is used on the reactor in accordance with authorized experiment review and approval procedures. Revision #1 of the renewal application was submitted to NRC on July 13, 1984.

Two SAR revisions were submitted during the year:

a) SAR Revision No. 29 was submitted to NRC in order to bring the SAR into conformance with the Technical Specifications as revised by License Amendment No. 20. That amendment deleted the fuel cladding fabrication tolerances and specified a new nominal minimum thickness of 0.008 inches. Two pages of the SAR were similarly changed by Revision No. 29.

b) SAR Revision No. 30 submitted changes to the "Physical Security Plan" (classified as Safeguards Information). The revision was approved by NRC's letter of April 30, 1984. It was reviewed internally under Safety Review #0-83-27.

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

a) Procedure 3.11.1, "In-Core Sample Assembly (ICSA) Sample Handling" was revised to include handling of samples in the reactor top glove box and to add cautions on avoiding spread of contamination (SR#-0-83-19).

b) A review of Abnormal Operating Procedures resulted in a number of minor changes as follows (SR#-0-83-23):

AOP	Change
5.2.4	- Substitutes closure of MV-5B for MV-7B. Since MV-7B, the outlet, is throttled and its position should not be changed.
	- Adds requirement to secure two heat exchangers.
	- Adds requirement to vent secondary side of secured heat exchangers.
5.2.8	- Adds requirement to shut HV-48 so that HP-3A indicates properly.
5.2.9	- Deletes requirement to shut down if cause of alarm is unknown. AOP #5.2.6 to be followed.
5.2.10	- Same as #5.2.4.
5.2.14	- Adds caution on possibility of spontaneous

combustion if charcoal filters dry out following immersion.

5.5.17 - Adds caution on need to check dump tank level hourly.

5.7.3 - Same as #5.2.14.

In addition, four other procedures (#5.2.3, 5.6.2, 5.7.8 and 5.8.1) were updated to bring them into conformance with the revised Emergency Plan and Procedures (SR#-0-84-4).

c) Procedure 2.3.1, "Normal Reactor Startup", contained a requirement to lower the shim bank and investigate if criticality has not been attained by the time that the bank height is 0.5" above the estimated critical position (ECP). The Procedure has been modified by explicitly stating that similar action shall be taken if criticality is attained at a position 0.5" or more below the ECP (SR#-0-83-24).

d) Procedures 4.4.4.1 - 4.4.4.16, MITR Emergency Procedures, were extensively rewritten and Procedure 4.4.5.2, Use of Operations Office Emergency Gauges, was added (SR#-0-83-25). The extensive revisions were principally for the purpose of implementing the amended Emergency Plan that had been submitted to NRC on September 3, 1982 and subsequently approved on June 24, 1983. In addition, procedures for testing and maintaining emergency preparedness, Procedures 6.6.1.1 - 6.6.1.4 and 6.6.2.1 - 6.6.2.4, were updated and augmented to comply with the amended Emergency Plan (SR#-0-84-2). These procedures are now listed separately under a new category, Emergency Plans, in Procedure 7.3.1, Schedule of Surveillance Tests and Calibrations, and in Procedure 7.3.1.1, Index of Surveillance Tests and Calibrations (SR#-0-84-3). Further clarifying revisions to Procedures 4.4.4.16 and 4.4.5.2 were added by SR#-0-84-8.

e) Procedures 4.4.4.17 and 4.4.4.18 are new security procedures to implement revisions to the Physical Security Plan (SR#-0-83-26).

f) A review of Procedure Manual Chapter 1, Administrative Procedures, resulted in a number of pages being updated for committee rosters, phone numbers, call lists, etc. A new subsection 1.4.6, Procedure Manuals, was added to specify the number and location of such manuals (SR#-0-84-1).

g) Flow calibrations in the past have been performed by connecting manometers in the Equipment Room across the d/p cells for each system and then running the systems at varying flows, thereby calibrating recorders and scrams against the manometer readings. A new method has been adopted that attaches to each d/p cell a flow calibration rig that can be read out remotely in the Control Room, simplifying comparison with flow recorders and scram indications, eliminating the need to operate the flow systems, and reducing exposures to personnel. During 1983, the new method was run in parallel with the original and found to be as accurate or more so. Accordingly, Procedures 6.1.3.3A, 6.1.3.12A, 6.1.3.13A, 6.2.3A, 6.2.3B and 6.5.15A

for calibration of flow recorders in the primary, D_2O, shield and secondary systems were revised (SR#-0-84-5).

h) An alarm system for the spent fuel storage pool that indicates loss of power, loss of flow, leak and low pool level was installed, and Procedure 5.7.12, "Spent Fuel Storage Pool", provides instructions for response to the alarm (SR#-0-84-7).

