

Date: Tue, 19 Feb 2002 08:34:19 -0800

Subject: Blue Alert - Unplanned X-Ray Exposure Incident

Title: Blue Alert- Unplanned X-Ray Exposure Incident

Identifier: B-2002-OR-X10UTB-0201 Date: 02-14-2002

Lessons Learned Statements:

1. Line managers and principal investigators should ensure that hazards are analyzed, controls are established and both are effectively communicated to all staff involved before work, including setup and testing, begins.
2. Work should be conducted according to procedures and established controls. New employees should not be granted unescorted access to work areas until they have the required training.
3. Line managers and principal investigators should be personally involved in self assessments in the work place.
4. Line managers should clearly define and communicate expectations on safety performance and should personally review experimental setups and question staff regarding the adequacy of hazard assessments and the related controls.
5. Thermoluminescent dosimeters (TLDs) should always be worn while at work in areas where they are required.

Discussion:

Between December 13 and December 26, 2001, seven members of the Oak Ridge National Laboratory (ORNL) Physics Division received unplanned exposures to X-radiation during low-power testing of an electron cyclotron resonance (ECR) ion source that is currently under development. The exposures took place in Building 6000 at the Ion Source Test Facility-2 (ISTF-2) during operation of the radio frequency (RF) microwave power supply. The Physics Division operates the ISTF-2 for the development, testing, evaluation, and improvement of ion sources or other beam preparation devices for research. The test stand includes an ion source mounted on a vacuum system, a high voltage power supply to provide accelerating potential for generated ions and the beam analysis system for determining properties of the accelerated beam. The ion source mounted at the ISTF-2, central to the X-ray incident, is a novel form of ECR ion source. RF power was provided by a 6.4-GHz, 3-kW microwave power supply coupled to the source by a wave guide and injection system. In an ECR ion source, electrons are confined in a magnetic field and energized by absorption of the microwave power. These energetic electrons collide with neutral atoms of gas in the ion source stripping off bound electrons from the atoms to produce positive ions. These ions can be extracted by an electrostatic potential and accelerated as an ion beam, the desired output of the source. X-rays are produced when high-energy electrons escape the magnetic confinement and impact the source walls. The intensity, energy, and direction of the resulting X-rays depend on the design and operating conditions of the source. X-rays generated in this fashion at ISTF-2 went undetected until the fourth day of operation resulting in the unplanned X-radiation exposures to the technical staff. Five of these individuals received measured or calculated doses that were above background. The maximum exposure was 35 mrem whole body and 145 mrem extremity. The other two individuals were not in the area long enough to record any measurable dose.

Analysis:

The root cause was identified as failure of the Task Leader (Supervisor) to provide necessary technical and safety leadership for the ECR ion source project.

1. The Task Leader failed to adequately communicate key technical facts and hazards of the experiment to all staff involved with the experiment.
2. The Task Leader did not ensure that all technical team members had current and appropriate training.
3. The Task Leader did not ensure appropriate radiation detection equipment or Radiological Support Services were available and used during start-up and testing.
4. The Task Leader did not visit the work site in a proactive manner to validate that the intended limitations were being met.
5. The Task Leader delegated responsibility for the experimental work to a junior staff member without ensuring the staff member was adequately knowledgeable of the hazards and clearly understood the responsibility.

Contributing causes include:

1. Management was not adequately involved in implementation or oversight of the Integrated Safety Management (ISM) Program.

- * Division management did not adequately communicate the expectation to Group Leaders, Task Leaders, and supervisors that they were to be personally involved in the deployment and functioning of the ISM program.

- * The Physics Division self-assessment program was not robust enough to detect the potential for single point failure mode for these types of experiments.

2. Roles, Responsibilities, Accountabilities, and Authorities (R2A2s) for ISM were not clearly defined or communicated.

- * The overall R2A2s for experimental work on the test stand were not clearly defined or communicated.

- * Significant management and staff changes occurred during the period leading up to the event.

3. Managers and staff did not conduct work according to procedures when a new hazard, the RF power supply, was introduced:

- * No Job Hazard Evaluation was performed.

- * No ES&H review was requested before work began.

- * No division approval was given to operate with the new hazard.

4. The staff's technical and safety knowledge was not commensurate with the work.

- * The Task Leader and staff member demonstrated a flawed understanding of ISM concepts.

- * The Task Leader and technical team had a misconception of "when work begins" stating that they were not "operating" yet and, therefore, did not require ES&H approvals.

- * Four members of the technical team removed their access badges with their TLDs attached during the start-up and testing under the belief that the badges would be adversely affected by the high magnetic fields.

- * Two members of the technical team had not received required training to do work at the test stand and training had expired for a third member.

- * The technical team's knowledge concerning the capability of the ECR ion source to produce high-energy X-rays during low RF power testing varied considerably.

Immediate Actions Taken:

1. Test stand operation was stopped.
2. ES&H Officer and Radiological Support Services were informed.
3. Division and Facility management were notified.
4. Initial dose estimate was made.
5. Training deficiencies were identified.
6. Improper removal of TLDs during work was realized. As a result, careful dose reconstruction to assign doses to four members of the technical staff was required.
7. Formal Stop Work Order was established by the Division Director.
8. Initial investigation team was established.
9. RF power supply was locked-out and tagged-out of service pending investigation.
10. Radiological Event Report, Occurrence Report and P-AAA screening form were submitted.
11. Management Review Committee received a written charge and charter from the Associate Laboratory Director for Physical Sciences.
12. A Management Review was done and the report was presented to the Associate Laboratory Director.

Resolution/Recommended Actions:

1. Accelerate the implementation of the new Work Control Subject Area for all types of experimental work in the Physics Division. Ensure subject matter expert and line management involvement.
2. Establish and communicate expectation for safety performance in procedures, training, R2A2s and personal performance plans. Emphasize expectation for management involvement and oversight of experimental activities.
3. Assure division required training is accomplished before work begins.
4. Reinforce training to all employees to always wear TLDs while at work.

Priority Descriptor: Blue / Information

ORNL Functional Category: Radiological Protection

Hazards: Personal Injury / Radiation / Contamination

ISM Core Function: Analyze Hazards, Define Work, Develop/Implement Controls, Perform Work

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Contact: C. E. Arnwine, Lessons Learned Coordinator, 865-241-3134

References:

- 1) Radiological Event Report, Number:6010-01-2183
 - 2) Occurrence Report ORO--ORNL-X10EAST-2001-0011 (I37756), Unexpected Radiological Exposure During New Equipment Testing
 - 3) NTS-ORO-ORNL-X10PHYSICS-2002-00013, Unplanned X-Ray Exposure
 - 4) Management Review Report, ORNL document #ORNL/CF-02/03, X-Ray Exposure Incident in the ORNL Physics Division, Report date: January 31, 2002
 - 5) ORNL-SF-2002-0202, Safety Flash - X-Ray Exposure Incident
- Keywords: x-ray, exposure, ISM, TLDs, JHE, training, R2A2s

Follow up Action: Information in this report is accurate to the best of our knowledge. As a means of measuring the effectiveness of this report, please notify Connie Arnwine at 865-241-

3134, or e-mail a93@ornl.gov, of any action taken as a result of this report or of any technical inaccuracies you find.