December 19, 2007

Dr. John A. Bernard, Jr.
Director of Reactor Operations
Massachusetts Institute of Technology
Research Reactor
MITNRL-NW 12
138 Albany Street
Cambridge, MA 021391

SUBJECT: NRC SPECIAL INSPECTION REPORT NO. 50-020/2007-203 AND NOTICE OF VIOLATION

Dear Dr. Bernard:

On November 20, 2007, the U.S. Nuclear Regulatory Commission (NRC) completed a Special Inspection at your Massachusetts Institute of Technology Nuclear Reactor Laboratory (MIT-NRL) facility. The special inspection included an examination of activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations. Within these areas, the inspection included selected examinations of procedures and representative records, interviews with personnel, and observations of activities in progress. The enclosed report documents the inspection findings, which were initially discussed with you, Professor David Moncton, Director of the Nuclear Reactor Laboratory, Dr. William VanSchalkwyk, Managing Director of Environmental Health and Safety Programs, Louis DiBerardinis, Director of Environmental Health and Safety, as well as other members of your staff on November 1, 2007. A second discussion of inspection findings was conducted on November 20, 2007, with the aforementioned individuals with the exception of Dr. VanSchalkwyk.

The event that led to the conduct of the Special Inspection can be summarized as follows. During work involving radioactive material, licensee employees of the MIT-NRL research reactor are required to wear an Optically Stimulated Luminescent dosimeter for whole body monitoring and a finger ring containing a Thermoluminescent dosimeter chip for extremity monitoring. These dosimeters are gathered and sent to a vendor for processing at the end of every quarter. Following this routine practice, at the end of September, personnel dosimeters were sent to the vendor to be processed. During the week of October 15, 2007, the licensee received the third quarter dosimetry results indicating that one individual had received an unexpectedly high exposure in excess of 4 rem during that period. On October 17, 2007, the licensee notified the NRC inspector who was on site conducting a routine inspection and subsequently the Massachusetts Radiation Control Program Manager.

Due to the potential significance of the exposure, as well as the complicated nature of personnel monitoring and dosimetry processing, and the uncertainty surrounding how the dose was received, a Special Inspection Team was assigned to review the event. The Special Inspection Team began their review on October 22, 2007. As noted above, this review was completed on November 20, 2007.

Based on the results of this inspection, the NRC has determined that two Severity Level IV violations of NRC requirements occurred. The violations were evaluated in accordance with the

NRC Enforcement Policy. The current Enforcement Policy is included on the NRC's Web site at www.nrc.gov; select **What We Do**, **Enforcement**, then **Enforcement Policy**. The violations are cited in the enclosed Notice of Violation (Notice) and the circumstances surrounding each are described in detail in the subject inspection report. The violations are being cited in the Notice because the facility staff failed to comply with regulatory and facility procedural requirements. One violation relates to the failure to conduct radiological surveys that are reasonable under the circumstances to evaluate the magnitude and extent of radiation levels and the potential radiological hazards. The other violation relates to the failure to provide adequate training in the health protection problems associated with exposure to radiation and/or radioactive material, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed.

You are required to respond to this letter and should follow the instructions specified in the enclosed Notice when preparing your response. The NRC will use your response in accordance with its policies to determine whether further enforcement action is necessary to ensure compliance with regulatory requirements.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice," a copy of this letter and its enclosure will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's document system (ADAMS), accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

Should you have any questions concerning this inspection, please contact Johnny H. Eads, Branch Chief, Research and Test Reactor Branch B, at 301-415-1471.

Sincerely,

/RA/

Michael J. Case, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-020
License No. R-37

Enclosures: Notice of Violation
NRC Inspection Report No. 50-020/2007-203

cc w/enclosures: See next page

cc:

City Manager
City Hall
Cambridge, MA 02139

Department of Environmental Protection
One Winter Street
Boston, MA 02108

Director
Radiation Control Program
Department of Public Health
90 Washington Street
Dorchester, MA 02121

Nuclear Preparedness Manager
Massachusetts Emergency Management Agency
40 Worcester Road
Framingham, MA 01702-5399

Test, Research, and Training
Reactor Newsletter
University of Florida
202 Nuclear Sciences Center
Gainesville, FL 32611

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ACCESSION NO.:ML073440173 **TEMPLATE #: NRR-106**

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NOTICE OF VIOLATION

Massachusetts Institute of Technology — Docket No. 50-020
Nuclear Reactor Laboratory — License No. R-37

During an NRC inspection conducted on October 22-25, October 29-November 1, and November 19-20, 2007, two violations of NRC requirements were identified. In accordance with the NRC Enforcement Policy, the violations are listed below:

1. 10 CFR 20.1501 requires that (a) Each licensee shall make or cause to be made, surveys that--(1) May be necessary for the licensee to comply with the regulations in this part; and (2) Are reasonable under the circumstances to evaluate--(i) The magnitude and extent of radiation levels; and (ii) Concentrations or quantities of radioactive material; and (iii) The potential radiological hazards.

   Contrary to the above, the licensee failed to make reasonable surveys to evaluate the magnitude and extent of radiation levels present in that, on at least five occasions during the third quarter of 2007, an individual who was processing silicon ingots contained in magnesium cans did not perform a survey of the work area during removal of the silicon from the conveyor system which resulted in the creation of a plane source of radiation to which the individual was exposed during each work period resulting in an unexpected high dose of radiation for the exposure period.

   This is a Severity Level IV violation (Supplement IV)

2. 10 CFR 19.12 requires that (a) All individuals who in the course of employment are likely to receive in a year an occupational dose in excess of 100 mrem (millirem) shall be (1) Kept informed of the storage, transfer, or use of radiation and/or radioactive material; (2) Instructed in the health protection problems associated with exposure to radiation and/or radioactive material, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed.

   Contrary to the above, the licensee failed to provide adequate instruction to an employee who was likely to receive an annual occupational dose in excess of 100 mrem in the purposes and functions of protective devices employed in that an individual did not receive adequate training in the use of his extremity dosimeter (finger ring) and during the third quarter of 2007, the individual wore his finger ring with the portion containing the TLD chip facing out instead of facing in, which is the proper way to wear the finger ring.

   This is a Severity Level IV violation (Supplement IV)

Pursuant to the provisions of 10 CFR 2.201, the Massachusetts Institute of Technology is hereby required to submit a written statement or explanation to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, D.C. 20555-0001 with a copy to the responsible inspector, within 30 days of the date of the letter transmitting this Notice of Violation (Notice). This reply should be clearly marked as a "Reply to a Notice of Violation; EA-06-113," and should include for each violation: (1) the reason for the violation, or, if contested, the basis for disputing the violation or severity level, (2) the corrective steps that have been taken and the results achieved, (3) the corrective steps that will be taken to avoid further violations, and (4) the date

when full compliance will be achieved. Your response may reference or include previous docketed correspondence, if the correspondence adequately addresses the required response. If an adequate reply is not received within the time specified in this Notice, an order or Demand for Information may be issued as to why the license should not be modified, suspended, or revoked, or why such other action as may be proper should not be taken. Where good cause is shown, consideration will be given to extending the response time.

If you contest this enforcement action, you should also provide a copy of your response, with the basis for your denial, to the Director, Office of Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Because your response will be made available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS), to the extent possible, it should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the public without redaction. ADAMS is accessible from the NRC Web site at (the Public Electronic Reading Room) http://www.nrc.gov/reading-rm/adams.html. If personal privacy or proprietary information is necessary to provide an acceptable response, then please provide a bracketed copy of your response that identifies the information that should be protected and a redacted copy of your response that deletes such information. If you request withholding of such material, you must specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim of withholding (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If safeguards information is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21.

In accordance with 10 CFR 19.11, you may be required to post this Notice within two working days.

Dated at Rockville, Maryland
this 19th day of December 2007

U. S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION

Docket No:	50-020
License No:	R-37
Report No:	50-020/2007-203
Licensee:	Massachusetts Institute of Technology
Facility:	Nuclear Reactor Laboratory
Location:	Cambridge, Massachusetts
Dates:	October 22-25, October 29-November 1, and November 19-20, 2007
Inspectors:	Craig Bassett Jessie Quichocho Sami Sherbini
Approved by:	Johnny H. Eads, Branch Chief Research and Test Reactors Branch B Division of Policy and Rulemaking Office of Nuclear Reactor Regulation

SUMMARY OF FINDINGS

Massachusetts Institute of Technology
Nuclear Reactor Laboratory
NRC Inspection Report No.: 50-020/2007-203

The report covered a period of four days of in-office document review by one inspector, four days of on-site inspection by three inspectors, and another two days of on-site inspection by one inspector. The NRC's program for overseeing the safe operation of research and test reactors is described in Manual Chapter 2545, "Research and Test Reactor Inspection Program." A Special Inspection was established in accordance with NRC Management Directive 8.3, "NRC Incident Investigation Program." The Special Inspection Team charter did not require the team to address compliance or assess significance of findings and observations. Another inspection will be scheduled to address the follow-up items identified by the team.

