

**Accelerator Health Physics:
Program Administration
and
Integrated Safety Management
(session 2)**

**2008 HPS
Professional Development School
Oakland, CA**

This Presentation Provides:

Session 1:

- A primer on the Integrated Safety Management (ISM) system in use at US Department of Energy (DOE) national laboratories
- Application of ISM to an industrial accelerator accident

This Presentation Provides:

Session 2

- Information on the DOE Accelerator Safety Order and Implementation Guide
- Information on ANSI standard N43.1 on accelerator safety (as available at time of course)
- Accelerator facility case studies: accidents and best practices

DOE Accelerator Safety Order (ASO) requirements

- **Safety Assessment Document (SAD)**
- **Accelerator Safety Envelope (ASE)**
- **Accelerator Readiness Review (ARR)**
- **Shielding Policy**
- **Un-reviewed Safety Issues (USI)**
- **Written Procedures**
- **Training and Qualification**
- **Internal Safety Review System**

Safety Assessment Document (SAD)

1. identify hazards and associated onsite and offsite impacts to workers, the public, and the environment from the facility for both normal operations and credible accidents;
2. contain sufficient descriptive information and analytical results pertaining to specific hazards and risks identified during the safety analysis process to provide an understanding of risks presented by the proposed operations;
3. provide appropriate documentation and detailed descriptions of engineered controls (e.g., interlocks and physical barriers) and administrative measures (e.g., training) taken to eliminate, control, or mitigate hazards from operation;

Safety Assessment Document (SAD)

4. include or reference a description of facility function, location, and management organization in addition to details of major facility components and their operation;
5. be prepared as a single document addressing the hazards of the entire accelerator facility or as separate SADs prepared for discrete modules of the facility such as injectors, targets, experiments, experimental halls, or other types of modules; and
6. be maintained current and consistent with the administrative control measures and physical configuration of the facility and major safety equipment.

Accelerator Safety Envelope (ASE)

1. A documented ASE must define the physical and administrative bounding conditions for safe operations based on the safety analysis documented in the SAD.
2. Any activity violating the ASE must be terminated immediately, and the activity must not recommence before DOE/NNSA has been notified.

Accelerator Readiness Review (ARR)

- ARR must be performed before approval for commissioning and routine operation and as directed by the DOE cognizant Secretarial Officer/NNSA Deputy Administrator or a DOE/NNSA field manager.

Shielding Policy

- The contractor must approve and implement a written statement of the shielding policy for ionizing and nonionizing radiation.

Un-reviewed Safety Issues (USI)

- Activities that involve USIs must not be performed if significant safety consequences could result from either an accident or a malfunction of equipment that is important to safety or for which a safety analysis has not been performed.
- Activities involving identified USIs must not commence before DOE/NNSA has provided written approval.

Written Procedures

- Written procedures and instructions for conducting activities safely must be maintained;
 - must be clear, current, and consistent with management systems and the configuration of the facility and equipment;
 - must be approved by a facility contractor's senior line manager who is actively involved in the day-to-day operation of the facility.
- Procedures must include descriptions of the tasks to be performed; appropriate safety and health precautions and controls; and requirements for initial conditions to be verified, operating conditions to be maintained, and data to be recorded, as applicable.

Written Procedures

At a minimum, the procedures must cover —

- operation startup,
- normal operation,
- emergency conditions,
- conduct of maintenance,
- approval and conduct of experiments,
- review and approval of facility modifications,
- management of safety-related changes, and
- control of facility access.

Training and Qualification

- **Requirements must be established for each individual at an accelerator facility whose activities could affect safety and health conditions or whose safety and health could be affected by facility activities. Training and qualification must be documented and kept current.**
- **Only appropriately trained and qualified personnel, or trainees under the direct supervision of trained and qualified personnel, are permitted to perform tasks that may affect safety and health.**
- **All personnel assigned to or using the accelerator facility (including emergency response personnel) must be trained in the safety and health practices and emergency plans consistent with their involvement and the hazards present.**

Internal Safety Review System

- A system must be established and maintained to periodically assess and document the condition of the facility, equipment, and engineered safety systems.
- Appropriateness and implementation of procedures, administrative controls, and personnel training and qualifications must be periodically reviewed and documented by the internal safety review system.

