May 11, 2006

EA-06-113

Dr. Theresa A. Maldonado, Deputy Director
Texas Engineering Experiment Station
Texas A&M University
1095 Nuclear Science Road
College Station, TX 77843-3575

SUBJECT: NRC SPECIAL INSPECTION REPORT NO. 50-128/2006-203 AND NOTICE OF VIOLATION

Dear Dr. Maldonado:

On March 29, 2006, the Nuclear Regulatory Commission (NRC) completed a Special Inspection at your Texas Engineering Experiment Station, Nuclear Science Center Research Reactor 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 and with the conditions of your license. Within these areas, the inspection included selected examination of procedures and representative records, observations of activities, and interviews with personnel. The enclosed report documents the inspection findings, which were discussed with you, Dr. W. D. Reece, the Facility Director, and Dr. Latha Vasudevan, the facility Radiation Safety Officer, on March 29, 2006.

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 Texas Engineering Experiment Station, Nuclear Science Center (NSC) 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. At the end of January 2006, the NSC Radiation Safety Officer (RSO) gathered all the dosimeters used during the month by facility personnel and sent them to the dosimetry vendor for processing. The RSO did not receive the dosimetry results report until February 24, 2006. The report indicated that a worker, who had been conducting neutron activation analysis (NAA) using the pneumatic transfer system during January, had received a potential extremity overexposure. The NSC Facility Director and RSO immediately noted the results, restricted the worker from further work with radioactive material that would contribute to an extremity dose, and began a review of the situation. After consideration of various factors, the Director and RSO determined that the extremity dose was an apparent anomalous result. The person involved was placed on "restricted" duty and allowed to continue work, although all the sample processing work for February had been completed at that point.

At the end of February, personnel dosimeters were again gathered and sent to the vendor for processing. Those dosimetry results, which were received on March 15, 2006, indicated that the worker conducting NAA using the pneumatic system had received a much higher than normal extremity dose during February. The licensee notified the NRC of the event on March 15, 2006. Subsequently, by written report dated April 14, 2006, you concluded that there was no overexposure of that individual or any individual at your facility. Additionally in your

written report you indicated that you have taken or plan to take various steps to prevent overexposure of individuals conducting NAA at your facility. These steps include that manufacturing holders and manipulators to minimize extremity doses from NAA work, conducting additional training on NAA and general handling of radioactive materials for employees, establishing a contractual agreement with your dosimetry provider to ensure that you receive immediate notification of doses greater than the annual regulatory limits, mounting a permanent radiation detector in NAA work area, developing specific written procedures on NAA work, and providing additional dosimetry for those involved in NAA work over the next several months.

Due to the significance of the potential overexposure event, an NRC inspector was dispatched to the site and arrived on March 20, 2006. Because of the complicated nature of personnel monitoring, dosimetry processing, and the apparent incongruent dosimetry results, a Special Inspection Team was assigned to review the event. The Special Inspection Team began their review on March 27, 2006.

Based on the results of this inspection, the NRC has determined that a Severity Level IV violation of NRC requirements occurred. The violation was 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 violation is cited in the enclosed Notice of Violation (Notice) and the circumstances surrounding it are described in detail in the subject inspection report. The violation is being cited in the Notice because the facility's staff had prior opportunity to identify the problem (on noting the higher extremity dose to a worker in October 2005), but failed to take action to prevent the event. Further, the facility's staff did not thoroughly assess the February 24, 2006, exposure report of a potential overexposure to identify the root causes of the problem and was too quick to dismiss it as being anomalous. The violation relates to the failure to provide radiological surveys that are reasonable under the circumstances to evaluate the magnitude and extent of radiation levels and the potential radiological hazards.

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 available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's document system (ADAMS). ADAMS is accessible from the NRC Web site at (the Public Electronic Reading Room) http://www.nrc.gov/reading-rm/adams.html.

Should you have any questions regarding this inspection, please contact Brian Thomas, Chief, Research and Test Reactors Branch at 301-415-2170.

Sincerely,

**/RA/**

Christopher Grimes, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-128
License No. R-83

Enclosures: 1. Notice of Violation
2. NRC Special Inspection Report No. 50-128/2006-203

cc w/encl.: Please see next page

cc w/encl:

Mayor, City of College Station
P.O. Box Drawer 9960
College Station, TX 77840-3575

Governor's Budget and
Planning Office
P.O. Box 13561
Austin, TX 78711

Texas A&M University System
ATTN: Dr. Warren D. Reece, Director
Nuclear Science Center
Texas Engineering Experiment Station
F. E. Box 89, M/S 3575
College Station, Texas 77843

Texas State Department of Health
Radiation Control Program Director
Bureau of Radiation Control
Dept. of Health
1100 West 49th Street
Austin, Texas 78756-3189

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

Should you have any questions regarding this inspection, please contact Brian Thomas, Chief, Research and Test Reactors Branch at 301-415-2170.

Sincerely,
**/RA/**
Christopher Grimes, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-128
License No. R-83

Enclosures: 1. Notice of Violation
2. NRC Special Inspection Report No. 50-128/2006-203

cc w/encl.: Please see next page

**DISTRIBUTION:**

| | | | |
|---|---|---|---|
| PUBLIC | PRTA r/f | AAdams | CBassett |
| PDoyle | TDragoun | WEresian | DHarrison |
| DHughes | EHylton | PIsaac | DStarkey |
| MMendonca | JQuichocho | WSchuster | BThomas |
| MVoth | KWitt | PYoung | DBarss (MS O6-H2) |

BDavis (Ltr only O5-A4) NRR enforcement coordinator (Only for IRs with NOVs, O10-H14)

**ACCESSION NO.: ML061090188** **TEMPLATE #: NRR-**

| OFFICE | PRT:RI | PRT:LA | PRT:BC | DPR:DIR |
|---|---|---|---|---|
| NAME | CBassett:tls* | EHylton* | BThomas* | CGrimes:tls* |
| DATE | 4/25/06 | 5/9/06 | 5/10/06 | 5/11/06 |

**OFFICIAL RECORD COPY**

# NOTICE OF VIOLATION

Texas A&M University
Texas A&M University Nuclear Science Center

Docket No.: 50-128
License No.: R-83

During an NRC inspection conducted on March 27-29, 2006, a violation of NRC requirements was identified. In accordance with the NRC Enforcement Policy, the violation is listed below:

10 CFR 20.1501(a) requires that each licensee shall make or cause to be made, surveys that: 1) may be necessary for the licensee to comply with the regulations, and 2) are reasonable under the circumstances to evaluate the magnitude and extent of radiation levels; and concentrations or quantities of radioactive material; and the potential radiological hazards.

Contrary to the above, the licensee failed to make reasonable surveys to evaluate the magnitude and extent of shallow dose equivalent radiation levels following the initial trial runs of vials containing plastic disks and following the first indication of a possible overexposure on February 24, 2006.

This is a Severity Level IV violation (Supplement IV).

Pursuant to the provisions of 10 CFR 2.201, Texas A&M University 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, United States 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 day of May 2006

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

| | |
|---|---|
| Docket No: | 50-128 |
| License No: | R-83 |
| Report No: | 50-128/2006-203 |
| Licensee: | Texas A&M University |
| Facility: | Texas Engineering Experiment Station<br>Nuclear Science Center |
| Location: | College Station, TX |
| Dates: | March 27-29, 2006 |
| Inspectors: | Craig Bassett<br>Sami Sherbini |
| Approved by: | Brian Thomas, Chief<br>Research and Test Reactors Branch<br>Division of Policy and Rulemaking<br>Office of Nuclear Reactor Regulation |

## SUMMARY OF FINDINGS

Texas A&M University
Texas Engineering Experiment Station
Inspection Report No. 50-128/2006-203

The report covered a period of three days of inspection by two inspectors. 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 Texas Engineering Experiment Station, Nuclear Science Center (NSC) 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. At the end of January 2006, the NSC Radiation Safety Officer (RSO) sent the dosimeters used by facility staff personnel to the dosimetry vendor for processing. The RSO did not receive the dosimetry results report until February 24, 2006. The report indicated that a worker, who had been conducting neutron activation analysis (NAA) using the pneumatic transfer system during January, had received a whole body dose of 0.033 rem and an extremity dose to the hand of 75.8 rem. The NSC Facility Director and RSO immediately noted the results, restricted the worker from further work with radioactive material that would contribute to an extremity dose, and began a review of the situation. After careful consideration of various factors involved, the Director and RSO determined that this was an anomalous reading and allowed the person to continue restricted activities, although all the sample processing work for February had been completed at that point. At the end of February, personnel dosimeters were again gathered and sent to the vendor for processing. Those dosimetry results, which were received on March 15, 2006, indicated that the worker conducting NAA using the pneumatic system had received a whole body dose of 0.006 rem and an extremity dose of 37.54 rem during February. The licensee notified the NRC of the event on March 15, 2006.