NRC-identified and Self-Revealing Findings

During work involving radioactive material, licensee employees of the Massachusetts Institute of Technology Nuclear Reactor Laboratory are required to wear an Optically Stimulated Luminescent dosimeter for whole body monitoring and a finger ring containing a Thermoluminescent dosimeter chip for extremity monitoring. These dosimeters are gathered and sent to a vendor for processing at the end of every quarter. Following this routine practice, at the end of September 2007, personnel dosimeters were gathered and sent to the vendor to be processed. During the week of October 15, 2007, the licensee received the third quarter dosimetry results indicating that one individual had received a total whole body dose of 4041 millirem for that period, an unexpectedly high exposure.

Upon reviewing the dosimetry results, the Reactor Radiation Protection Officer notified the Massachusetts Institute of Technology Reactor Facility Director. They immediately restricted the affected individual from further work with radioactive material that would contribute to a whole body dose and began a review of the situation. After careful consideration of various factors involved, the Director and the Radiation Protection Officer determined that this was an unplanned high exposure and an investigation was initiated.

On October 17, 2007, the licensee notified an NRC inspector who was on site conducting a routine inspection and subsequently notified the Massachusetts Radiation Control Program Manager. Although an NRC inspector was on site, due to the potential significance of the exposure, as well as the complicated nature of personnel monitoring and dosimetry processing, and the uncertainty surrounding how the dose was received, a Special Inspection Team was assigned to review the event. The Special Inspection Team began their review on October 22, 2007.

The initial review by the Special Inspection Team consisted of in-office document and data review. On October 29, 2007, the team arrived on site to continue gathering information concerning this event. On November 19, 2007, the team leader returned to the site to meet with licensee representatives and review their conclusions concerning the high exposure. The team found that the licensee had initiated an extensive investigation into the event. The investigative efforts were divided into seven categories including: 1) device review, 2) personnel actions, 3) dose reconstruction, 4) records review, 5) review of work areas, 6) radiological information review, and 7) external review. The team noted that, although the individual exposure was higher than

expected, it had not exceeded any regulatory limit and no formal notification of the event to the NRC was required. The team reviewed the licensee's immediate corrective actions, including dose calculations, and found those actions to be acceptable.

Nevertheless, based on the results of this inspection, the team found that the licensee failed to conduct adequate surveys of the work area during work involving silicon ingot handling which lead to an individual receiving a high dose of radiation. The licensee also failed to provide adequate training to the individual involved in the silicon work such that the individual was wearing his extremity dosimetry (finger ring) improperly.

REPORT DETAILS

1. Introduction

a. Background

The Massachusetts Institute of Technology Reactor (MITR) is operated under the authority and administration of the Director of the MIT Nuclear Reactor Laboratory. The MITR is located in the Nuclear Reactor Laboratory and is managed by the Director of Reactor Operations and his staff. Daily operations activities are conducted under the supervision of the Superintendent of Operations, while experiment and other support activities are supervised by the Assistant Director, Research Development and Utilization and the Assistant Director, Reactor Engineering. Radiation protection activities and radiological support are overseen by the Reactor Radiation Protection Officer (RRPO). During the third quarter of this year, various maintenance projects and routine operations were undertaken and completed. Several activities were ongoing, including silicon irradiation and processing using the facility's 5 megawatt reactor and the silicon ingot transfer and conveyor system. During this work involving radioactive material, licensee employees are required to wear an Electronic Dosimeter and an Optically Stimulated Luminescent (OSL) dosimeter for whole body monitoring and a finger ring containing a thermoluminescent dosimeter (TLD) chip for extremity monitoring.

b. Event Description

During the third quarter of 2007, an individual who was in the reactor operator training and qualification program, had assisted in many of the processing and irradiation activities as a part of that training at the facility. (The person subsequently took and passed the NRC operator examination during this period.) One of these processing activities involved silicon billets or ingots. The process requires that a person physically pick up magnesium containers or "cans" containing silicon ingots and perform various operations with the cans. These operations include loading the cans onto a conveyor system on one side of the reactor (the conveyor system moves the cans through the reactor where they are irradiated), removing the cans from the conveyor system on the opposite of the reactor, removing the silicon ingots from the cans, and finally cleaning the silicon ingots and cans and placing the cans in storage.

The dosimetry results for the third quarter, received from the dosimetry processing vendor on October 15, 2007, indicated that this individual had received a whole body dose of 4041 millirem (mrem) and an extremity dose of 5810 mrem. This dose to the individual was unplanned and unexpected. Although there were other tasks that contributed to the total dose, the great majority of the dose received by this individual was apparently received during periods when the person was involved in the silicon processing operation at the facility.

2. Event Follow-up - Sequence of Events

a. Inspection Scope

The inspectors interviewed licensee personnel, observed tests and demonstrations conducted by the licensee to develop the following sequence of events leading up to and following the unplanned high exposure of the individual (hereafter referred to as Worker A), and reviewed various procedures and documents listed in Attachments A and B.

b. Observations and Findings

(1). Work Activities Performed by the Individual

As noted above, during the third quarter of the year, the individual involved in the high exposure event performed numerous jobs and tasks at the facility. He often assisted others at the facility in completing routine work or participated in training activities in preparation for the NRC operator examination. The following table, Table 1, lists activities in which the individual was involved during the third quarter of 2007. It also lists others who were present during those activities such as other trainees, Reactor Operators (ROs), Senior Reactor Operators (SROs), the Training Coordinator (TC), and the Assistant Superintendent of Operations (ASO). The last column lists the potential dose rates involved in the activities.

Table 1

Work or Training Activity	Other Employees Involved	Potential Dose Rates
Perform various surveillances and maintenance activities in the Containment Building (most of the work completed by Worker A during the third quarter was of this type)	Various other trainees, ROs, SROs, and the TC	LOW
Entry into Equipment Room to complete Startup and Shutdown checklists and to assist with various surveillance and maintenance activities with the reactor shutdown	Various other trainees, ROs, SROs and/or the TC	LOW to MODERATE
Removal of spent fuel from the top of the reactor, moving spent fuel equipment, preparing and loading spent fuel into the spent fuel cask	Various other trainees, ROs, SROs, the TC, and the ASO	LOW with a few very localized spots HIGH
Load cans containing silicon ingots onto the conveyor system	None (after the individual was trained)	MODERATE
Assist with the removal or installation of incore experiments	Various other trainees, ROs, SROs, and the ASO	MODERATE
Load silicon ingots or billets and containers (cans)	ASO (during the training of the individual)	MODERATE to HIGH
Entry into Equipment Room with reactor at power – but for very short periods, i.e., seconds or minutes	None	HIGH
Unload silicon ingots and containers from the conveyor system	None (after being trained)	HIGH
Process silicon ingots, clean ingots and cans and store them	None (after being trained)	HIGH

(2) Chronology or Sequence of Events

The licensee developed a timeline for the individual during the badging period (i.e., the third quarter of 2007) by interviewing the individual, obtaining data from the security access card, from the electronic dosimeter (ED), and from daily operations schedules. Based on this data, the licensee generated a list of high, medium, and low dose activities that were performed by the individual (similar to those noted above).

The chronology or sequence of events below is based on interviews with licensee staff and all the data accumulated by the licensee. Aside from the first and last few entries, it generally lists only those activities and jobs that had the potential of resulting in exposure for the personnel involved. Personnel entries into the Equipment Room that are listed below were at times when the reactor was shutdown unless otherwise indicated.

Date	Event Description
01/08/2007	Worker A began work at the MITR facility after recently being discharged from the U. S. Navy.
01/09 – 06/30/2007	Worker A was involved in the reactor operator training program and participated in numerous training and job related activities throughout the facility.
07/02/2007	*Beginning of the Third Quarter* - Worker A assisted others in inserting a sample in a vertical port; also entered the Equipment Room with other trainees and the Training Coordinator (TC) to complete the Shutdown Checklist. The individual also, helped unload silicon under supervision.
07/03/2007	Worker A entered the Equipment Room with other trainees and the TC for Shutdown Checklist valve repositioning.
07/07/2007	Worker A entered the Equipment Room multiple times with other trainees and the TC to complete the Startup and Shutdown Checklists
07/08/2007	Worker A entered the Equipment Room multiple times with other trainees and the TC to complete the Startup and Shutdown Checklists
07/09/2007	Worker A helped remove an incore experiment at the reactor top. The individual also helped unload silicon under supervision.
07/10/2007	Worker A entered the Equipment Room various times and assisted others in draining the heat exchanger.
07/11/2007	Worker A entered the Equipment Room various times and assisted others in draining the heat exchanger and with a valve replacement.