ISM Core Functions

1. Define the Scope of Work
2. Analyze the Hazards
3. Develop and Implement Hazard Controls
4. Perform Work within Controls
5. Provide Feedback and Continuous Improvement

Accelerator Safety Order (ASO)

Implementation of ISM Core Functions

ASO Requirement

ISM Core Function

Safety Assessment Document (SAD). The SAD describes in sufficient detail all significant hazards presented by the facility and its operations and the controls by which these hazards will be managed to an acceptable level of risk.	1,2,3
Shielding Policy. A written statement of the shielding policy for ionizing and non-ionizing radiation must be in place.	2
Un-reviewed Safety Issues (USI). Activities that involve USI may not be performed if significant safety consequences could result.	2,3
Written Procedures. Written procedures for conducting activities safely must be in place.	3
Accelerator Readiness Review (ARR). An ARR must be performed before approval for commissioning and routine operation of the facility.	3
Accelerator Safety Envelope (ASE). The ASE defines the set of physical and administrative bounding conditions for safe operations.	4
Training and Qualification. Training and qualification requirements must be established for each individual at an accelerator facility whose activities could affect safety and health conditions or whose safety and health could be affected by facility activities.	4
Internal Safety Review System. An internal safety review system must be established.	5

ISM Guiding Principles

1. Line Management Responsibility for Safety
2. Clear Roles and Responsibilities
3. Competence Commensurate with Responsibilities
4. Balanced Priorities
5. Identification of Safety Standards and Requirements
6. Hazard Controls Tailored to Work Being Performed
7. Operations Authorization

Tailoring of Accelerator Safety Requirements

Hazard Level	Accelerator Facility Features
Low	<p>Small non-complex facilities with local work area impacts only</p> <ul style="list-style-type: none">• Radiation generating devices• Small single purpose units• Electron microscopes, ion implanters• X-ray or neutron generators• Not capable of high radiation area• Developmental/experimental units• Bench top, or single room
Medium	<p>Complex facilities with negligible offsite impacts</p> <ul style="list-style-type: none">• External/extractable beam(s)• Multiple points of entry, caves, users• Multiple active safety systems
High	<p>Unique non-radiation hazards not covered under 10 CFR 835 Facilities with credible potential for more than negligible offsite impacts</p> <ul style="list-style-type: none">• Normal operations, > 10 mrem/yr at site boundary from potential pathways, and/or• Accident conditions, expect > 1 rem or > ERPG-14 at site boundary for a mitigated release
Very High	<p>Facilities or module thereof involving or producing sufficient inventory of fissionable materials to create potential for criticality</p>

ANSI N43.1

Accelerator Safety Standard

- Presentation on ANSI N43.1 to be based on information available at the time.

- Accident cases for discussion (continued)

Case #2 Accelerator Accident in Forbach, France

What happened.

- In August 1991 workers at an industrial accelerator facility in Forbach, France were treated for radiation injuries. This accident, described by Thomas (1993), bears striking similarity to the Maryland accelerator accident described above.
- The accelerator was a 2.5 MV, 35 A Van de Graaff type electrostatic electron accelerator, with maximum in-beam beam dose rates of 80,000 Gy sec⁻¹.
- Three workers entered the irradiation area to repair a conveyer belt while believing the irradiator to be in a safe state. They were part-time workers hired from a temporary employment agency, and allegedly untrained as to radiation hazards or radiation safety,

Case #2 Accelerator Accident in Forbach, France

- Although the electron source current had been shut down, the high voltage had not been cut off. Residual radiation generated under these conditions was due to dark current. Under these conditions, the beam dose rate was evaluated to be about 0.1 Gy sec^{-1} .
- One of the victims was exposed to a skin dose of 40 Gy and subsequently suffered skin burns; sections of his fingers and ears were amputated, and he underwent multiple skin grafts on his arms, legs and chest. The other two persons were exposed to 9 and 5 Gy respectively. The maximum whole-body dose was estimated to be 1 Gy.