i) In the course of revising the abnormal and emergency procedures, reference was made in several abnormal procedures (#5.1.3, 5.2.12, 5.5.7, 5.5.8, 5.5.18, 5.6.2, 5.8.2 and 5.8.6) and emergency procedures (4.4.4.1 and 4.4.4.3) to the Radiation Emergency Plan or to the Medical Emergency Plan, instead of to the corresponding procedures. This situation was rectified by SR#-0-84-9 in response to a recommendation in NRC's Report No. 50-20/84-1 covering an appraisal of MITR's emergency preparedness.

j) Also in response to the above NRC appraisal report, additional changes were made to the abnormal and emergency procedures as follows (SR#-0-84-14):

Abnormal Operating Procedure 5.0 and Emergency Procedures 4.4.4, 4.4.4.12, 4.4.4.14 and 4.4.4.15 were revised to specify explicitly who is responsible for particular actions under each procedure.

Emergency Procedures 4.4.4.1 - 4.4.4.9, 4.4.11 and 4.4.4.14 were revised to incorporate tables showing what emergency class corresponds to various abnormal or emergency conditions, the purpose of which is to assist the emergency team in assigning the appropriate emergency classification.

Procedure 6.6.2.4, "Inventory of Emergency Supplies and Equipment", was revised to add high range dosimeters to the Control Room locker inventory.

Instructions to provide dosimeters to Campus Police paramedics and ambulance attendants responding to injuries involving radiation or contamination were added to Emergency Procedure 4.4.4.10, Medical Emergency.

k) Procedure 5.7.8, "Smoke Detector System", specifies that building ventilation be maintained in order to minimize smoke and enable personnel to escape. The procedure originally stated that this should be done by raising the plenum monitor trips, if necessary, to the levels given in the Emergency Plan. The revision allows raising the trips to full scale until the building (except for the control room) has been evacuated (SR#-0-84-9).

l) Instructions on the use of self-contained breathing devices were added to Procedure 5.7.8, "Smoke Detector System" (SR#-0-84-14).

m) Emergency Procedure 4.4.4.2, "Storm, Flood, or Earthquake", was

revised to specify that, if a tornado funnel is present in the area, the reactor is to be secured and all airlock doors opened and dampers kept open in order to permit rapid equalization of pressure within the containment building. In the event of an earthquake, Buldings NW12 and NW13 are to be evacuated to the parking lot.

n) Miscellaneous minor changes to operating procedures and 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 FY84) (normally at 4.9 MW)	216.7	252.0	234.3	222.9	925.9
b) MITR-II (MIT FY76-83)					6,044.6
c) MITR-I (MIT FY59-74)					10,435.2
d) Cumulative, MITR-I & MITR-II					17,405.7
2. Hours of Operation MIT FY1984, MITR-II					
a) At Power (>0.5 MW) for research	1177.1	1266.9	1159.5	1181.5	4,785.0
b) Low Power (<0.5 MW) for training(1) and test	41.4	10.0	32.6	15.7	99.7
c) Total critical	1218.5	1276.9	1192.1	1197.2	4,884.7

Note (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 previous line.

C. SHUTDOWN AND SCRAMS

During the period of this report there were 9 inadvertent scrams and 10 unscheduled power reductions or shutdown.

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 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 last year in order to facilitate a comparison.

	Total
I. Nuclear Safety System	
Withdraw Permit Circuit Open, due to:	
a) electrical noise	1
b) short during maintenance on power supply	1
c) chan. 4 scram while resetting level trip	3
d) chan. 6 scram during chamber plateau check	1
Subtotal	6
II. Process Systems	
a) Primary coolant pump breaker tripped off due to overload on control circuit	1
b) Low Flow Primary Coolant scram during servicing of flow recorder	2
Subtotal	3
III. Other Scrams or Unscheduled Shutdowns	
a) Shutdowns due to Electric Company power loss	6
b) Operator lowered power to investigate:	
i) Heat exchanger primary to secondary leak	1
ii) Low pressure in the helium supply to an irradiation thimble	3
Subtotal	10
Total	19

The 19 scrams and shutdowns during FY 84 compare with the 25, 28 and 24 experienced in FY 83, FY 82 and FY 81 respectively.

D. MAJOR MAINTENANCE

Major maintenance projects during FY84, including the effect, if any, on safe operation of the reactor, are described below in this section.