07/12/2007	Worker A entered the Equipment Room various times to adjust core purge flow and to perform the 100kW checklist with the TC and other trainees.
07/13/2007	Worker A entered the Equipment Room to perform full power startup checklist with the TC and other trainees, to remove a ground wire, and to assist with a valve replacement.
07/16/2007	Worker A helped others with the removal of an incore experiment at the reactor top; also performed swapping of dummy elements.
07/17/2007	Worker A helped others to perform blade thickness measurements and other inspections of Shim Blade #2.
07/25/2007	Worker A entered the Equipment Room for the morning check (reactor at power).
07/30/2007	Worker A assisted others with the insertion of an incore experiment and with the insertion of a sample in a separate vertical port.
08/02/2007	Worker A entered the Equipment Room for the morning check (reactor at power).
08/10/2007	Worker A helped others load spent fuel into the spent fuel cask.
08/13/2007	Worker A entered the Equipment Room for the morning check (reactor at power) and helped others prepare the spent fuel cask for shipment.
08/16/2007	Worker A lost his third quarter finger ring. He was issued a replacement.
08/17/2007	Worker A entered the Equipment Room for training.
08/20/2007	Worker A entered the Equipment Room briefly to perform Preventive Maintenance procedure 3.5 (PM 3.5).
08/23/2007	Worker A entered the Containment Building to load four-inch (4″) silicon without any assistance.
08/24/2007	Worker A entered the Containment Building to unload 6″ silicon from conveyor and process the ingots without any assistance.
09/03/2007	Worker A and other trainees conducted a detailed walk through of the entire facility.
09/05/2007	Worker A entered the Equipment Room with an NRC examiner as part of the qualification examination.
09/06/2007	Worker A entered the Containment Building to load 6″ silicon without any assistance.

09/11/2007 Worker A entered the restricted area multiple times to organize the Silicon Storage Room.

09/12/2007 Worker A entered the Equipment Room to perform preventive maintenance. Worker A also entered the Containment Building later that day to load 6″ silicon.

09/13/2007 Worker A entered the Equipment Room to perform the morning check.

09/17/2007 Worker A entered the Containment Building and help move a lead shielded container (“pig”) from the Hot Cell into the silicon corral.

09/19/2007 Worker A entered the Equipment Room briefly to perform PM 3.5. Worker A also entered the Containment Building later that day to load 6″ silicon.

09/20/2007 Worker A entered the Containment Building to unload and process 6″ silicon without any assistance.

09/21/2007 Worker A entered the restricted area to package silicon for shipment.

09/23/2007 Worker A entered the restricted area to package silicon for shipment.

09/26/2007 Worker A entered the Equipment Room briefly to perform PM 3.5. The individual also entered the Containment Building to load 6″ silicon with another person. Worker A also entered the restricted area to move items out of the Silicon Storage Area but forgot to turn on his ED. The ED was apparently left off for about four hours.

09/27/2007 Worker A entered the Equipment Room briefly to perform PM 3.5. The individual also helped others package low level radiological waste. Worker A also entered the Containment Building to unload and process 6″ silicon. The person also entered the Equipment Room to investigate a low level shield tank indication and exited (reactor at power); then entered to commence filling the tank and exited; and finally entered to secure filling the shield, then exited.

09/30/2007 *End of the Third Quarter* - The dosimeters for licensee personnel were collected and sent to the vendor for processing.

10/15/2007 The licensee received the exposure results of the dosimetry vendor. The individual with the unplanned high exposure was prohibited from entering restricted areas of the facility, including the reactor containment, and from working with or handling radioactive material.

10/17/2007 The licensee notified the NRC inspector who was on site of the high exposure event.

10/23/2007 A meeting of the MIT Reactor Safeguards Committee (RSC) Standing Subcommittee was held to review the high exposure event and the actions taken to date at that time.

c. Conclusions

Based on the records reviewed, Worker A participated in various high, medium, and low dose rate jobs. It was determined that the majority of the dose to the individual was apparently from the silicon processing activities.

3. Licensee Investigation of the High Exposure Event

a. Inspection Scope (Inspection Procedure [IP] 93812)

The inspectors reviewed the licensee's investigation of the event with respect to Technical Specifications (TS) Sections 7.6 and 7.10 and 10 CFR 20.2202(b)(1)(i) and 20.2203(a)(2). In addition, the inspectors reviewed the procedures and documents listed in Attachments A and B.

b. Observations and Findings

(1) Licensee Investigative Efforts

Once the licensee was notified of the unplanned exposure, the facility took immediate actions by placing the individual in a non-radiological work status, informed the NRC of the unexpected exposure, and took immediate actions to investigate the event. The licensee has sufficient internal procedures to report such an event. However, the facility may need to reassess the periodicity of the RSC meetings to ensure that, should an event occur, a meeting should convene to ensure timely actions and response by the facility.

The licensee divided their investigative efforts into seven categories. These were: 1) Device Review, 2) Personnel Actions, 3) Dose Reconstruction, 4) Records Review, 5) Review of Work Areas, 6) Radiological Information Review, and 7) External Review. The following discusses some of the main actions taken, but is not a comprehensive list of all actions taken by the licensee.

(a) Device Review
- Worker A's dosimetry for the fourth quarter was sent to the vendor for processing.
- The licensee initiated a survey of the dosimetry storage location to check for contamination or other problems which might explain the high doses recorded by the dosimeters.
- The licensee initiated a survey of Worker A's dosimetry to check for contamination which, if present, may explain the high doses recorded by the dosimeters.
- The ED vendor was contacted in an effort to extract all the data possible from the dosimeter.

(b) Personnel Actions
- The licensee conducted extensive interviews with facility staff.
- Worker A was sent for whole body counting to ensure that the high

exposures were not accompanied by intakes of radioactive materials.
- An RSC Standing Subcommittee meeting was held on October 23, 2007, to review the event.
- An RSC Ad Hoc Subcommittee meeting was held on November 15, 2007, to review the high exposure event and the possible causes thereof.

(c) Dose Reconstruction
- The licensee began interviewing Worker A and his coworkers to establish a time-line of activities during the badging period.
- A review of access logs was begun to determine times of entry by workers into the restricted area, as well as entries made into areas with relatively high radiation fields such as the reactor equipment room.
- The licensee initiated an extensive effort to reconstruct the dose received by Worker A.

(d) Records Review
- In addition to those mentioned above, the licensee began a review of year-to-date dose records for all employees and other related records and procedures.

(e) Review of Work and Work Areas
- The silicon processing operation was stopped until a full review could be conducted and those involved could be retrained.
- The licensee initiated an effort to recommission the silicon process.

(f) Radiological Information Review
- Facility surveys were initiated in an attempt to identify any unknown high doses areas that could have caused this problem.
- The licensee also reviewed the postings at the radiologically controlled areas (RCAs) to ensure that they were correct.
- The licensee initiated efforts to develop a dose profile of the Equipment Room to verify the sources of high radiation in that area.
- A check the chart recordings of area radiation monitors in the vicinity of the silicon work area was begun to determine if any unusual readings were recorded.

(g) External Review
- A Certified Health Physicist was retained to conduct a review of the Radiation Protection Program at MITR.
- Health Physicists from the campus EH&S office were consulted and asked to help in the dose reconstruction efforts and analysis of the OSL and TLD results.
- The ED manufacturer was contacted in an effort to clarify the operation and functioning of the dosimeter and help explain if the device might have malfunctioned.
- The dosimetry vendor was contacted in an effort to have them further explain the dose results for Worker A.

(2) NRC Review of the Investigation

The following discusses some of the observations of the NRC Special Inspection Team.

- After determining that the evidence supported the conclusion that Worker A's high recorded doses did reflect actual exposures, and after determining that the silicon operations were the most likely source of these exposures, the licensee performed a detailed dose reconstruction for the exposed worker during the five known separate occasions in which he did silicon work during the 3rd quarter. The reconstruction was based on detailed descriptions of how Worker A performed the work, the layout of the silicon canisters during the work, the location of Worker A with respect to the canisters, knowledge of the usual contact dose rates on the canisters obtained from past experience, and a set of reasonable assumptions regarding the distribution of the radiation field around Worker A. The reconstruction yielded dose estimates with an upper limit of about 3 rem. Considering the assumptions and uncertainties involved in the calculations, the agreement between the reconstructed dose of 3 rem and the dosimeter reading of 4 rem is quite good. The inspectors reviewed the details of the reconstruction and concluded that the assumptions and calculations were valid and reasonable. However, because there were no indications that the dosimetry readouts were faulty, and because these readings involve fewer approximations than the dose reconstruction, the inspectors stated that the dosimetry readings were probably more accurate and representative of the dose received by Worker A, with the dose reconstruction providing strong support for this position.

- During reviews of the electronic dosimetry system and the manner in which it is used, the inspectors noted several weaknesses that were discussed with the licensee. Many of these had already been identified by the licensee prior to the start of the inspection. The electronic dosimeters issued to the workers are set by the system reader in the manner of an on-off switch. Each time the dosimeter is inserted in the reader, it is set to the opposite condition from previous one. If the dosimeter was on, it is turned off and vice versa. It appears that in many cases, workers inadvertently turned off their dosimeters as they entered the restricted area and turned them on as they left. There are indications that this occurred on at least one occasion with the exposed worker. Although the system produces different and distinctive sounds when it turns the dosimeter on and when it turns it off, workers apparently occasionally confuse these sounds, or do not pay attention to them. In some cases, workers do not turn off their dosimeters when they leave the area, and the dosimeter therefore continues to tally time, and dose, until it reaches the maximum time it can record and then resets to the time to zero and restarts timing. Doses accumulated during these periods when the dosimeters are on but not in use are very small because the dosimeters are stored in racks in a low radiation area of the facility.