Case #2 Accelerator Accident in Forbach, France

Lessons learned

- Materials, design and work organization had not been defined to reduce both individual and collective doses to the minimum values below regulatory limits in accordance with the ALARA principle.
- Absence of physical non-accessibility barriers preventing access to the beam during irradiation.
- The absence of any French translation of the danger warning signs observed when the irradiator was operating.

Case #2 Accelerator Accident in Forbach, France

- The absence of any training of the workers involved as to the potential dangers of the machine.
- The absence of radiation protection controls prior to putting the machine into service.
- Absence of a designated radiation protection specialist who would have periodically analyzed the different exposed working posts, ensured that radiation protection measures were being respected and made an inventory of working situations likely to lead to exceptional radiation exposure or accident conditions; it would also have been the radiation protection specialist's responsibility to provide basic radiation protection safety training to the persons implicated in the use of the irradiator.

Case #3 Accelerator Accident in Illinois

What happened.

- On February 18, 1965 a radiation accident occurred in Rockford Illinois, as reported by Lanzl et al. (1967). This case involved a 10 MeV electron beam from an industrial linear accelerator used to irradiate materials.
- As in the Maryland case, this accelerator was located in a shielded room with a protective labyrinth. A conveyor belt was used to transport industrial products from and adjacent service room to be irradiated by the accelerator beam, and then back into the service room.
- The conveyor system occupied part of the entryway between the service room and accelerator room. In order to accommodate this conveyor system, the bottom of the door guarding the entryway had been sawed off leaving a gap. The conveyor belt was not moving before, during, or after the accident.

Case #3 Accelerator Accident in Illinois

- The worker apparently entered the irradiation room to place an item on the conveyor belt in the beam path, exposing primarily his hands and to a lesser extent other parts of his body.
- The worker gained entrance to the accelerator room through the gap under the sawed-off door where the conveyor passed through, without tripping the interlocks.
- Unlike the Maryland and Forbach accidents which involved exposure to dark-current electrons, the Illinois accident involved a beam-on situation.
- Film badge data was available and was useful in reconstructing doses.

Case #3 Accelerator Accident in Illinois

- The Lanzl et al. paper focuses on the clinical aspects of the case not the technical aspects, except to state that after the accident, the door was redesigned to accommodate the conveyor system without leaving a gap.
- The radiation dose to the worker's hand was estimated to be between 400 to 2400 Gy, resulting in double amputation 5-6 months after exposure. The deep dose at points in the body was estimated to be 2 – 5 mGy.

Lessons learned

- While more detailed information on safety systems is not available for the Illinois case, it is clear that there are certain similarities with the lessons learned Maryland described above, in that there were engineering controls in place, including an interlocked entry, and this was deliberately thwarted by the worker who was injured.

Case #4 Gulf Oil Accelerator Accident

What happened.

- On October 4, 1967 an accident occurred as Gulf Oil Company technicians were using a 3 MeV Van de Graaff accelerator for the activation of soil samples, as reported by S. Porter (1992).
- The combination of an interlock failure on the power key of the accelerator console and the taping of several of the interlocks on the safety tunnel door and the target room inside door produced serious accidental exposures to three individuals.
- Film badges were read which contributed to dosimetry evaluations.

Case #4 Gulf Oil Accelerator Accident

- One individual received approximately 1 Gy whole-body dose equivalent, the second received close to 3 Gy whole-body dose equivalent and the third received approximately 6 Gy whole-body dose equivalent, in addition to approximately 60 Gy to the hands and 30 Gy to the feet.
- Timely medical attention saved the life of the person with the highest exposure. The heroic procedure of a complete bone marrow transplant together with the use of reverse isolation and quality medical care were all major factors in saving this person's life.

Case #4 Gulf Oil Accelerator Accident

Lessons Learned

- If the simple operating procedure of always using a survey meter when entering the exposure room had been followed, this tragic accident would have been avoided.
- At least two interlocks had been taped closed for long periods of time prior to this accident. Defeating of protective interlocks is intolerable.
- Regular maintenance checks should have been made on the key-operated power interlocks for the accelerator.