An NRC inspector was dispatched to the site and arrived on March 20, 2006. Because of the complicated nature of personnel monitoring, dosimetry processing, and the apparent incongruent dosimetry results, a Special Inspection Team was assigned to review the event. The Special Inspection Team began their review on March 27, 2006. The team found that the licensee's initial response to the event was less than acceptable. The licensee did not thoroughly assess the first report of a potential overexposure and was too quick to dismiss it as being erroneous. Also, there was confusion on the need to report such an event. However, the team also reviewed the licensee's immediate corrective actions, including the dose calculations, and found those actions to be generally acceptable.

Nevertheless, based on the results of this inspection, the team found that the licensee failed to conduct acceptable surveys of the sample vials of irradiated material when a NAA experiment involving the pneumatic system was first initiated, failed to train and monitor a worker on handling sample vials with his hands/fingers, and failed to conduct surveys of the sample vials of irradiated material following the first indication of a possible overexposure on February 24, 2006, to determine the cause of the problem which together lead to a substantial increase in the extremity exposure of one worker at the facility.

## REPORT DETAILS

### 1. Introduction

a. Event Description

The licensee's research and test reactor (RTR) is operated under the authority and administration of the Deputy Director of the Texas Engineering and Experiment Station (TEES). The RTR is located in the Nuclear Science Center (NSC) and is managed by the Director of the NSC and his staff. Daily operations activities are conducted under the supervision of the Associate Director, while the support activities, including radiation protection, are overseen by the Radiation Safety Officer (RSO). One of the projects in progress during January was neutron activation analysis (NAA) of small plastic disks using the facility pneumatic transfer system. During this work involving radioactive material, licensee employees are required to wear an Optically Stimulated Luminescent (OSL) dosimeter for whole body monitoring and a finger ring containing a thermoluminescent dosimeter (TLD) chip for extremity monitoring.

At the end of January, the licensee sent the dosimeters used by all employees who worked at the NSC during the month to the dosimetry vendor for processing. The licensee did not receive those dosimetry results until February 24, 2006. The results indicated that one employee, who will be referred to in this report as Worker A, had received a whole body dose (or deep dose equivalent (DDE)) of 0.033 rem and an extremity dose (or shallow dose equivalent (SDE)) of 75.8 rem. The individual, who had been conducting NAA work using the pneumatic transfer system, was immediately prohibited from any work which could cause an increase dose to the extremities.

Upon receiving the dosimetry report, the RSO began a review of the situation. The licensee determined that processing these NAA samples was a standard procedure that had been conducted numerous times over the past year and nothing in the process had changed. While Worker A had not been the primary person responsible for NAA processing in the past, he had assisted in the procedure many times during the previous six months and was trained on, and familiar with, the operation. The licensee also noted that the dosimetry processor had, on occasion in the past, supplied erroneous dosimetry reports to the facility, including a high reading for an individual who had not used his dosimeter for several months. After consideration of the circumstances fo the event, the licensee concluded that this was an anomalous reading and prepared a dose assessment report based on the average extremity dose of the individual from the past three months. Worker A was placed on "restricted" duty and allowed to return to work although all the NAA samples for the testing period had already been processed.

At the end of February, the dosimeters were again gathered and sent to the vendor for processing. The licensee received those dosimetry results on March 15, 2006, which indicated that Worker A had received a DDE of 0.006 rem and a SDE of 37.54 rem. The licensee notified the NRC of the event on March 15, 2006. However, because the next two days and the following weekend were scheduled as "Spring Break" for the University, no one was available at the facility during Thursday or Friday. An NRC inspector was dispatched to the site and arrived the morning of Monday, March 20, 2006. Because of the numerous questions involved with the dosimetry aspects of the event, a Special Inspection Team was subsequently formed and began their review of the potential overexposure on March 27, 2006.

b. Background and Chronology of Work Activities

As noted above, the licensee had been processing these NAA samples using the pneumatic transfer system at the facility for approximately one year. Another person, Worker C, had been the primary person who had handled the samples during 2005. A third person, Worker B, also performed the work of handling the samples on occasion. Worker A had been assisting as needed with this work for about six months. During 2005, neither Worker B nor Worker C had received extremity doses of the magnitude received by Worker A in January and February 2006. The highest extremity dose during 2005 was 1.58 rem and was received by Worker C. The most recent numbers of samples, the period of time worked, and the finger ring TLD readings are shown below in Table 1.

Table 1

| Employee | Number of Samples and Types of Material | Period of Time | TLD Results, rem |
|---|---|---|---|
| Worker C | 226 (silicon (Si)) | October 2005 | 1.58 |
| Worker C | 240 (Si and silver (Ag)) | November 2005 | 0.88 |
| Worker B | 88 (NIST Ag) | December 2005 | 0.08 |
| Worker B | 195 (Ag and iodine (I)) | January 10-27, 2006 | 0.18 |
| Worker A | 140 (Ag) | January 17-30, 2006 | 75.8 |
| Worker A | 141 (Si, Ag, and I) | February 6-22, 2006 | 37.54 |
| Worker A | 0 | March 1-23, 2006 | 0.04 |

As will be detailed below, during January and February 2006, Worker A also helped complete one radioactive material shipment, conducted various routine surveys, and performed routine calibrations of counting instruments. Again, other licensee employees also helped with and/or completed the same or similar tasks during this same time period.

**2. Event Follow-up - Sequence of Events**

a. Inspection Scope

The inspectors interviewed licensee personnel, observed tests conducted by the licensee, and reviewed various logs, dose calculations, and other documentation to develop the following sequence of events leading up to and following the potential overexposure.

b. Observations and Findings

| Date | Event Description |
|---|---|
| 01/01-16/2006 | Worker A was out of the country on vacation. |

| | |
|---|---|
| 01/17-30/2006 | Worker B processed 195 Ag- and I-samples using the pneumatic transfer system. |
| 01/17/2006 | Worker A processed 21 Ag-samples using the pneumatic system. |
| 01/23/2006 | Worker A processed 34 Ag-samples using the pneumatic system. |
| 01/24/2006 | Worker A completed the shipping surveys and the associated paperwork for a radioactive material shipment consisting of shielded containers of Argon-41 (Ar-41). |
| 01/25/2006 | Worker A processed 41 Ag-samples using the pneumatic system. |
| 01/30/2006 | Worker A processed 44 I-samples using the pneumatic system. |
| 01/31/2006 | Worker A and Worker B completed the monthly Facility Air Monitoring (FAM) test using a source containing 4.68 nanocuries (nCi) of Technetium-99 (Tc-99) and a source containing ~22.5 millicuries (mCi) of Cobalt-60 (Co-60). |
| 02/01-02/2006 | The licensee collected facility personnel dosimeters used during January and mailed them to the dosimetry processor for processing. |
| 02/06/2006 | Worker A processed 51 I-samples using the pneumatic system. |
| 02/07/2006 | Worker A processed 15 I-samples using the pneumatic system. |
| 02/13/2006 | Worker A assisted two other individuals in completing the Channel 6 Building Gas Monitor calibration which involved setting up tubing which passed Ar-41 gas through the gas monitor detector. |
| 02/15/2006 | Worker A processed 27 Si-samples using the pneumatic system.<br><br>Worker A completed calibration of the sample counters using the source containing 4.68 nCi of Tc-99 and completed the calibration of the alarming rate meters using an electronic pulser and a small check source (containing <10 microcuries of Cesium-137 (Cs-137)). |
| 02/21/2006 | Worker A processed 24 I-samples using the pneumatic system. |
| 02/22/2006 | Worker A processed 24 I-samples using the pneumatic system. |
| 02/24/2006 | The licensee received the results from the dosimetry processor which indicated that Worker A had received a dose to the extremities of 75.8 rem.<br><br>The worker was suspended from working with pneumatic samples and an investigation was begun immediately. |

02/27/2006 Worker A and Worker B completed the monthly FAM test using a source containing 4.68 nCi of Tc-99 and a source containing ~22.5 mCi of Co-60.