- The inspectors noted that one of the more significant weaknesses, however, is that the electronic dosimetry system is not provided with adequate software that permits workers and their supervisors to easily monitor ongoing doses during the badging period. Radiation Protection staff did monitor accumulated doses periodically, but there is no formal requirement to do so by supervisors, and most supervisors apparently do not do so on a regular basis. Without this monitoring function, workers are in effect unmonitored, because the quarterly dosimetry reports provide after-the-fact data, and cannot therefore be used to control worker's doses on an ongoing basis, permit access restriction for

workers accumulating high doses, or quickly identify trends that may require immediate corrective actions. The licensee stated that they understood all of these weaknesses, and committed to conduct a review of the entire electronic dosimetry system and the manner in which it is used, and to provide corrective action, including replacing the system if necessary..

c. Conclusions

Actions taken by the licensee following discovery of the high exposure were prompt, comprehensive, and technically sophisticated. The NRC inspection team noted various weaknesses in the licensee's dosimetry program. The licensee had not completed all of the actions that were started as a result of this incident, and committed to continue their efforts until all of the work is completed and all of the weaknesses identified during the inspection have been addressed.

4. Licensee Response to the Event

a. Inspection Scope (IP 98312)

The inspectors reviewed the following concerning the licensee's response with respect to TS Sections 7.6 and 7.10 and 10 CFR 20.2202(b)(1)(i) and 20.2203(a)(2). In addition, the inspectors reviewed the procedures and documents listed in Attachments A and B.

b. Observations and Findings

(1) Licensee Response and Corrective Actions Taken or Planned

The licensee has taken or plans to take the following actions as a result of the exposure event:

(a) *Corrective Action Completed*

(i) Device Review
- Worker A's dosimetry for the fourth quarter was sent to the vendor for processing. The total whole body dose through the middle of October was determined to be 4,629 mrem.
- The dosimetry storage location was checked for contamination or other problems which might explain the high doses recorded by the dosimeters. None was found.
- Worker A's dosimetry was checked for contamination but none was found.
- The licensee exposed spare TLDs and EDs to various sources at the facility to determine if the devices were responding properly. No problems were noted.

(ii) Personnel Actions
- Worker A was restricted from further radiological work for the remainder of the calendar year. This action was taken because the total year-to-date DDE for Worker A was 4.629 rem, which is sufficiently close to the regulatory limit of 5 rem that additional radiation exposure would risk exceeding the limit for the current year.
- Worker A was sent for whole body counting to ensure that the high

exposures were not accompanied by intakes of radioactive materials. No internal contamination was found.

- Various "All Hands" meetings were held with all staff personnel. To date, the licensee has held meetings on four separate occasions with all workers at the facility to discuss the case and any changes to the radiological controls procedures on site that were instituted as a result. The proper use of EDs and the use of manual sign-in sheets when working in a radiation area were two of the various issues discussed.
- Operators were not permitted to perform silicon work until they were retrained on the proper procedures involved in the work and precautions to minimize doses. The retraining was completed during November 19 through 29, 2007.

(iii) Dose Reconstruction

- A time-line of activities during the badging period was established.
- Access logs were checked to determine times of entry by workers into the restricted area, as well as entries made into areas with relatively high radiation fields such as the reactor equipment room.
- The licensee reviewed: security logs, Area Radiation Monitor logs, reactor console logs, hourly logs, silicon reports, Equipment Room entries, Sample Irradiation records, the Daily Operations Schedule, and Phantom ED/TLD results.
- The licensee determined the energy spectrum for the silicon cans and other materials in use at the facility. This did not provide any new information for the dose reconstruction effort.

(iv) Records Review

- The following were reviewed: year-to-date dose records for all employees, TLD reports for co-workers of the individual, the ratios of whole body, shallow dose, and ring dose were checked for consistency, area badge results, Silicon Process Reports, Equipment Room Dose Profile, Silicon Handling Procedures, and individual training records.

(v) Review of Work and Work Areas

- The licensee resurveyed all areas of the facility in an attempt to identify any unknown high doses areas that could have caused this problem. None was found.
- The RRPO instituted a requirement that the Radiation Protection Office was to be contacted prior to any work in any of the RCAs of the facility.

(vi) Radiological Information Review

- The licensee resurveyed all areas of the facility in an attempt to identify any unknown high doses areas that could have caused this problem. None was found.
- The licensee also reviewed the postings at the RCAs to ensure that they were correct. Postings were found to be proper.
- A dose profile of the Equipment Room was developed to verify the sources of high radiation in that area. No new sources were noted.

- Chart recordings of area radiation monitors (ARMs) in the vicinity of the silicon work area were checked to determine if any unusual readings were recorded. None were found. (The inspectors noted that there are two ARMs near the silicon work area, but they are too far, about 25 feet, from the work location to show any unusual fields arising in the work area, even if high radiation fields did exist in that area at any time.)

(vii) External Review

- A Certified Health Physicist was retained to conduct a review of the Radiation Protection Program at MITR and help determine further actions to take to prevent recurrence of such an event. A report had been written but it was not available at the time of the inspection.
- Health Physicists from the campus EH&S office were consulted and asked to help in the dose reconstruction efforts and analysis of the OSL and TLD results. The licensee used their input in developing the dose assignments.
- The ED manufacturer was contacted in an effort to clarify the operation and functioning of the dosimeter and help explain if the device might have malfunctioned. This was still ongoing during the inspection.
- The dosimetry vendor was contacted in an effort to have them explain the apparently contradictory dose results for Worker A. No viable explanation was available at the time of the inspection.

(b) *Corrective Action Pending or Planned*

(i) Device Review

- Analyze the data obtained from exposing spare TLDs and EDs to various sources at the facility.
- Determine codes for ED “states”.
- Obtain additional ARMs for monitoring various work evolutions.
- Revise the ED alarms settings.
- “Turn on” history maintenance for all EDs.

(ii) Personnel Actions

- Retrain staff on how EDs function, the alarms settings, and on the proper use of dosimetry.
- “All Hands” de-briefing concerning the inspection findings. Other “All Hands” meetings are also planned to review the event.

(iii) Dose Reconstruction

- Examine non-routine work activities to determine their possible contribution to high doses at the facility.

(iv) Records Review

- Continue analysis of TLD/ED comparisons.
- Continue analysis and review of the ED system.

(v) Review of Work, Work Areas, and Process
- Review current system for initiating changes or reporting problems to management, i.e., reevaluate the Continuous Improvement Program.
- Complete the review of the current computerized systems in use at the facility to determine the need for revision, replacement, and/or coordination
- Review the current locations of the various ARMs at the facility and determine their adequacy as to location and coverage.

(vi) Radiological Information Review
- Develop a site wide work planning and ALARA review requirement prior to job initiation for all future work evolutions.
- Review the ALARA Program and consider the possibility of revising that program.
- Revise the training program on radioactive materials handling.

(vii) External Review
- Review the report of the Certified Health Physicist retained to conduct a review of the Radiation Protection Program at MITR and determine further actions to be taken to prevent recurrence of such problems.
- Continue to consult with the ED manufacturer in an effort to clarify the operation and functioning of the dosimeter.
- Continue to consult with the dosimetry vendor in an effort to have them explain the apparently contradictory dose results for Worker A.

The licensee was informed that the corrective actions taken to date appear to be appropriate. Those that are yet to be taken will be followed by the NRC as an Inspector Follow-up Item (IFI) and will be reviewed during a future inspection (IFI 50-020/2007-203-01).

c. Conclusions

The licensee's corrective actions, including the dose calculations, were extensive and were found to be acceptable.

5. Root Cause Determination and Related Contributing Actions

a. Inspection Scope (IP 93812)

The inspectors reviewed the licensee's actions to determine the root cause with respect to 10 CFR Parts 19 and 20 and TS Sections 7.5, 7.6, and 7.10. In addition, the inspectors reviewed the procedures and documents listed in Attachments A and B.

b. Observations and Findings

(1) Licensee Root Cause Determination

The licensee reviewed the high exposure event and wrote an internal report, an Unusual Occurrence Report (UOR), UOR No. 2007-1, concerning their findings. The inspectors reviewed a preliminary version of the UOR which described the occurrence and the licensee's response. Based on reconstruction of the individual's dose and the various factors which apparently contributed to the event, the licensee

concluded that the dose was likely the result of improperly handling the silicon and that there were multiple causes for the abnormal exposure. These were divided into two main categories: personnel and programmatic.