- ISM Good Practices

FermiLab dismantling and removal of the beam absorber inside the beam cavity of the SM12 magnet



- A moveable rectangular steel and lead blanket shield fixture was constructed to surround personnel working inside the beam cavity
- Exposure rate of 0.75 mSv hr^{-1} was reduced to approximately 0.15 mSv hr^{-1}
- Time limits were instituted to minimize doses

The total collective dose for this phase of the project was 0.25 person-mSv which reflects an estimated dose reduction of approximately 1.0 person-mSv

Princeton Plasma Physics Laboratory

Key Activity for Re-Invigorating ISM

An improved hazard awareness training course involves small groups in both classroom training and field exercises



Effects. Behaviors and practices have been improving and they have led to improvements in work safety performance measures.

Significant Radiation Dose Reduction

at the Berkeley Lab 88-Inch Cyclotron

1998-2001

Integrated **S**afety **M**anagement Success

96%

Reduction

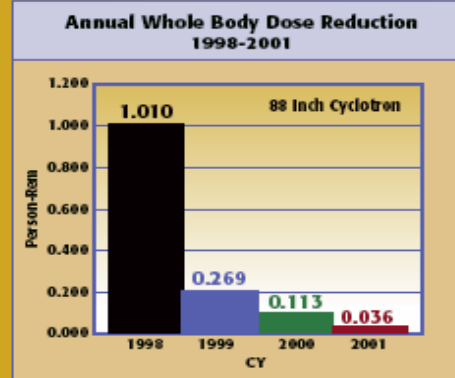
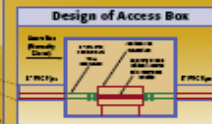
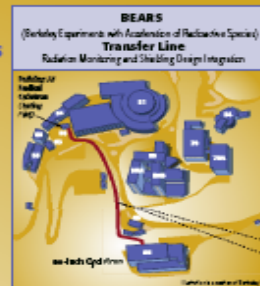
Through close cooperation and partnering of line management with Radiation Protection staff and application of ISM principles, personnel doses have been reduced 96% since 1998.

"LBNL ranks the lowest in both average measurable dose and collective dose of all the SC multi-program laboratories, and both dose measures are trending down. LBNL has a number of policies within the framework of ISM that contribute to maintaining occupational radiation doses as low as reasonably achievable (ALARA)."

From SC-83's Occupational Radiation Exposure Profile For the Office of Science Laboratories-2001

WORK PLANNING

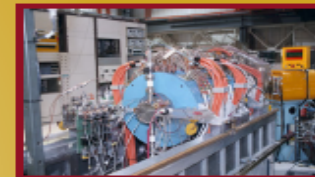
- Partnering between researchers and radiation protection staff
- Collaborative designs integrating radiation safety controls to reduce both environmental and personnel doses
- Improved pre-planning for high dose deflector maintenance work



Dose reduction achieved through application of ISM principles

HAZARD IDENTIFICATION

- Thorough review and evaluation of research proposals
- Legacy radioactive material characterized and removed



RADIATION SAFETY CONTROLS

- Cyclotron-specific radiation safety training provided
- Improved shielding designs and upgrades
- Implemented use of portable shields



WORK PERFORMANCE

- Improved authorization program control and compliance with required documentation
- Cave entry survey requirements upgraded and improved for better hazard communication



"Under the auspices of ISM, the partnership that developed between the EH&S and Nuclear Science Division management has had a very positive impact on radiation safety at the cyclotron and in the overall dose reduction."

Claude Lyneis 88-Inch Cyclotron Facility Director

The 88-Inch Cyclotron is operated as a national user facility in support of U.S. Department of Energy programs in basic nuclear science. The central component is a sector-focused, variable-energy cyclotron that can be fed by either of two Electron Cyclotron Resonance (ECR) ion sources. This versatile combination produces heavy-ion beams of elements throughout the periodic table. The facility supports Berkeley Lab research as well as outside users performing nuclear structure experiments, nuclear astrophysics and reactions studies. The 88-inch Cyclotron facility presents a wide variety of challenging health physics issues that have been successfully managed by the radiation protection staff in the EH&S division at the Berkeley Lab.

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REVIEW AND FEEDBACK

- On-going ALARA reviews and analysis of personnel and environmental doses
- On-site radiological control technician supporting research and maintenance activities

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- Accelerator facility case studies: accidents and best practices