The licensee contacted the dosimetry vendor to confirm that the finger ring dosimeter results were accurate.

02/28/2006 Worker A completed a radiation and contamination survey of the Material Handling Area and calibrated the instrument to be used to count the swipes using a check source containing 4.68 nCi of Tc-99.

03/01-02/2006 The licensee collected facility personnel dosimeters used during February and mailed them to the dosimetry processor for processing.

03/06/2006 Worker A processed 7 “background” samples using the pneumatic system. Worker A also helped process 8 nautical archeology samples for a student lab.

03/07/2006 Worker A helped process 14 nautical archeology samples for a student lab.

03/09/2006 Worker A helped process 13 gold (Au) foil samples for a student lab.

03/15/2006 The licensee received the results from the dosimetry processor which indicated that Worker A had received a dose to the extremities of 37.54 rem.

The NRC was notified immediately and an investigation of the event begun.

03/16-19/2006 Texas A&M University spring break.

03/20/2006 An NRC inspector arrived on site to conduct a preliminary review of the potential overexposure and conduct a routine inspection.

The inspector observed a time-motion study of pneumatic sample handling performed by Worker A to determine the length of time his hands were in contact with each sample. The time was measured as 15 seconds per sample.

03/21/2006 The licensee initiated extremity dose calculations using the computer code VARSKIN - Mod2 and also using a separate computer code MCNP model.

The licensee again contacted the dosimetry vendor to confirm that the finger ring dosimeter results were accurate.

03/22/2006 The inspector observed as Worker D processed two Ag-samples using the pneumatic transfer system and measured the dose rates from the various components with an open-window ion chamber. The results were as follows in Table 2:

Table 2

| Items | Contact Reading |
|---|---|
| Outer vial (with foam and inner vial) | 2.6 Roentgen per hour (R/hr) |
| Foam cushioning material separately | 470 mR/hr |
| Outer vial separately | 26 mR/hr |
| Inner vial (with plastic disk sample) | 2.4 R/hr |

From these measurements and using a volume correction factor of 10, the licensee calculated a dose to the extremities from processing 140 pneumatic samples of 20.22 rem.

03/23/2006 Initial licensee dose estimates using VARSKIN - Mod2 indicated a worst case beta dose to the extremities from processing 140 pneumatic samples of 17.46 rem.

03/24/2006 Initial dose modeling using MCNP resulted in a dose estimate to the extremities from processing 140 pneumatic samples of 9.94 rem.

03/25/2006 The inspector observed the calibration of 15 TLD chips using a known source of radiation against a NIST traceable Farmer's ion chamber.

03/26/2006 The inspector observed as the 15 TLD chips were processed to determine the dose received. The TLD chips were then annealed in anticipation of using them in another test on Monday.

03/27/2006 A Special Inspection Team arrived on site to conduct a review of the potential overexposure and the licensee's response.

The licensee received the results from the dosimetry processor indicating that the extremity exposure received by Worker D during the re-enactment of sample handling was not measurable.

The team observed a test conducted by the licensee to expose (for one minute) a set of 6 TLDs to an irradiated sample vial processed in a similar manner as those that had been processed during January and February. Two TLD chips were placed so as to be in contact with the source at the side of the sample vial. This test was conducted twice with two different sets of TLDs. Two vendor finger rings were also exposed to the sample sources (placed in contact with the vials for one minute) and subsequently sent to the vendor for processing.

The NRC began calculating a potential extremity dose using VARSKIN to estimate a worst case beta dose from processing 140 pneumatic samples.

03/28/2006 The inspectors observed as the TLD chips, which had been exposed to the sample vials on March 27, were processed to determine the dose received.

Dose estimates using the dose numbers derived from the exposure of the TLD chips indicated a dose to the extremities from processing 140 pneumatic samples of approximately 24.7 rem.

The licensee again contacted the dosimetry vendor to discuss the finger ring dosimeter results and to obtain information on the vendor's processing procedures and techniques.

The NRC began modeling the event scenario using MCNP to obtain a second estimate of the worst case extremity dose from processing 140 pneumatic samples.

03/29/2006 The dosimetry processor provided results for the two finger rings that were sent indicating a dose of 0.39 rem for one minute exposure on one ring and 0.46 rem for one minute exposure on the other. This would result in a "worst case" extremity exposure of 16.1 rem from processing 140 samples.

The inspectors observed a re-enactment by Worker A of the sample handling technique concentrating on the time required to transport the sample from the pneumatic transfer area to the counting area. The average time was 12 seconds.

03/30/2006 Worker A was sent for a medical examination. The doctor found no problems or abnormalities. Consultation with another specialist was scheduled by the first doctor. A follow-up exam was scheduled for April 27, 2006.

c. Conclusions

Based on the records reviewed, following notification of a potential overexposure, the licensee restricted the individual with the potential extremity overexposure from handling NAA pneumatic samples. However, the sample handling work for the period had been completed at that point.

## 3. Procedures and Training

a. Inspection Scope (IP 69001)

The inspectors reviewed selected aspects of the following to verify compliance with TS Section 6.3 concerning facility procedures:

- Pneumatic System Training Module
- Facility records for pneumatic system and radiation worker training
- Reactor Safety Board (RSB) meeting minutes from 2004 through the present
- NSC Standard Operating Procedure (SOP), Section I, Procedure D, "Format," Rev. 3, dated February 25, 2002
- NSC SOP, Section I, Procedure E, "Origination," Rev. 1, dated February 25, 2002
- NSC SOP, Section I, Procedure F, "Review and Approval," Rev. 1, dated February 25, 2002
- NSC SOP, Section I, Procedure G, "Distribution and Binding," Rev. 0, dated July 31, 1986
- NSC SOP, Section IV, Procedure C, "Pneumatic System Operation," Rev. 0, dated February 8, 1991
- NSC SOP Section VII, Procedure A-3, "Reporting Requirements," Revision 2, dated December 19, 1997
- NSC SOP Section VII, Procedure A-5, "Annual Review of SOP Section VII (HP Procedures)," Revision 3, dated August 19, 2003
- NSC SOP Section VII, Procedure A-6, "ALARA," Revision 0, dated December 12, 2002
- NSC SOP Section VII, Procedure C-10, "Radioactive Materials Handling," Revision 2, dated December 19, 1997
- NSC Form 595, "Procedure Change Notice (PCN)," latest revision dated January 31, 2005
- NSC Form 844, "Radiation Work Permit," Number (No.) 005, Revision (Rev.) No. 05-0, dated November 15, 2005
- Texas A&M University, Nuclear Science Center, Pneumatic System Training Module, Rev. dated January 10, 2001
- Texas A&M University, Nuclear Science Center, Radiation Worker Training Module, no revision date

b. Observations and Findings

The inspectors reviewed various NSC SOP Sections and selected procedures. These SOP Sections and procedures provided guidance for the administrative, operations, and health physics functions of the facility. The inspectors confirmed that written procedures were available for those tasks and items required by TS Section 6.3. The licensee controlled changes to procedures and the RSB conducted the review and approval process as required.

The inspectors also reviewed the procedures, Radiation Work Permit (RWP), and training modules that were related to the potential overexposure event. It was noted that, although the procedures and training modules gave guidance and instruction on the general use and handling of radioactive material, very little specific information was included on use of survey meters during processing samples and on remote handling of radioactive material and the use of tongs or other tools to provide distance and/or shielding from a potential source of radiation. Licensee personnel indicated that such issues were generally taught and discussed in class. It was also noted that facility staff members were not forbidden from using their hands for a brief period to perform some functions such as removing the inner sample vial from the outer vial if the dose rates allowed. The licensee was informed that the issue of ensuring that

sufficient guidance and instruction on the proper handling of radioactive material was an area for improvement and would be followed by the NRC as an Inspector Follow-up Item (IFI) (IFI 50-128/2006-203-01).