In the personnel category, the following were viewed as causes:

- Worker A did not follow the approved procedure for silicon handling. He continued to unload billets even though contact readings exceeded 200 millirem per hour (mr/hr).
- Worker A did not make adequate use of survey meters while unloading the silicon.
- Worker A did not wear the licensee-issued ring badge properly.
- Worker A used poor radiation work practices and stored full and empty cans on carts in the immediate work area thereby creating a plane source in that area.
- The Silicon unload procedure failed to provide sufficient ALARA guidance on the handling of cans.
- There was a lack of a two person rule for unloading silicon.
- The training of Worker A was not adequate as evidenced by the failure to perform adequate surveys and improper use of the finger ring badge.
- There was a failure to implement ALARA practices to minimize dose.
- The individual failed to follow ED login and logout process and was logged into the controlled area for greater than 100 hours.

In the programmatic category, the following were viewed as causes:

- There was an insufficient number of area radiation monitors in the silicon work area and the placement was not optimum.
- There were sufficient problems with the ED so that it was perceived to be unreliable.
- There was no requirement to keep workers informed of their cumulative dose.
- There was a lack of a formal process for management oversight of worker accumulated doses.
- The ALARA review process was inadequate for reviewing site work including the silicon process.
- The training of personnel on the use of the ED system, use of ring badges, and survey meters was inadequate.
- The interface between Operations and the Radiation Protection Office (RPO) was poorly defined.
- Some workers apparently felt that they did not need to follow the written procedures exactly.
- There was no Radiation Protection Office review of the silicon handling procedures.
- The Radiation Protection program was poorly documented.
- A formalized, documented, and reviewed accounting process for dose accumulated on specific work in the field was lacking.
- There was insufficient supervision and review of workers on a regular frequency to assure adherence to written procedures.

(2) NRC Root Cause Investigation

The inspectors reviewed the licensee's actions and associated review following the high exposure event. It was noted that Worker A had apparently not been properly

trained in the health protection problems associated with exposure to radiation or radioactive materials, in precautions to minimize exposure, and in the purposes and functions of protective devices. As a result the individual was not wearing his finger ring correctly and did not take actions and/or precautions that would have minimized his exposure. Training in other areas such as use of survey meters when working with radioactive material and following procedure was also viewed as inadequate.

Contributing factors were considered as well. The most apparent factor was the failure to follow licensee procedure. This resulted in the individual removing silicon canisters from the conveyor system that had dose rates in excess of the established limit. As the canisters with high dose rates were accumulated, the individual created a source term with a significant dose rate. The person then proceeded to work in that area for up to two hours. Another issue was the failure to conduct adequate surveys prior to the incident and during the periods when the person likely received the high exposure. The inspectors also noted that the licensee had not made measurements to determine the types of energies of the radiations from the silicon process to which the workers were exposed in this process.

Various other contributing factors were also noted and were discussed with the licensee. Many of these were captured in the licensee's UOR (and are noted above). Management attention and support is warranted to correct these issues.

c. Conclusions

The licensee determined that there were a multitude of causes for this event. The NRC concluded that inadequate training of Worker A was the basic problem. This lead to failure to make adequate surveys to fully establish the radiological hazards that were present during silicon processing activities. Failure to follow procedure also caused Worker A to receive excessive dose.

6. Dose Assessment

a. Inspection Scope (IP 93812)

The inspectors reviewed the licensee's dose assessment with respect to 10 CFR Parts 19 and 20 and TS Sections 7.5, 7.6, and 7.10. In addition, the inspectors reviewed the procedures and documents listed in Attachments A and B.

b. Observations and Findings

The purpose of this part of the special inspection was to assess the licensee's dose assessments after identifying the unusually high exposures recorded by one worker's dosimeter and to review any corrective actions implemented by the licensee in this area

(1) Licensee Dose Assessment

(a) Initial Notification

Upon receiving the third quarter dosimetry results from the vendor, the RRPO reviewed the electronic data and found the OSL dosimetry results for Worker A were 4041 millirem (mrem) whole body dose or deep dose equivalent (DDE), 4231 mrem lens dose equivalent (LDE), 4773 mrem shallow dose equivalent

(SDE), and an extremity dose from the associated ring badge of 5810 mrem SDE. The RRPO then verified these values with the dosimetry vendor, requested a reanalysis, and calculated the year-to-date dose for the individual to be 4560 mrem DDE, 4750 mrem LDE, 5269 mrem SDE, and 6470 mrem SDE to the extremities. An additional 58 mrem whole body dose for the fourth quarter was estimated by using the results of the ED for a total whole body dose of 4618 mrem. Although no regulatory limits were exceeded, the RRPO and MITR management restricted the individual from further access to the RCA and informed the NRC inspector who was on site conducting a routine inspection. The individual's fourth quarter dosimetry was immediately sent in for processing. With those results, the final year-to-date dose totals were calculated to be: 4629 mrem whole body DDE, 4819 mrem LDE, 5340 mrem SDE, and 6660 mrem SDE to the extremities.

(b) Investigation into Work Performed

As noted previously, the licensee conducted numerous interviews with various staff members, conducted an extensive review of various facility logs and assorted records, and conducted tests and reenactments. These actions lead the licensee to conclude that the silicon process likely caused the majority of the exposure in this event. The Reactor Radiation Protection staff then made various assumptions concerning the silicon loading and offloading process. As a result, a total estimated dose for Worker A of 2520 mrem was calculated for the offload work and 56 mrem for the loading work. The dose from other maintenance work, training activities, sample handling, and equipment room entries was estimated to be 490 mrem for a total estimated or calculated dose of 3066 mrem.

(c) Dose Assignment

Since the estimated whole body dose of 3066 mrem was reasonably close to that reported on the TLD, the licensee decided to assign Worker A the final dose as reported by the TLD. Therefore, the final doses for Worker A for the third quarter were assigned as: 4041 mrem whole body DDE, 4231 mrem LDE,and 4733 mrem SDE.

The finger ring dose assigned was conservatively doubled because the individual had lost his original ring half way through the third quarter and a new ring was issued on August 16, 2007. The dose to the extremities for the third quarter was assigned as 11,620 mrem SDE.

(2) NRC Review of the Dose Assessment

(a) Dosimetry Readings

The main dosimeter provided to workers at the MIT reactor facility, and the one used to provide formal documentation of workers' exposures, is an OSL dosimeter. Dosimeters are issued to monitored personnel at the beginning of the badging period, and returned to the dosimetry vendor at the end of the period for processing and dose reporting. The MIT facility uses a quarterly badging cycle, issuing new badges and collecting the exposed ones at the beginning of each calendar quarter.

The sensitive element of the dosimeter is enclosed in a holder that is provided with four windows, each covering part of the element, and each window is provided with a different filter, as shown in Table 2 below (thicknesses rounded to the nearest milligram per centimeter squared (mg/cm^2)).

Table 2

Location of Element	Window Filter	Thickness - mg/cm^2
Area 1	Paper & plastic	38
Area 2	Paper & plastic	207
Area 3	Paper, plastic, aluminum, & copper	799
Area 4	Paper, plastic, & aluminum	267

The readouts from the four areas of an exposed dosimeter are entered into a proprietary algorithm maintained by the vendor that calculates the shallow dose equivalent (SDE), lens dose equivalent (LDE), and deep dose equivalent (DDE), all doses required to be monitored by 10 CFR Part 20. Table 3 illustrates the results of the dosimetry report for the 3rd quarter 2007 which showed the following doses for Worker A:

Table 3

Dose Equivalents	Calculated Dose
Shallow Dose Equivalent (SDE)	4733 millirem
Lens Dose Equivalent (LDE)	4231 millirem
Deep Dose Equivalent (DDE)	4041 millirem

There were no neutron exposures, and the exposure pattern on the dosimeter indicated little if any beta exposure. Upon receipt of this report, the licensee asked the vendor to reexamine the data and verify its accuracy, and also to report the raw data, that is, the readings of the four dosimeter areas before processing through the algorithm. These readings were as follows:

Table 4

Location of Element	Readings Before Processing Through the Algorithm
Area 1	2811 millirem
Area 2	2350 millirem
Area 3	4329 millirem
Area 4	2707 millirem

The vendor reported that the readouts from the dosimeter did not show any indications of abnormal behavior, and that their examination of the dosimeter and its response characteristics did not indicate that the dosimeter had malfunctioned, although there was some indication that the radiation may have been incident on the dosimeter at a somewhat acute angle. The licensee, however, considered the readings shown above to indicate possible erroneous readings because the ratio of the readings from Area 3 to Area 1 was 1.54, much higher than the ratio normally observed at the facility of 0.9 - 1.1. At the time these factors were being considered, the licensee had not identified any radiation source sufficiently intense, and exposure durations sufficiently long, to account for the observed readings.