FY84 saw a continuation of the program for upgrading reactor instrumentation that was begun several years ago. Another new shield plug which has several neutron detector positioning tubes was installed in instrument port 4IH3. It incorporates two uncompensated ion chambers and a fission chamber. One of the ion chambers was installed to replace a defective detector in one of the startup channels. The remaining ion chamber and the fission chamber were installed as spare units intended for replacements of the older chambers in the future. A new amplifier/meter assembly manufactured by the Keithley Corporation was obtained as a spare unit for the starup instrumentation. Two of the incore magnets, which are electro-magnetically coupled to the control blade absorbers, showed signs of peeling of the chrome plating on the surfaces. Efforts are being made to reduce the number of sharp radii on the finished surface of the magnet in the fabrication procedure so as to reduce the likelihood of peeling.

Electrical ground fault interrupters were installed on the reactor floor, reactor top, and fuel storage pool circuits. These safety devices prevent operation of equipment with internal shorts. New alarms and interlocks were installed on the fuel storage pool cleanup system to warn the operator-in-charge of any abnormal conditions such as low flow, low level, leak, and loss of power. The interlocks will automatically trip off the pump in the event of leaks and/or low level. A new flow switch designed with a water trap was installed in the core purge system in order to reduce the rate of deterioration of the switch due to moisture accumulation. A cut-off switch was installed for cutting off power to the bell of the scam annunciator during the unattended weekend periods.

The spent fuel racks had storage positions for twenty-six MITR-II type fuel elements. Twenty-four more storage positions were made available by installation of cadmium-lined boxes between the existing twenty-six storage locations thus bringing the racks to their maximum storage capacity. New portable hoses were obtained for the Emergency Core Cooling System.

The main intake damper actuating arm had developed an interference because of the wear on the gasket, and the piston rod of the hydraulic operating cylinder broke as a result of this interference. The hydraulic operating cylinder and the gasket for the main intake damper were consequently replaced. As an effort to reduce the wear and tear on the main intake damper system during the startup checks, a new circuit was installed to allow testing of the control action and response of the system without the actual operation of the dampers. This modification should reduce the frequency of the damper operation, thus decreasing the cyclic fatigue loads on the piston rod.

A major component, a vacuum tank, of the Fatigue Cracking Experiment was relocated to provide installation of a permanent direct beam experiment - a time of flight and Bragg angle diffraction experiment. This new experimental set-up was designed for use by the MIT Junior Physics Lab students and is equipped with safety shutters, beam guards, and beam catchers. The water shutter in one of the horizontal beam ports, 6SH4, was completely repiped due to leakages. In addition, the triple axis spectrometer installed as a permanent equipment for this port was completely rebuilt and fully computerized. Software was developed such that the multi-crystal alignment in the spectrometer can be changed automatically and accurately with a single computer command.

The cooling towers have been deteriorating due to age and ice forming on the outside panels. More than 50% of the exterior slats at the base of the cooling towers were replaced. Screens and broken panels which were damaged by falling ice during thawing periods were repaired. New and larger heaters were installed in the pump sheds to prevent piping from freezing in the Winter months. Much of the preventive maintenance on the cooling towers is continuing. Efforts are being made to improve the heat removal capacity of the entire secondary system through cleaning of both the heat transfer surfaces and spray nozzles.

One of the three main heat-exchangers developed a small leak between the primary and secondary sides of the heat-exchanger. It is currently isolated and in a stand-by condition. Repairs of defective tubes and hydro-tests will be performed at a later date in conjunction with the cooling tower and secondary system repairs.

Many other routine maintenance and preventive maintenance jobs were done 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 Chief, Standardization and Special Projects Branch, Division of Licensing, 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".

1. 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).

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

A joint project involving computer analysis and signal validation of data from reactor instruments was continued with the Charles Stark Draper Laboratory in Cambridge. Tests were conducted on reactor power, temperature, and flow instruments during transient conditions. These experiemnts showed that the computer-aided signal validation technique did improve reactor plant reliability. Signals used in the experiments have been decoupled from the reactor by isolation amplifiers.

Once the signal validation technique was demonstrated, digital controllers were designed to control the reactor's regulating rod. That rod, whose worth is limited to 0.7% $\Delta K/K$ and is actually worth 0.2% $\Delta K/K$, is normally positioned by an analog controller. The digital controller has been shown to be equal to the analog one during near steady-state conditions while transients such as those due to xenon or temperature are in progress. Replacement of the constant speed regulating rod drive motor by a variable speed drive motor further improves control.

Studies are in progress to develop and perfect a digital controller for power changes. 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 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. Safety studies are now in progess to determine how the techniques can be extended to the control of shim blades.

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. To date no unreviewed safety questions requiring advance NRC approval have been identified.