(The issue of proper handling of radioactive material will be addressed in more detail in Section 5 of this report.)

The inspectors also reviewed the 2005 training records and interviewed NSC staff members concerning the training received at the facility. The inspectors determined that the training of personnel on procedures and general Radiation Worker and ALARA training was acceptable, although as discussed above that specific guidance and instructions will be the subject of future inspector follow-up actions.

c. Conclusions

Based on the procedures and records reviewed and observations of NSC staff during the inspection, the inspectors determined that the procedural control and implementation program was acceptably maintained. Procedures, RWPs, and the training program could be improved with respect to radioactive material handling and the use of tools and shielding devices.

## 4. Licensee Investigation of and Response to the Event

a. Inspection Scope

The inspectors reviewed the following concerning the licensee's response to the event to ascertain compliance with 10 CFR 20.2202(b)(1)(iii):

- Pneumatic System Training Module
- various licensee records and E-mails
- RSB meeting minutes from 2004 through the present
- Personnel dosimetry records for 2005 through the present
- RSB completed audits and reviews from 2004 through the present
- Facility records for pneumatic system and radiation worker training
- Annual Report for the Texas A&M University Nuclear Science Center for 2004
- various forms associated with the procedures mentioned below for 2005
- NSC Safety Evaluation for the Use of Pneumatic Transfer Systems, undated
- NSC Form 111, Experiment Authorization, "Pneumatics Transfer System Irradiations," dated January 1, 1989
- NSC SOP Section VII, Procedure A-1, "Radiation Protection Program," Rev. 3, dated December 4, 1997
- NSC SOP Section VII, Procedure A-3, "Reporting Requirements," Rev. 2, dated December 19, 1999
- NSC SOP Section VII, Procedure A-6, "ALARA," Rev. 0, dated February 25, 2002
- NSC SOP Section VII, Procedure B-14, "Personnel Dosimeters," Rev. 6, dated October 15, 1999 and Procedure Change Notice (PCN) dated August 28, 2002
- NSC SOP Section VII, Procedure C-10, "Radioactive Materials Handling," Rev. 2, dated December 19, 1997

- NSC SOP Section VII, Procedure D-1, "Health Physics Training," Rev. 0, dated October 3, 1990
- NSC SOP Section VII, Procedure E-1, "Personnel Dosimetry," Rev. 0, April 13, 1995

b. Observations and Findings

(1) Initial Notification of Potential Overexposure

10 CFR 20.2202(b) states, in part, that: "Each licensee shall, within 24 hours of discovery of the event, report any event involving loss of control of licensed material possessed by the licensee that may have caused, or threatens to cause, any of the following conditions: (1) An individual to receive, ***in a period of 24 hours*** [empahsis added]–. . . .(iii) A shallow-dose equivalent to the skin or extremities exceeding 50 rems (0.5 Sv) . . . ."

The licensee's response upon receiving the first dosimetry report, for the January 2006 period, was to restrict Worker A from work that would result in extremity exposure. At the time this action was taken Worker A had already worked most of the following period, February 2006, because the report for January was received toward the end of February. The licensee also initiated an investigation of the work performed by Worker A to determine if there was anything unusual that may have contributed to the high dose, but none was found. The licensee stated that in the past, dosimetry reports have occasionally shown high readings that were later proven to be false and, because their investigation did not, at first, reveal anything unusual in this case, they believed the reading to be false, and did not report the initial dosimetry results to the NRC.

The licensee immediately notified the NRC upon receipt of the second report containing an unusually high reading for the same worker. Although these responses by the licensee are generally acceptable, the NRC must be notified of any conditions that conform to the notification and reporting requirements in Part 20, even in the face of great uncertainty regarding the validity of the data, as was the case in this event. The licensee did not notify the NRC after receiving the first high dosimetry report even though the dose reported was substantially above the limit. As noted above, they evaluated the problem and reached the conclusion that the 75.8 rem dose was erroneous. Although the dose was not likely to have been received in 24 hours, the conservative action would have been to report.

Because the licensee did not report the potential overexposure as required by the regulations, the licensee indicated that Event Notification to the NRC will be carefully evaluated for the future so that proper notifications are made in a timely manner. The licensee was informed that review of the Event Notification procedure would be followed by the NRC as an IFI and would be reviewed by the NRC during a future inspection (IFI 50-128/2006-203-02).

It was noted that, following the receipt of the dosimetry report on February 24, 2006, the licensee did not conduct any type of surveys of sample vials containing irradiated material to determine the potential dose that could be received by a

person handling the material. Based on their review of the employee's work duties and assignments, his previous dose history, and the extremity dose to the hands that had been received by another worker, who had handled samples in January, the licensee decided that a calculated dose assessment was needed for the employee. This NRC determined that the licensee did not do as thorough a job as they could have in investigating the first reported high dosimeter reading (for January). The issue of not conducting a proper evaluation of the event was noted as a problem by the NRC and will be discussed further later in the report.

(2) Second Notification of Potentially High Dose to the Extremities

On March 15, 2006, the licensee received the results from the dosimetry processor which indicated that Worker A had received a dose to the extremities of 37.54 rem during February. The Facility Director and RSO reviewed the results and the NRC was notified immediately.

After licensee personnel returned to work on Monday, March 20, they began an intensive investigation into the cause of the apparent extremity overexposure. The Facility Director and the Radiation Safety Officer (RSO) investigated several possibilities. These included the following:

- Reiterated the restriction that Worker A was not to be involved in handling any radioactive samples or any work that would cause further dose to the extremities.
- Reviewed the dosimetry records of everyone who had been involved in the NAA project for the past 12 months.
- Conducted various interviews with the individual involved in the apparent overexposure to determine exactly what the individual had done for the months of January and February of 2006. (These activities are summarized in Paragraph 2 - Sequence of Events above.)
- Determined the number of samples processed by the individual during those months. During January, the individual processed 140 samples and during February, 141 samples.
- Conducted time-motion studies on the pneumatic sample processing. The licensee concluded that each sample was handled for approximately 15 seconds.
- Completed various test runs of samples to verify the beta and gamma dose rates on the vials and foam after the end of irradiation (EOI) and about five seconds after the sample was returned to the lab. Separate radiation readings were taken of the outer vial containing all the enclosed components, the outer vial by itself, the foam packing used to cushion the inner vial, and the inner vial containing the small plastic disk sample. (The readings noted are given in Paragraph 2 - Sequence of Events above.)
- Calculated doses to the extremities based on the time-motion studies and the dose rates noted from the various tests that they conducted. (The initial estimates are given in Paragraph 2 - Sequence of Events above and are summarized in a table in Paragraph 6.b.(4) below.)

- Contacted the customer to ascertain whether or not the composition of the samples had changed. The licensee was informed that the composition of the plastic disks being tested had not changed.
- Reviewed the analyses of the samples run during January and February to determine whether or not the relative quantities of the various isotopes noted in the samples had changed. No changes were noted and all samples contained relatively the same quantities of isotopes. Typical quantities included 90 microcuries (FCi) of Ag-108 and 15 FCi of I-128.
- Reviewed the location where all employees' dosimeters are stored. The individual involved indicated that he always placed his dosimeter and finger ring in the storage rack, as did all other employees. No problems were noted.
- Reviewed the use and storage of the various sources that are maintained at the facility. No anomalies were noted.
- Contacted the dosimeter vendor to request that the doses for January and February be checked and reevaluated. The vendor indicated that the processing and calculations were correct and forwarded the resulting "glow curves" to the licensee.
- The licensee reviewed the dosimeter results of others who had handled the samples and noted that another person, Worker B, had also used the pneumatic transfer system during January but had received an extremity dose of 0.18 rem and had handled more samples than Worker A.
- Sent Worker A's finger ring used during March to the dosimetry process for emergency processing. The results indicated an exposure of 0.040 rem for March.
- Using MICROSHIELD, calculated the gamma dose rates that Worker A received to the extremities during January and February. The results would not significantly increase the person's dose.