The inspectors reviewed the dosimetry data provided by the licensee and by the dosimetry vendor, as well as dosimetry records for all workers for the previous 12-month period. The inspectors also performed their own calculations to determine the expected response of the dosimeter under different irradiation conditions. The purpose of the calculations was to determine if the high ratio of 1.54 observed in this case could have been the result of unusual exposure conditions. The calculations showed that the observed ratio would be expected to occur under certain irradiation conditions that could have existed when Worker A received the dose recorded by his dosimetry. Specifically, the calculations showed that the relatively thick filter over Area 3 acts as a charged particle build-up layer, enhancing the dose delivered to the underlying area compared with that for the lightly filtered Area 1. This effect is not significant at the lower photon energies for which the dosimeter is calibrated, normally 0.66 million electron volts (MeV), and that would normally be expected when much of the radiation exposures are due to scattered radiation. However, the build-up becomes increasingly marked as the photon energy increases above about 1 MeV, causing the reading under Area 3 to rise more rapidly in comparison with that under Area 1 with increasing photon energy. Such conditions could have existed if Worker A was exposed to a higher proportion of direct radiation from the source than is normally encountered at the facility. Given this information and the vendor's report that the dosimeter was not defective, the inspectors concluded that the dosimeter readings are unlikely to be erroneous. This conclusion was supported by reviews of past dosimetry records, which showed that the dosimeter issued to the same worker for the 2nd quarter of 2007 also showed the same unusual ratio as that seen for the 3rd quarter. It appeared, therefore, that the unusual dosimeter pattern was caused by the nature of Worker A's activities rather than by a defect in the dosimetry.

The conclusion that the dosimeter readings are probably valid was further supported by the readings of the ring dosimeter that Worker A was using during the 3rd quarter. Workers are issued ring dosimeters that are used whenever they handle radioactive materials. The dosimeter is in the form of a plastic ring containing one thermoluminescent chip enclosed in a protective cover. The dosimeter is intended to be worn on the finger closest to the source of the radiation, with the TLD chip facing the palm side of the hand. Interviews with the exposed worker revealed that he did wear his ring dosimeter during work activities, but that the dosimeter was worn on the small finger because it would not fit on any of the other fingers. It was also worn with the TLD chip facing the back of the hand. In this configuration, the dosimeter monitored the general

area radiation in the vicinity of the hand rather than the dose to the hand. Processing of the TLD chip at the end of the 3rd quarter showed a dose of 5830 mrem. Since the two dosimeters worn by Worker A are independent of each other and are processed differently, the inspectors viewed the possibility that two independent dosimeters malfunctioned and both read high and nearly equal doses as being very unlikely, and it was therefore concluded that the dose readings are valid.

The dose received by Worker A's hands could not be estimated without identifying the source of the radiation exposure. This is because the TLD reading may have been a result of the existence of a high general area radiation field, and the dose to the hand in this case would be about the same as the shallow dose equivalent recorded by the OSL dosimeter. On the other hand, if the radiation field was caused by an object being handled by Worker A, then the dose to the hands would be expected to be considerably higher than that recorded by the ring dosimeter. The next step in reviewing the dosimetry for this case was to identify the source of the radiation field to which Worker A was exposed.

(b) Source of the High Exposure

The conclusion that the dosimeter readings are valid and that Worker A had in fact been exposed to a high radiation field led to a search for areas and activities at the facility that could deliver such a dose. Current and past radiation surveys of the facility were reviewed, and records were examined to determine the activities performed by Worker A during the 3rd quarter 2007. Based on the findings from these reviews, it was concluded that the silicon operation was the only plausible candidate. This does not eliminate all other possibilities, since there may still be an unknown source of exposure that had not been identified. This is unlikely, however, because detailed reviews of Worker A's involvement in silicon work provided the circumstances that can account for the high exposures. Although some areas of the facility, such as the reactor equipment room, had radiation levels of around 1 rem/hr or more during reactor operation, stay times in these areas are carefully controlled and are limited to a few minutes. These short exposure durations do not provide adequate time to result in accumulation of a 4 rem dose.

Silicon work involves placing the silicon ingots inside magnesium cans, irradiating the cans in the reactor for specified time intervals, removing the cans after a suitable decay time period, and removing the silicon from the cans. A review of reports describing the silicon operation showed that neutron irradiation produces ^{31}Si, a radioactive isotope of silicon that has a half-life of about 2.6 hours and is a nearly pure beta emitter. There are no significant impurities in the silicon that may produce other activation products because the silicon is electronic grade, ultra pure, material. The source of the high radiation fields is therefore not the silicon but the magnesium cans in which they are placed for irradiation. At the time of the inspection, the licensee did not know what isotopes were activated in the magnesium material, nor the characteristics of the radiations emitted by the cans. However, it was known that the cans do become quite radioactive, and could read contact dose rates in excess of 200 mrem/hr when they reach the reactor's silicon removal port.

Detailed interviews with Worker A revealed that he had been involved in five silicon jobs during the 3rd quarter, each lasting up to an estimated 90 minutes. In addition, the manner in which the work was performed deviated significantly from that normally used by the other workers who perform silicon work. The usual methods of handling the silicon cans is to place one can at a time on the work table, perform the work necessary to remove the silicon from the can, store the can behind a shield, and then proceed to the next can. In this case, however, it appears that all the cans in the batch, which could number up to 15, were placed in the vicinity of Worker A at the same time, and they remained there during work on all of the cans, thereby creating a high radiation field in the work area.

Interviews and document reviews also provided evidence that supported the existence of a high radiation field in the area where this person worked. Among the dosimetry issued to workers involved in this type of activity is an alarming dosimeter, which alarms at preset doses and dose rates. The dose rate has two settings: warning and alarm, with the warning set at 100 mrem/hr and the alarm at 1 rem/hr. The warning on Worker A's dosimeter sounded several times during the silicon work periods, and Worker A reset the dosimeter each time it alarmed but did not stop work and contact Radiation Protection, as is normally required. These warnings indicate that radiation fields existed in the work area that were between 100 mrem/hr and 1 rem/hr. The combination of radiation fields of this magnitude and a total work duration of up to 7 – 8 hours provides sufficient exposure to account for the doses recorded by both the whole body dosimeter and the finger dosimeter. There is little doubt therefore that the exposures recorded by the dosimetry are real and that they occurred in connection with improper work practices during silicon operations. The evidence supporting this conclusion, however, is circumstantial, and cannot be proven conclusively.

(c) Shallow Dose Equivalent

As indicated above, Worker A wore his ring dosimeter on the small finger of his hand, with the TLD chip facing away from the palm. Placing the dosimeter on the small finger is likely to put it away from the highest exposed part of the palm. Having determined that Worker A's high exposures most probably resulted from handling the silicon cans, the dose to the hands would be expected to be higher than the 5810 mrem recorded by the ring dosimeter, because of the incorrect placement of the dosimeter. A review of the dosimetry records for workers involved in silicon operations showed that the ratio of the finger ring dose to the DDE is about 1.5 – 2.2. Multiplying Worker A's 3rd quarter DDE of 4041 mrem by these ratios gives a range for the SDE for the quarter of 6000 – 9000 mrem. The dosimetry records for the other quarters of 2007 showed a total ring dosimeter dose for this worker of 660 mrem. The total for the year is therefore of the order of 10 rem, which is substantially below the regulatory limit of 50 rem/yr. One complicating factor was that Worker A had lost his finer ring dosimeter halfway into the third quarter, and any dose recorded on that dosimeter was lost. However, records showed that Worker A was in training during the 3rd quarter up to the time a new finger ring was

issued, and he had not been involved in silicon work during that quarter before that date. Therefore, any dose that may have been recorded on the lost dosimeter was probably very small.

(d) Electronic Dosimetry

Each worker who enters the restricted area at the reactor facility is assigned an electronic dosimeter in addition to the OSL and ring dosimeters. The electronic dosimeter also functions as an alarming dosimeter and an alarming dose rate meter, and has warning and alarm settings for both the dose and dose rate readings. The dose rate warning is set at 100 mrem/hr and the alarm at 1 rem/hr, and the dose warning is set at 20 mrem and the alarm at 50 mrem. A worker entering the restricted area places the dosimeter in a reader that turns the dosimeter on and resets its internal clock, and when leaving the area again places the dosimeter in the reader. The reader records the data on the dosimeter and turns it off. The electronic dosimeter assigned to Worker A registered a total dose of 199 mrem DDE for the quarter, which is considerably lower than the 4041 mrem registered by the OSL dosimeter and the 5810 mrem recorded by the ring dosimeter.

The licensee attempted to determine the reasons for this large discrepancy, and also contacted the manufacturer for assistance in retrieving data stored in the system. These efforts were unsuccessful at the time the inspection ended, but the licensee committed to continue in its attempts to understand the behavior of the dosimeter. The inspectors reviewed the manner in which the electronic dosimeters are used by observation and interviews with workers, and concluded that the system is not sufficiently reliable to cast serious doubt on findings obtained from other sources regarding the magnitude of Worker A's exposures, and the 199 mrem reading is considered an anomaly that may eventually be resolved by the licensee.

c. Conclusions

Based upon various factors, including the vendor's report that the dosimeter was not defective, the inspectors concluded that the dosimeter readings were unlikely to be erroneous. Also, the Electronic Dosimetry system used by the licensee was not sufficiently reliable to cast serious doubt on findings obtained from the vendor-supplied dosimeters. Therefore, the dose assigned to Worker A by the licensee was appropriate.