Reactor Staff approval 10/06/80
MIT Reactor Safeguards Committee Approval 12/03/81
MIT Reactor Safeguards Subcommittee Approval 05/27/82
MIT Reactor Safeguards Committee Approval 12/06/82
MIT Reactor Safeguards Subcommittee Approval 03/04/83, 05/27/83
MIT Reactor Safeguards Committee Approval 12/20/83
MIT Reactor Safeguards Subcommittee Approval 06/25/84

2. SR#-0-83-22 (9/14/83)

Revision to D_2O System Blowout Patch

The original layout contained no isolation valve on the line to the blowout patch. This made changing the patch hazardous because tritium vapor would be released while the system was open for the patch replacement. Local ventilation was the only means of preventing exposure to the tritium. Experience indicates that, since the tritium concentration continues to increase with time, the local ventilation may eventually not provide adequate protection.

The new system provides an isolation valve which can be shut to permit rapid safe changeouts of the patch. Procedure 7.3.4.1 covers the replacement of the new patch. The valve will be kept locked open. The system is protected against overpressure by an oil leg as well as the blowout patch. So, failure to reopen the valve following a changeout will not leave the system without protection. This system change does not involve an unreviewed safety question.

Reactor Staff approval 9/16/83

F. ENVIRONMENTAL SURVEYS

Environmental surveys, outside the facility, were performed using area monitors. The systems (located approximately in a ¼-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, 1983 - June 30, 1984
North	2.5 mR/year
South	2.1 mR/year
East	1.3 mR/year *
West	2.7 mR/year
Green (East)	0.4 mR/year

* The measurement period was from November 1, 1983 to April 30, 1984

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

G. RADIATION EXPOSURES AND SURVEYS WITHIN THE FACILITY

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

Period 7/01/83 - 6/30/84

Whole Body Exposure Range (Rems)	No. of Personnel
No Measurable	42
Measurable - Exposure less than 0.1	86
0.1 - 0.25	8
0.25 - 0.5	15
0.5 - 0.75	5
0.75 - 1.0	1
Total Rem - 12.57	Total Personnel - 157

Summary of th results of radiation and contamination surveys from July 1983 to June 1984:

During the 1983-1984 period, the Reactor Radiation Protection Office continued to provide radiation protection services for full-power (5 megawatts) operation of the reactor. Such services (performed on a daily, weekly, or monthly schedule) include 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. The 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 three sources of such wastes during the year: the cooling tower blowdowns; the liquid waste storage tanks; and laboratory drains. All of the liquid volumes are measured, by far the largest being the 6,350,000 liters discharged during FY 1983 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, including those briefly discharged from a small leak in a heat exchanger in May 1984, 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 8361 Ci of Ar-41 was released at an average concentration of 2.18×10^{-8} µCi/ml for the year. This represents 55% of MPC (4×10^{-8} µCi/ml).

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 1984

	Ar-41 Discharged (Curies)	Average Concentration[1] (μCi/ml)
July 1983	597	1.97×10^{-8}
August	886	2.33
September	694	2.39
October	785	2.70
November	986	2.72
December	518	1.78
January 1984	554	1.91
February	653	1.80
March	743	2.56
April	712	2.39
May	752	2.02
June	481	1.61
12 months	8361	2.18×10^{-8}
MPC (Table II, Column I)		4×10^{-8}
% MPC		55%

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

Table H-2

SUMMARY OF MITR RADIOACTIVE SOLID WASTE SHIPMENTS

FISCAL YEAR 1984

	UNITS			TOTAL
1. Solid waste packaged	Cubic Feet	67.5		67.5
2. Total activity (irradiated components, ion exchange resins, etc.) ^{60}Co, ^{51}Cr, $^{55-59}Fe$, ^{65}Zn, etc.	Curies	0.039		0.039
3. (a) Dates of shipment (b) Disposition to licensee for burial		12/07/83 Radiation Service Organization		

NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

O.K. HARLING
Director

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L. CLARK, JR.
Director of Reactor Operations

August 29, 1984

Dr. Thomas E. Murley, Administrator
U.S. Nuclear Regulatory Commission
Region #1
631 Park Avenue
King of Prussia, PA 19406

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

Dear Dr. Murley:

Forwarded herewith are two (2) copies of the Annual Report for the MIT Research Reactor for the period July 1, 1983 to June 30 1984, in compliance with paragraph 7.13.5 of the Technical Specifications for Facility Operating License R-37.

Sincerely,

Lincoln Clark, Jr.

Lincoln Clark, Jr.
Director of Reactor

Operations

/gpt
Enclosure: As stated

cc: MITRSC
USNRC-OI&E
USNRC-DMB
USNRC-OMIPC

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