(3) Corrective Actions Taken or Planned

The licensee has taken various actions to improve their radiation protection program. One of these actions, which was in fact initiated before this incident, was to develop a plastic jig that is to be used to hold the sample vial while the workers cuts off the top. This will prevent any direct handling of the vials by the worker's hands. A tool will also be used to permit quicker cutting than is achievable using a razor blade. The jig was ready for use at the time of this inspection, but had not yet been adopted for routine use. The licensee also stated that they will be holding training sessions for all of their workers to describe this incident and to instruct them on the proper handling of the samples and the use of the jig. The radiation safety program at the facility, including sample monitoring and contamination control practices, were otherwise found to be acceptable for the type of radiation work conducted at the facility.

In addition, the licensee has also taken or plans to take the following actions as a result of the exposure event:

*Corrective Action Completed*

- Restricted the individual from working with any pneumatic system samples or doing work that would cause an extremity dose.
- Conducted a separate study of the pneumatic system sample handling process using another individual and had that person's finger ring analyzed after two sets of samples were processed. Those results indicated a "minimum" dose.
- Held a meeting on Thursday, March 30, for the NAA pneumatics-trained personnel to review the event and review the subjects of ALARA, radioactive material handling, and the use of the newly developed tools and beta shields.
- Worker A was sent for a medical examination on Thursday, March 30. The doctor found no problems or abnormalities. A follow-up exam was scheduled for April 27, 2006.
- An RSB meeting was held on April 13, 2006, to review the event.
- Worker A's was reclassified as a "Non-Rad Worker" and will no longer be issued dosimetry (at least for the remainder of this year).

*Corrective Action Planned*

- Hold a meeting for all NSC personnel to review the event and review the subjects of ALARA, radioactive material handling, and the use of tools, tongs, and beta shields.
- Plan to issue two finger ring badges to each NAA worker and send the finger rings to the vendor for processing every two weeks, instead of every month, for the next three months.
- Lock the storage cabinets containing the sources at the facility.
- Revise the training program on radioactive materials handling.
- Initiate a program for the NSC Director and/or the RSO to observe work practices on a regular basis to note good and bad practices and correct any problems noted.
- Review the SOP for radioactive material handling and consider special handling procedures in the laboratories.
- Event Notification to the NRC will be carefully evaluated for the future so that proper notifications are made in a timely manner.
- Reassess the dosimetry vendor's response and licensee needs for reliable and rapid information on potential overexposures.
- Work with the dosimetry vendor to ensure that E-mail can and will be sent following any indication of an overexposure after the vendor processes the OSL or TLD badges.
- Plan to permanently install a radiation detector inside the Fume Hood near the point where the pneumatic transfer system tube ends.

The licensee was informed that the corrective actions taken will be followed by the NRC as an IFI and will be reviewed during a future inspection (IFI 50-128/2006-203-03).

c. Conclusions

Even though the licensee concluded that it was not valid, they did not take the conservative action to notify the NRC within 24 hours of receiving notification of a possible extremity overexposure. The licensee did not do as thorough a job as they could have in investigating the first reported high dosimeter reading (for January). The licensee's subsequent corrective actions, including the dose calculations, were found to be acceptable.

**5. Root Cause Determination and Related Contributing Actions**

a. Inspection Scope (IP 69001)

The inspectors reviewed selected aspects of the following to verify compliance with 10 CFR Parts 19 and 20 and TS Sections 3.5, 4.5, 5.4, and 6.6 requirements:

- Licensee records and E-mails
- Licensee dose calculations and test data
- RSB meeting minutes from 2004 through the present
- Personnel dosimetry records for 2005 through the present
- RSB completed audits and reviews from 2004 through the present
- Facility records for pneumatic system and radiation worker training
- Personnel dosimetry records for facility personnel for 2005 to date
- Annual Report for the Texas A&M University Nuclear Science Center for 2004
- various forms associated with the procedures mentioned below for 2005
- NSC Safety Evaluation for the Use of Pneumatic Transfer Systems, undated
- Experiment Authorization No. E-2-1, "Pneumatics Transfer System Irradiations," dated January 1, 1989
- NSC SOP, Section IV, Procedure C, "Pneumatic System Operation," Rev. 0, dated February 8, 1991
- NSC SOP Section VII, Procedure A-3, "Reporting Requirements," Revision 2, dated December 19, 1997
- NSC SOP Section VII, Procedure A-6, "ALARA," Revision 0, dated December 12, 2002
- NSC SOP Section VII, Procedure C-10, "Radioactive Materials Handling," Revision 2, dated December 19, 1997
- NSC Form 844, "Radiation Work Permit," Number (No.) 005, Revision (Rev.) No. 05-0, dated November 15, 2005
- Texas A&M University, Nuclear Science Center, Pneumatic System Training Module, Rev. dated January 10, 2001
- Texas A&M University, Nuclear Science Center, Radiation Worker Training Module, no revision date

b. Observations and Findings

(1) Licensee Root Cause Determination

The licensee initially concluded that, based on the calculations and measurements made, even in full contact with the NAA sample vial (the source),

doses reported by the dosimetry processor could not be reached. The licensee indicated that the original dosimetry results were most likely overly conservative. Considering the sources available at the NSC, it was not known how such high extremity doses could be received in a one month period. However, after more consideration, the licensee determined that the root cause of the event was failure to follow procedure in that Worker A apparently handled the sample vials in a different manner than any of the other workers had and held the sample vial in his hands as opposed to touching it briefly while cutting the end off.

The licensee also noted that no other employee had ever received hand doses unexpectedly, especially at the levels reported in this event. No other work had ever produced such hand doses, nor should it be possible if procedures are followed. The licensee conjectured that the possibility remained that the rings were removed and placed next to a source for an extended period of time. However, Worker A did not recall any such circumstance.

(2) NRC Root Cause Investigation

10 CFR 20.1501(a) requires that each licensee shall make or cause to be made, surveys that: 1) may be necessary for the licensee to comply with the regulations, and 2) are reasonable under the circumstances to evaluate the magnitude and extent of radiation levels; and concentrations or quantities of radioactive material; and the potential radiological hazards.

The inspectors reviewed the licensee's review and associated actions following the initial proposal to conduct the NAA experiments on the client's plastic disks. It was noted that this experiment was conducted under Experiment Authorization (EA) No. E-2-1, "Pneumatic Transfer System Irradiations," dated January 1, 1989. The EA, the associated Safety Evaluation, SOP IV-C, "Pneumatic System Operation," and the "Pneumatic System Training Module," provided general guidance on using the system and how to handle a sample once it returns from being irradiated in the reactor. Those instructions included checking the sample with an ionization chamber before removing it from the pneumatic system and handling the sample carefully because of external contamination concerns. None of the aforementioned documents required that the initial samples run under a new experiment be surveyed in detail to determine the extent of radiation hazards that might be present. The licensee indicated that surveys were taken and that the radiation levels were known but that no survey documentation was made, i.e., no survey results were available to document surveys that were reportedly conducted during the initial trial runs of the sample vials containing plastic disks after irradiation. It was noted that no procedural steps were written and no engineering controls were implemented to ensure that occupational doses would not be adversely affected. The failure to make adequate surveys to fully establish the radiological hazards that were present following the initial trial runs of vials containing plastic disks was determined to be a root cause of the problem.

Contributing factors were considered as well. The most apparent factor was the improper handling of the sample vials in that Worker A handled the sample vials with his hands. Tongs were provided for use in handling the vials but their use

was not mandatory. Although the practice of using one's hand/fingers to handle the sample vials was not prohibited by facility procedure, and indeed allowable as taught during pneumatics system training, the handling was only supposed to be for a brief period and at the opposite end of the vial from where the sample was located. During a demonstration, Worker A held the sample vials in a different manner than taught or intended by management and apparently in a different manner than other workers. Typically, workers held the vial close to the top, away from the source, with the finger tips, while handling. Worker A, however, at least during the demonstration, grasped the vial with his fingers folded around it, with the vial resting against his palm, while handling and cutting off the end cap. The training and monitoring of these activities did not prevent or identify in a timely manner this improper handling of the sample by Worker A and resulted in a significantly increased dose to the extremities.