7. Procedures and Training

a. Inspection Scope (IP 93812)

The inspectors reviewed the licensee's program for training with respect to 10 CFR 19.12, radiation protection program with respect to 10 CFR 20.1501 concerning surveys, and Technical Specifications (TS) Section 7.8 concerning facility procedures. In addition, the inspectors reviewed the procedures and documents listed in Attachments A and B.

b. Observations and Findings

(1) TS Required Procedures

The inspectors reviewed various MIT-NRL procedures. These procedures provided guidance for the administrative, operations, and radiation protection functions to be used during various activities at the facility including the silicon processing operation. The inspectors confirmed that written procedures were available for those tasks and items required by TS Section 7.8. The licensee controlled changes to procedures and the MIT Reactor Safeguard Committee conducted the review and approval process as required.

(2) Regulatory Issues

10 CFR 20.1501 requires that (a) Each licensee shall make or cause to be made, surveys that--(1) May be necessary for the licensee to comply with the regulations in this part; and (2) Are reasonable under the circumstances to evaluate--(i) The magnitude and extent of radiation levels; and (ii) Concentrations or quantities of radioactive material; and (iii) The potential radiological hazards.

The inspectors reviewed the MIT-NRL procedures used during silicon processing. It was noted that silicon processing was apparently the major contribution to the dose of the individual. During this review, the inspectors noted that the procedures were not followed by Worker A. Examples of this include improperly maintaining the magnesium cans and lids on the work table, not performing surveys due to changing radiological conditions, and not performing surveys during silicon ingot removal. In addition, it was noted that these procedures did not readily identify precautions or radiological hazards that may be involved during the Si process. It was further noted that Worker A failed to report to RPPO upon receiving an alarming dose on the ED and did not reassess the changing work conditions when the dose rate alarm on the ED continued to alarm. This was contrary to the safety process as described in the training of the individual, which the facility described as a procedure. The licensee was informed that failure to conduct adequate surveys was an apparent violation (VIO) of 10 CFR 20.1501 (VIO 50-020/2007-203-02).

As a second example of failure to conduct an adequate survey, the inspectors noted that, prior to the high exposure event, the licensee had not determined the radiological characteristics of the silicon processing operation. For example, they had not determined what materials were activated when the magnesium cans were irradiated in the reactor and what the energy spectrum was for the cans. Consequently, the licensee did not know what type of radiation (low energy or high energy) was emitted. Also, they had not investigated the possibility of using cans with compositions that such as to minimize the production of activation products. Again, this noted as a second example of failure to conduct an adequate survey.

In response to the event, RPPO initiated increased radiological controls by having an RP technician present during all Si processes. The RPPO also established an ED log book to be used by personnel entering containment and increased monitoring of the ED database on a daily basis. In addition, the silicon procedures were revised to clearly require that individuals monitor the radiation levels in the work area during silicon processing operations. The RP group then conducted training for all individuals concerning of the procedure changes and increased

radiological controls. In addition, the licensee conducted experiments to determine the energy spectrum of the silicon cans and other materials in use at the facility. The licensee indicated, however, that this did not provide much useful information for the high exposure event.

The facility has responded to this event with due diligence and attention. Although the facility does not have a formal deficiency log to track, monitor, and ensure timely completion of deficiencies identified, the RP staff does have an internal database that they use to track an lessons learned and will incorporate the actions as a result of this event in that database.

(3) Procedural Issues

TS Section 7.8 requires that the licensee will have operating procedures. MIT-NRL Silicon Program, Procedure No. 7.5.1-2, "6″ Unload Procedure," Rev. A, dated July 26, 2004, required in Section 4.1 that the person performing the offloading operation stop unloading materials when the dose rates reach 200 millirem per hour (mr/hr).

The inspectors conducted an extensive interview with Worker A. The inspectors inquired about how Worker A followed the procedure for loading and unloading the silicon can during processing operations. The person indicated that, on various occasions, he had continued to unload silicon cans from the conveyor system even though the dose rates on the cans indicated a dose rate in excess of 200 mr/hr. He realized that this was contrary to procedure but wanted to get the job done. If he had not removed the silicon cans then, the work would have had to be completed at a later date. The licensee had also conducted an interview with Worker A and had identified this as a problem with this person's approach to silicon processing. As has been indicated previously, Worker A was immediately prohibited from entering restricted areas of the facility, including the reactor containment, and from working with or handling radioactive material. The licensee also briefed the individual in the seriousness of his actions and counseled him that his actions were not appropriate. "All Hands" meetings were also held to inform the entire staff of the problem and instruct them to follow the procedure or stop work and have the procedure revised or evaluated so that corrections could be made.

The licensee was informed that, because the violation was identified by the licensee was not repetitive, was not willful, and because significant remedial actions were taken, this will be identified as a Non-Cited Violation (NCV) in accordance with Section VI.A.8 of the NRC Enforcement Policy (NCV 50-020/2007-203-03).

(4) Training Issues

10 CFR 19.12 requires that all individuals who, in the course of employment, are likely to receive in a year an occupational dose in excess of 100 mrem shall be instructed in the health protection problems associated with exposure to radiation and/or radioactive material, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed

The inspectors conducted an extensive interview with Worker A. The inspectors noted that Worker A had not received adequate training in various areas. During

silicon processing operations, on various occasions, the person conducting the work had not been properly instructed in the purposes and functions of protective devices. This was exemplified by the fact that the individual was wearing his extremity dosimeter (finger ring) with the portion containing the TLD chip facing out instead of facing in, which is the proper way to wear the finger ring. With the finger ring facing in, the TLD chip would be in close contact with the radioactive materials being handled and this would provide a more complete and accurate indication of the dose received by the hands. The licensee was informed that failure to provide a worker with adequate training was an apparent violation of 10 CFR 19.12 (VIO 50-020/2007-203-04).

c. Conclusions

The NRC inspection team identified two apparent violations and one Non-Cited Violation. Based on the procedures and records reviewed and observations of MIT NRL staff during the inspection, the inspectors determined that the licensee did respond to the event and the problems noted with rigorous and directed actions. The facility does have a tracking system, although internal to the RPPO, to track, monitor, and ensure timely completion of corrective actions. However, because of the magnitude and the interactions needed to strengthen the radiation protection program and ALARA program, management needs to be actively involved to support and respond as necessary to ensure action items are completed in a timely manner.

8. Exit Meeting

The inspectors presented the inspection results to licensee representatives at the conclusion of the inspection on November 1 and on November 20, 2007. The inspectors discussed the observations for each area reviewed. The licensee acknowledged the findings and did not identify as proprietary any of the material provided to or reviewed by the inspectors during the routine inspection.

PARTIAL LIST OF PERSONS CONTACTED

Licensee Personnel

J. Bernard	Director of Reactor Operations
E. Block	Maintenance Supervisor
P. Drooff	Health Physicist, Reactor Radiation Protection, EHS
J. Foster	Assistant Superintendent of Operations
R. Dresios	Senior Technician, Reactor Radiation Protection, EHS
D. Kelly	Senior Reactor Operator
E. Lau	Assistant Operations Superintendent
F. McWilliams	Reactor Radiation Protection Officer and Deputy Director, EHS
D. Moncton	Director of the MIT Nuclear Reactor Laboratory
T. Newton	Associate Director, Reactor Engineering
B. Rice	Project Technician, Reactor Radiation Protection, EHS
S. Tucker	Quality Assurance Supervisor

Other Personnel

L. DiBerardinis	Director of Environmental Health and Safety, MIT
W. McCarthy	Senior Officer, Environmental Health and Safety, MIT
W. VanSchalkwyk	Managing Director, Environmental Health and Safety Programs, MIT

INSPECTION PROCEDURES USED

IP 93812 Special Inspection

ITEMS OPENED, CLOSED, AND DISCUSSED

OPENED:

50-020/2007-203-01	IFI	Follow-up on the licensee's corrective actions that are yet to be taken in response to the higher than expected exposure event.
50-020/2007-203-02	VIO	Failure to conduct adequate surveys of the work area as required by 10 CFR 20.1501.
50-020/2007-203-03	NCV	Failure to follow procedure in that the worker removed silicon canisters reading greater than the 200 mr/hr limit stipulated in NTR MIT-NRL Silicon Program, Procedure No. 7.5.1-2, "6″ Unload Procedure," Rev. A, dated July 26, 2004.
50-020/2007-203-04	VIO	Failure to provide the worker involved adequate training in health protection problems associated with exposure to radiation and/or radioactive material, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices as required by 10 CFR 19.12

CLOSED:

50-020/2007-203-03	NCV	Failure to follow procedure in that the worker removed silicon canisters reading greater than the 200 mr/hr limit stipulated in NTR MIT-NRL Silicon Program, Procedure No. 7.5.1-2, "6″ Unload Procedure," Rev. A, dated July 26, 2004.