An additional contributing factor was failure to follow procedure. The procedure requires that the person processing the samples measure the samples with a portable radiation survey instrument after the samples return from being irradiated in the reactor core. During an interview with Worker A, the individual admitted that he did not monitor each sample upon its return. His practice was to look at the survey meter that was placed just outside the Fume Hood and adjacent to some shielding that was near the pneumatic transfer system return tube. When the sample vials arrived back in the Fume Hood return tube, the worker would glance at the meter and, if there were no "high" readings, he would pick up the sample vial for further processing. This practice may have resulted in the worker picking up the vials too soon after they returned from being irradiated in the reactor core.

The NRC concluded that: failure to make adequate surveys to fully establish the radiological hazards that were present following the initial trial runs of vials containing plastic disks and failure to conduct surveys of the sample vials of irradiated material following the first indication of a possible overexposure on February 24, 2006, to determine the cause of the problem lead to failure to acceptably train and monitor workers regarding the handling of sample vials with their hands/fingers (VIO 50-128/2006-201-04).

c. Conclusions

The licensee determined that the root cause for this event was failure to follow procedure. The NRC determined that failure to conduct an acceptable survey of the sample material when the experiment was first initiated was the root cause of the problem that lead to a potential overexposure. The lack of initial surveys, as well as, allowing workers to handle sample vials which lead to improper sample handling by Worker A and failure to follow procedure were contributors to a violation of the regulations.

## 6. Dose Assessment

a. Inspection Scope (IP 69001)

The inspectors reviewed selected aspects of the following to verify compliance with 10 CFR Parts 19 and 20 and TS Sections 3.5, 4.5, 5.4, and 6.6 requirements:

- various licensee records and E-mails
- licensee dose calculations and test data
- personnel dosimetry records for facility personnel for 2005 to date

b. Observations and Findings

The routine personnel dosimetry used at this facility for workers handling irradiated samples consists of one whole body dosimeter to monitor whole body and eye doses, and one finger ring dosimeter to monitor hand exposures. The whole body dosimeter is an OSL dosimeter, and the finger ring dosimeter consists of a standard TLD chip, suitably encapsulated and encased in a plastic ring that can be worn on one of the worker's fingers. Workers are instructed to wear the finger ring dosimeter facing the radiation source and on the finger likely to receive the highest dose. The dosimetry change period at the facility is monthly. The licensee received the first unusual dosimetry report from the dosimetry processor on February 24, 2006, and the report was for the period January 1, 2006 to January 31, 2006. All of the results in the report were within the expected range except for the affected worker, referred to in this report as Worker A. This worker's whole body dosimeter showed a DDE of 0.034 rem, which is within the expected range for the type of work he performed, but the SDE was reported to be 75.8 rem. This result was well outside the normal range, the history of the facility indicating that SDE have not previously exceeded about 1.5 rem for a badging period. The licensee restricted Worker A from further radiation work, conducted a review of the worker's activities, and performed bounding calculations. The calculations indicated that the activities in which Worker A had engaged in during the month could not have delivered that high a dose. Having previously encountered erroneous dosimetry reports from the vendor, including a high reading for a dosimeter used to monitor background in a reception area, the licensee concluded that the high reading was erroneous, and was preparing to contact the dosimetry processor to discuss the case. Before that was done, however, the dosimetry report for the period February 1, 2006 to February 28, 2006.

As in the previous month's report, the DDE for Worker A, 0.006 rem, was low, as expected, but the SDE was 37.54 rem, again far higher than expected. The licensee immediately notified the NRC of a potential exposure above the applicable regulatory limit and initiated a more thorough investigation of both the January and February high readings. The dosimetry processor did not immediately report either of the high readings to the licensee, as is usual good practice when an unusual dosimetry result is obtained during processing.

(1) Re-enactments

Following initiation of an NRC inspection, and before the start of the NRC special inspection, an NRC inspector observed Worker A re-enacting the type of radiation work he had been performing during the months of January and February. The work consisted the following steps:

1. Retrieve the plastic vial containing the irradiated sample from the reactor's pneumatic system.
2. Survey the sample for radiation levels.

3. Cut of the top of the plastic vial, which had been heat-sealed, using a razor blade.
4. Retrieve the inner plastic vial that contains the irradiated sample.
5. Place the inner vial containing the sample in a small glass vial and count on a high-resolution gamma spectroscopy system to identify the activated radionuclides in the sample and quantify their activities.

These steps were the usual steps followed by all the workers engaged in this type of work. However, one unusual feature was noted in the manner in which Worker A cut the tops off of the vials with the razor blade. Normally, the worker would hold the vial close to the top, away from the source, with the finger tips, while cutting. Worker A, however, grasped the vial with his fingers folded around it, with the vial resting against his palm, while cutting. He is left handed, and the vial was grasped with the right hand. The finger ring was also worn on the right hand, with the sensitive element facing the palm side of the hand, almost directly opposite the activated sample. This manner of wearing the finger ring dosimeter conforms to recommended monitoring practices for the facility. During the re-enactments, it was found that he held the vial in this position for an average of 15 seconds per sample. Records indicated that he had handled 140 samples during each of the two months in question.

(2) Experimental Dose Estimates

Order of magnitude calculations performed by the licensee as well as by NRC of the doses that may arise from the samples showed that the reported SDE's of 75.8 and 37.54 rem could not have been due to photon emissions from the samples. The activities in the samples were of the order of 100 μCi for one of the activated radionuclides, and far less for the other activated components. The estimated doses resulting from the photon emissions from such activity levels were several orders of magnitude lower than the values that could account for the high SDE dosimeter readings. It was therefore tentatively concluded that, if the dosimeter readings were not erroneous, they were probably caused by beta emissions from the samples. The total thickness of the two plastic vial walls plus a surgical glove worn by the worker is about 0.25 cm, and beta radiation with energies above about 0.6 MeV will penetrate this thickness of plastic material. The beta emissions from nearly all of the activation products in the samples were sufficiently energetic that significant fractions of their energy spectra fell above 0.6 MeV.

In an attempt to quantify the dose rates from the vials, several samples identical to the ones handled by Worker A were irradiated in the reactor during the NRC inspection, for the same length of time, namely four minutes, as that used during routine irradiations. Upon removal from the pneumatic system, each sample vial was placed on a bench and a set of TLD chips were held against the wall of the vial for a period of approximately one minute. Six chips were used in each test, distributed along the length of the vial to obtain an axial dose distribution. Two of these chips were placed opposite the irradiated sample, which is the location expected to yield the highest dose rate. In addition, a finger ring dosimeter was also placed against the vial wall opposite the activated sample. The TLD chips

were stored overnight to permit unwanted parts of the glow curves to decay away (standard procedure), and were read by the licensee the following morning. The finger ring dosimeters were sent to the dosimetry processor for emergency processing. The licensee operates a TLD chip reader system calibrated using radiation measuring detectors traceable to the National Institute of Standards and Technology (NIST). The dose rates obtained from these experimental measurements are shown in Table 3 below.

Table 3

| Location of Chip | Dose Rate - mrad/min | Location of Chip | Dose Rate - mrad/min |
|---|---|---|---|
| 1 | 38.2 | 7 | 42.6 |
| 2 | 81.4 | 8 | 104.3 |
| 3 | 419.9 | 9 | 681.0 |
| 4 | 1115.4 | 10 | 622.0 |
| 5 | 180.4 | 11 | 187.4 |
| 6 | 23.2 | 12 | 18.2 |

The readings are all corrected for background. Chips #1 and #7 were close to the top of the vial, Chips #2 and #8 were about halfway along the length of the vial, chips #3, #4, #9, and #10 were opposite the irradiated sample, and chips #5, #6, #11, and #12 were below the bottom of the vial.

If the reading of the four chips opposite the sample are averaged, the result is 710 rad/min. Using an estimated 15 seconds contact time per sample, based on re-enactments, and 140 samples handled per month, the total contact time is estimated to be 35 minutes, and the dose would in this case be 24.8 rads. Using the highest chip reading of 1115.4 rad/min, the total dose resulting from a contact time of 35 minutes would be 39.0 rads, whereas using the smallest of the four center chip readings gives a total dose of 14.7 rads. The results of the two finger ring irradiations were reported by the processor before the end of this inspection as 460 and 390 mrad/min. Using the exposure duration of 35 minutes, these dose rates give a total dose for the month of 16.1 and 13.7 rad, respectively.

(3) Dose Calculations

As a second approach in attempting to assess the doses received by Worker A, and to provide supporting data for the experimental measurements, both the licensee and the NRC calculated the doses that would result from handling the irradiated samples. The licensee attempted to use the computer codes VARSKIN to calculate doses resulting from beta radiation, and MICROSHIELD to calculate the doses arising from photons. However, neither code is capable of representing the exposure geometry in this case with sufficient accuracy, and

both the licensee and NRC also used the Monte Carlo transport code MCNP to supplement the VARSKIN calculations. MCNP can be used to model the exposure geometry with any desired degree of accuracy, and can calculate doses resulting from both photons and electrons. The dimensions used for the vials were 7.5 cm length and 1.7 cm outer diameter for the larger outer vial, and 1.0 cm length and 1.2 cm outer diameter for the inner vial. Each of the vials has a wall thickness of 0.1 cm, and the vials are made of polyethylene. The calculations were based on sample activities obtained by reviewing the records of the isotopic gamma analyses and also by irradiating several samples during the inspection under the same conditions used by Worker A. The isotopic composition used in the calculations is shown in Table 4 below.

Table 4

| Radionuclide | Activity, µCi |
|---|---|
| Ag-108 | 90.0 |
| Al-28 | 2.48 |
| Cl-38 | 0.19 |
| I-128 | 15.9 |
| Na-24 | 0.54 |

The silver and iodine activities arise from the silver iodide contained in the irradiated samples, and the aluminum, sodium, and chlorine most likely arise from irradiation of trace constituents in the vial material.

The dose arising from photon irradiation was calculated by NRC to be about 0.03 rem for the badging period, and is therefore a negligible contributor to the total SDE. The dose arising from beta radiation was estimated using MCNP to be about 21 rads for a badging period of one month, using a total exposure duration of 35 minutes. The licensee's result from their MCNP calculations were 12.3 rads without surgical gloves and 5.0 rads with the gloves. NRC also used VARSKIN to calculate the beta dose. Although this code cannot accurately model the actual exposure geometry, an approximation to that geometry was used, and the dose calculated for the monitoring period of one month was 22 rads. The licensee's estimate using VARSKIN was 17.5 rads.

(4) Summary of Measurement and Calculation Results

Table 5 below summarizes the results of the TLD and ring badge measurements and the calculations performed by NRC and the licensee. All the doses shown are based on estimating the dose rate per minute and multiplying by an exposure duration of 35 minutes to obtain the dose for the month.

Table 5

| Type of Dose Estimate | Dose During the Month, rad |
|---|---|
| Mean of TLDs chip readings | 24.8 |
| Maximum TLD chip reading | 39.0 |
| Minimum TLD chip reading | 14.7 |
| Finger ring reading | 16.1 |
| Finger ring reading | 13.7 |
| | |
| MCNP calculation with gloves (NRC) | 21.0 |
| MCNP calculation with gloves (licensee) | 5.0 |
| MCNP calculation w/o gloves (licensee) | 12.3 |
| | |
| VARSKIN calculation (NRC) | 22.0 |
| VARSKIN calculation (licensee) | 17.5 |

The results shown in the table show reasonable agreement considering the various methods of calculation and measurement used to obtain these estimates. They span a range of about 5 - 40 rads if the high TLD chip reading is included, but span a much narrower range of 14 - 25 rads if the high reading is excluded, as well as the licensee's MCNP calculation with gloves. It therefore appears that much of the data support the conclusion that the dose to Worker A was of the order of probably not more than 25 rad, assuming the exposure duration of 35 minutes per month is correct. This is a factor of about 3 lower than the dose of 75.8 rad reported for the January period, and still significantly lower, by a factor of about1.5 for the February period. The dose rates on which the tabulated doses are based are probably reliable, especially since the calculations and measurements are in agreement. The exposure duration was obtained by multiplying the estimated contact time per sample, namely 15 seconds, by the number of samples handled during the month. The number of samples handled is a matter of record, and the exposure duration per sample is based on timing the re-enactments observed by the NRC inspector.

It is possible that during the actual handling of samples, Worker A took much longer to perform the required sample handling than was demonstrated during the re-enactments, especially if one makes the reasonable assumption that this worker gained increasing skill in handling the samples during this period. The SDE pattern reported by the processor, namely 75.8 and 37.5 rads, is consistent with this possibility. The time available to handle a sample, however, is not unlimited, but is constrained by the nature of the process of sample irradiation

and analysis. Most of the radioactive materials produced by sample irradiation have half-lives of the order of a few minutes, and the sample must therefore be quickly transferred from the pneumatic system to the counting detector before the activity decays away, thereby precluding the possibility of accurate isotopic analysis. Re-enactments and interviews with Worker A and others have shown that the total time taken from removal of the sample from the reactor pneumatic system to the start of counting on the gamma spectrometer is very close to one minute. Of this, 5 seconds are used to remove the sample from the pneumatic system, and 10 seconds to set up the counting system in preparation for counting. This leaves a maximum of about 45 seconds to handle the sample. If the assumption is made that all of this time is taken up in sample handling, the doses for the month based on a 15-second handling time are increased by a factor of three. For example, a dose of 25 rads for the month estimated on the basis of the mean TLD chip results becomes a dose of 75 rad, which is the SDE dose reported for January. Improved handling skills would lead to reduced handling time, and therefore a reduced dose for the month of February.

It should be noted that the above is highly speculative, and requires making some unlikely assumptions, such as that the worker took 45 seconds to handle each of the 140 samples during January, and that during each of these, the worker's fingers were placed around the sample such that the dosimeter chip was always opposite the irradiated sample. Although not impossible, these coupled conditions are highly unlikely. A more convincing conclusion is that the dose received for January was of the same order of magnitude as that received during February, and that the dosimeter used during the January badging period read on the high side, an occurrence that is not infrequent.

(5) Dose Assignment

NRC's 10 CFR Part 20 defines the SDE as the dose at a depth of 0.007 cm in skin averaged over the 10 $cm^2$ area of skin that receives the highest dose from the source of exposure. NRC performed calculations using MCNP to determine the ratio of the dose registered by the finger ring dosimeter to the dose averaged over the highest exposed 10 $cm^2$ area of the skin of the worker's hand. The result showed the ratio to be 2.9. This means that the doses registered by the dosimeter should be divided by 2.9 to determine the dose to be used to show compliance. If the reported SDE for January and February, namely 75.8 and 37.54 rads, respectively, are considered valid and used to show compliance, the total reported dose for January and February would be 113.3 rads, and the dose to be assigned to Worker A would be 39.1 rads for the period starting January 1$^{st}$ through the end of February. If the dose estimated on the basis of measured and calculated dose rates and a 15-second handling period per sample, namely about 25 rads, is used for each of the 2 months, the total dose would be 50 rads, and the assigned total dose would be 17 rads. In either case, the assigned dose is significantly lower than the regulatory dose limit on SDE, which is 50 rem for the year.

c. Conclusions

The inspectors concluded that, by using dose averaging to determine the SDE as prescribed by the regulations, the assigned dose for the individual involved in the event would be lower than the annual dose limit to the extremities for the year.

## 7. Licensee Actions to Ensure Regulatory Requirements Are Met

a. Inspection Scope (IP 69001)

The inspectors reviewed selected aspects of the following to verify compliance with 10 CFR Parts 19 and 20:

- Licensee records and E-mails
- Licensee dose calculations and test data
- Personnel dosimetry records for facility personnel for 2005 to date
- NSC SOP Section VII, Procedure A-3, "Reporting Requirements," Revision 2, dated December 19, 1997
- NSC SOP Section VII, Procedure A-6, "ALARA," Revision 0, dated December 12, 2002
- NSC SOP Section VII, Procedure C-10, "Radioactive Materials Handling," Revision 2, dated December 19, 1997
- NSC Form 844, "Radiation Work Permit," Number (No.) 005, Revision (Rev.) No. 05-0, dated November 15, 2005
- Texas A&M University, Nuclear Science Center, Pneumatic System Training Module, Rev. dated January 10, 2001
- Texas A&M University, Nuclear Science Center, Radiation Worker Training Module, no revision date

b. Observations and Findings

As noted above, once the licensee was aware of the dosimetry results for January, Worker A was restricted from handling any radioactive samples and a review of the situation was initiated. After consideration of the sample handling process and other factors involved, the licensee concluded that this was an anomalous reading and a dose estimate, based on past extremity doses, was prepared. Worker A was then allowed to resume "restricted" or "limited" duty. Worker A did some tasks around the facility but did not process any additional NAA sample vials because all the samples for the period had already been processed.