LIST OF ACRONYMS USED

10 CFR	Title 10 of the *Code of Federal Regulations*
ACI	Advanced Clad Irradiation
ADAMS	Agencywide Documents Access and Management System
ALARA	As Low As Reasonably Achievable
ARMs	Area Radiation Monitors
ASO	Assistant Superintendent of Operations
CFR	*Code of Federal Regulations*
CIP	Continuous Improvement Program
DDE	Deep dose equivalent
ED	Electronic dosimeter
EH&S	Environmental Health and Safety
IFI	Inspector Follow-up Item
IP	Inspection Procedure
LDE	Lens dose equivalent
MeV	million electron volts
MIT	Massachusetts Institute of Technology
MITR	Massachusetts Institute of Technology Research Reactor
mrem	millirem
mrem/hr	millirem per hour
NCV	Non-cited violation
NRC	Nuclear Regulatory Commission
NRL	Nuclear Reactor Laboratory
OSL	Optically stimulated luminescent (dosimeter)
RCA	Radiologically Controlled Area
Rev.	Revision
RO	Reactor Operator
RRPO	Reactor Radiation Protection Officer
RSC	Reactor Safeguards Committee
SDE	Shallow dose equivalent
SRO	Senior Reactor Operator
TC	Training Coordinator
TLD	Thermoluminescent dosimeter
TS	Technical Specification
UOR	Unusual Occurrence Report
VIO	Violation

Attachment A

Licensee Procedures Reviewed

- Massachusetts Institute of Technology – Nuclear Reactor Laboratory (MIT-NRL) Administrative Procedure No. 1.1, "Organization," Subsection 1.1.3, "Radiation Protection Office," latest revision dated September 19, 1979
- MIT-NRL Administrative Procedure No. 1.4, "Review and Approval of Plans, Procedures, and Facility Equipment and Changes Thereto," latest revision dated June 22, 1988
- MIT-NRL Administrative Procedure No. 1.11, "Radiation Protection Office," latest revision dated September 19, 1979
- MIT-NRL Administrative Procedure No. 1.12, "Radiological Training and Dosimetry Classification," latest revision dated November 9, 2004
- MIT-NRL Silicon Program, Procedure Number (No.) 7.1-1, "Silicon Irradiation Planning," Revision (Rev.). F, dated November 17, 2005
- MIT-NRL Silicon Program, Procedure No. 7.5.1-1, "6″ Load Procedure," Rev. B, dated July 26, 2004
- MIT-NRL Silicon Program, Procedure No. 7.5.1-2, "6″ Unload Procedure," Rev. A, dated July 26, 2004
- MIT-NRL Silicon Program, Procedure No. 7.5.1-3, "4″ Load Procedure," Rev. B, dated September 16, 2004
- MIT-NRL Silicon Program, Procedure No. 7.5.1-4, "4″ Unload Procedure," Rev. A, dated July 27, 2004
- MIT-NRL Silicon Program, Procedure No. 7.5.1-7, "Cleaning Empty Cans and Dummies," Rev. A, dated July 29, 2004
- MIT-NRL Silicon Program, Procedure No. 7.5.5-1, "General Radiological Guidelines," Rev. A, dated August 2, 2004
- MIT-NRL Silicon Program, Procedure No. 7.5.1-1, "6″ Load Procedure," Rev. D, dated November 18, 2007
- MIT-NRL Silicon Program, Procedure No. 7.5.1-2, "6″ Unload Procedure," Rev. C, dated November 18, 2007
- MIT-NRL Silicon Program, Procedure No. 7.5.1-3, "4″ Load Procedure," Rev. D, dated November 18, 2007
- MIT-NRL Silicon Program, Procedure No. 7.5.1-4, "4″ Unload Procedure," Rev. C, dated November 18, 2007
- MIT-NRL Silicon Program, Procedure No. 7.5.1-7, "Cleaning Empty Cans and Dummies," Rev. C, dated November 18, 2007
- MIT-NRL Silicon Program, Procedure No. 7.5.5-1, "General Radiological Guidelines," Rev. C, dated November 18, 2007
- MIT-NRL Preventive Maintenance (PM) Procedure No. 3.1.1.1, "Startup Checklists – Two Loop Mechanical," dated August 28, 2006
- MIT-NRL PM Procedure No. 3.1.1.2, "Full Power Startup Checklist – Two Loop Instrumentation," dated August 29, 2006
- MIT-NRL PM Procedure No. 3.1.3, "Startup for Less Than 100 kW Operation," dated July 11, 2005
- MIT-NRL PM Procedure No. 3.1.5, "Independent ECP Calculation," dated September 27, 1991
- MIT-NRL PM Procedure No. 3.1.6, "Restart Following an Unanticipated or a Brief-Duration Scheduled Shutdown," dated September 27, 1991
- MIT-NRL PM Procedure No. 3.2.1, "Shutdown Checklists," dated July 25, 2005
- MIT-NRL PM Procedure No. 3.2.2, "Shutdown from Less Than 100 kW Operation," dated July 11, 2005
- MIT-NRL PM Procedure No. 3.2.3, "Maintenance Checklist," dated April 25, 1997

- MIT-NRL PM Procedure No. 3.3.1, “Movement of Fuel - Refueling,” dated January 10, 1994
- MIT-NRL PM Procedure No. 3.3.1.1, “Fuel Element Transfers: Core/Storage Ring/Vault,” dated April 22, 1980
- MIT-NRL PM Procedure No. 3.3.3, “General Conduct of Removal of Spent Fuel,” dated July 28, 1981
- MIT-NRL PM Procedure No. 3.3.2.1, “Fuel Element Transfers: Storage Ring/Storage Pool,” dated July 28, 1981
- MIT-NRL PM Procedure No. 3.3.3, “General Conduct of Transfer of Spent Fuel To Fission Converter,” dated February 2, 2000
- MIT-NRL PM Procedure No. 3.5, “Daily Surveillance Check,” dated May 25, 2004
- MIT-NRL PM Procedure No. 3.6, “Waste Storage Tank Dump Procedure,” dated November 27, 1996
- MIT-NRL PM Procedure No. 3.8.1A, “Makeup Water System Check List,” dated July 1, 1975
- MIT-NRL PM Procedure No. 3.9, “Transfer of D_2O Between Storage and Dump Tanks,” dated July 24, 1975
- MIT-NRL PM Procedure No. 3.11.2, “3GV Sample Procedure,” dated April 18, 1995
- MITR Reactor Radiation Protection (RRP) Procedure No. 3001, “Radiological Surveys,” Rev. 4, dated October 2003, and associated forms
- MITR RRP Procedure No. 4008, “Area Radiation Monitoring System - Quarterly,” Rev. 5, dated May 2007, and associated tables and forms

Attachment B

Licensee Documents and/or Vendor Documents Reviewed

Annual Reports for the MIT Nuclear Reactor Laboratory for 2005 and 2006
Daily Operations Schedule maintained by the Superintendent of Operations
DMC-2000 Electronic Dosimetry System Signoff form (for Worker A)
Dose Evaluation Report (for Worker A) including Attachments A through I:
- Attachment A – Dose Evaluation Report Investigation
- Attachment B – UOR (Unusual Occurrence Report) No. 2007-1
- Attachment C – Landauer High Dose Investigation Report
- Attachment D – Landauer TLD reports for individuals
- Attachment E – Security Logs
- Attachment F – ED System Logs
- Attachment G – Individual Work Summary for Third Quarter
- Attachment H – Site ED/Whole Body Badge Ratio – Third Quarter 2007
- Attachment I – High Dose Investigation Actions

Dosimeters Off-Scale and Lost Dosimetry Report (for Worker A) dated August 16, 2007
Electronic Dosimeter Logs and associated reports and records
High Dose Investigation Actions, copy updated November 19, 2007
Instructions for Taking Web-Based General Employee Radiological Training
Licensee's timeline development which included security logs, Reactor Console logs, hourly logs, Silicon Production Reports, Equipment Room entries, Sample Irradiation records, Area Radiological Monitor logs, listing of high, medium, and low dose contributors
MIT Reactor Radiation Protection GERT Reactor Practicum Checklist (for Worker A)
MITR Security logs and associated records
Personnel dosimetry records for 2006 through the present
Reactor General Employee Radiological Training course and outline
Reactor Radiation Protection Qualification Form for Issuance of Dosimetry (for Worker A)
Reactor Safeguards Committee meeting minutes from 2006 through the present including the RSC Standing Subcommittee meeting on October 23, 2007, and the RSC Ad Hoc Subcommittee meeting held on November 15, 2007
Reactor Safeguards Committee completed audits and reviews from 2006 through the present
Recommissioning Plan for Silicon Operations, dated November 15, 2007
Revised Electronic Dosimetry Training (Features, Uses, and Responses to Alarms) – to be presented to all staff members
Safety Review Form No. 0-07-4, "NTD Silicon Procedures for Radiological Guidelines, Unload, Load, and Cleaning Cans/Dummies," dated November 7, 2007
Various licensee E-mails
Worker A Daily Activity Report for the Third Quarter 2007