On March 15, 2006, the licensee received the results from the dosimetry processor which indicated that Worker A had received a dose to the extremities of 37.54 rem during February. The Facility Director and RSO reviewed the results and the NRC was notified immediately. It was reiterated that Worker A was only to be involved in 'limited" duty which did not involve dose to the extremities. As noted above, the licensee then conducted re-enactments of the sample handling process, completed careful measurements of the dose rates of the irradiated sample vials, and initiated dose calculations using the dose measurements and various computer programs and models including VARSKIN and MCNP. All NSC staff members were made aware of

the event and the fact that Worker A was not allowed to perform work involving radioactive material that would result in a dose to the extremities. Worker A was also sent for a medical examination on Thursday, March 30. The doctor found no problems and no abnormalities. A follow-up exam was scheduled for April 27, 2006.

c. Conclusions

The inspectors determined Worker A had been restricted from working with or handling radioactive material that would result in any additional dose to the extremities.

**8. Timely Reporting in the Future**

a. Inspection Scope (IP 69001)

The inspectors reviewed selected aspects of the following to verify compliance with 10 CFR Parts 19 and 20:

- NSC SOP Section VII, Procedure A-3, "Reporting Requirements," Revision 2, dated December 19, 1997
- NSC SOP Section VII, Procedure A-6, "ALARA," Revision 0, dated December 12, 2002
- NSC SOP Section VII, Procedure C-10, "Radioactive Materials Handling," Revision 2, dated December 19, 1997
- NSC Form 844, "Radiation Work Permit," Number (No.) 005, Revision (Rev.) No. 05-0, dated November 15, 2005
- Texas A&M University, Nuclear Science Center, Pneumatic System Training Module, Rev. dated January 10, 2001
- Texas A&M University, Nuclear Science Center, Radiation Worker Training Module, no revision date

b. Observations and Findings

As noted above, on February 24, 2006, the licensee received the results from the dosimetry processor which indicated that Worker A had received a dose to the extremities of 75.8 rem. Following receipt of this report, the Facility Director and the Radiation Safety Officer informed the person of the extremity dose and prohibited the individual from any duties that would add to his extremity dose. They subsequently initiated an investigation. Worker A was questioned about his activities including: 1) where he typically stored his dosimetry when it was not in use, 2) whether or not he had had any medical procedures involving radioactive materials, 3) whether he had handled any radioactive material which was unknown to the NSC staff, or 4) whether he was aware of any thing that would cause a high extremity dose. The individual had no recollection of anything that would result in a high exposure to the hands other than the high volume of pneumatic samples that were being processed during January and February. The employee had handled 140 silver samples in January 2006.

In reviewing the apparent overexposure, the licensee reviewed various circumstances: 1) The process had been ongoing for over a year and no one had ever received doses

that exceeded 1.58 rem while performing this task. 2) Even during January 2006, another employee had handled 195 samples and had received only 0.18 rem extremity exposure. 3) Nothing in the process had changed and the composition of the samples had not changed. 4) The dosimetry vendor had, in the past, contacted the licensee to notify them of a potential problem with high doses. This was not done in this case for some reason. 5) The dosimetry vendor also had sent the licensee anomalous readings in the past and the current potential overexposure of the employee's hands was determined to be such based on past experience with handling this type of sample. Based on the above and the employee's work duties and assignments, his previous dose history, and the extremity dose to the hands that had been received by another worker, who had handled samples in January, the licensee decided that a calculated dose assessment was needed for the employee.

On March 15, 2006, the licensee received the results from the dosimetry processor which indicated that Worker A had received a dose to the extremities of 37.54 rem during February. The Facility Director and RSO reviewed the results and the NRC was notified immediately and it was reiterated that Worker A was restricted from any handling of radioactive material that would produce an extremity dose. As noted above, the licensee then conducted re-enactments of the sample handling process, completed careful measurements of the dose rates of the irradiated sample vials, and initiated dose calculations using the dose measurements and various other computer models. All NSC staff members were made aware of the event and the fact that Worker A was not allowed to perform work involving radioactive material that would result in a dose to the extremities.

As a result of the event and the subsequent investigation of the possible cause(s) of the reported overexposure, licensee management and staff were forcefully reminded of the requirements in the regulations and their own procedures for reporting such events in a timely manner. The corrective action for this problem, as indicated by the licensee, was simply to report any such instances in the future. The licensee determined that it would be much more prudent to report such an event, even if there are questions about the veracity of the data, than to not report it. Also, if the data show that the report was made in error, the report could be retracted.

c. Conclusions

The inspectors determined that the licensee will report any such event in the future.

**9. Exit Interview**

The inspection scope and results were summarized on March 29, 2006, with licensee representatives. The inspectors discussed the findings for each area reviewed. The licensee acknowledged the findings presented and did not identify as proprietary any of the material provided to or reviewed by the inspectors during the inspection.

## PARTIAL LIST OF PERSONS CONTACTED

Licensee

| | |
|---|---|
| T. Fisher | Supervisor, Reactor Maintenance |
| T. Maldonado | Deputy Director, Texas Engineering Experiment Station |
| B. Pack | Health Physics Technician |
| D. Reece | Director, Nuclear Science Center |
| J. Remlinger | Manager, Reactor Operations |
| L. Vasudevan | Radiation Safety Officer |

## INSPECTION PROCEDURE USED

IP 69001 Class II Research and Test Reactors

## ITEMS OPENED, CLOSED, AND DISCUSSED

Opened

| | | |
|---|---|---|
| 50-128/2006-203-01 | IFI | Follow-up on the issue of ensuring that sufficient guidance and instruction on the proper handling of radioactive material was included in procedures, RWPs, and in the training program (Paragraph 3.b.). |
| 50-128/2006-203-02 | IFI | Follow-up on the licensee's review of their Event Notification procedure (Paragraph 4.b.(1)). |
| 50-128/2006-203-03 | IFI | Follow-up on the licensee's corrective actions taken in response to the exposure event (Paragraph 4.b.(3)). |
| 50-128/2006-201-04 | VIO | Failure to make adequate surveys to fully establish the radiological hazards that were present following the initial trial runs of vials containing plastic disks and failure to conduct surveys of the sample vials of irradiated material following the first indication of a possible overexposure on February 24, 2006, to determine the cause of the problem which lead to a failure to acceptably train and monitor workers regarding the handling of sample vials with their hands/fingers (Paragraph 5.b(2)). |

Closed

None

## LIST OF ACRONYMS USED

| | |
|---|---|
| Ag | Atomic symbol for silver |
| ALARA | As low as reasonably achievable |
| Ar | Atomic symbol for argon |
| CFR | Code of Federal Regulations |
| $cm^2$ | centimeters squared |
| Co | Atomic symbol for cobalt |
| DDE | Deep dose equivalent |
| HP | Health Physics |
| I | Atomic symbol for iodine |
| IFI | Inspector Follow-up Item |
| IP | Inspection Procedure |
| FCi | microcurie |
| mCi | millicurie |
| MeV | million electron volts |
| mrad | milliRAD |
| mrem | millirem |
| nCi | nanocurie |
| NAA | Neutron activation analysis |
| NIST | National Institute of Standards and Technology |
| NSC | Nuclear Science Center |
| NRC | Nuclear Regulatory Commission |
| OSL | Optically stimulated luminescent |
| RAD | Radiation Absorbed Dose |
| RSO | Radiation Safety Officer |
| RSB | Reactor Safety Board |
| RWP | Radiation Work Permit |
| SDE | Shallow dose equivalent |
| Si | Atomic symbol for silicon |
| SNM | Special Nuclear Materials |
| SOP | Standard Operating Procedure |
| Tc | Atomic symbol for technetium |
| TLD | Thermoluminescent dosimeter |
| TS | Technical Specifications |
| TEES | Texas Engineering Experiment Station |
| VIO | Violation |