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DOE-HDBK-1141-2008
August 2008

DOE HANDBOOK

Radiological Assessor Training

U.S. Department of Energy
Washington, D.C. 20585

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Foreword

This Handbook describes an implementation process for training as recommended in Implementation Guide G441.1-1B, *Radiation Protection Programs,* March 2007, and as outlined in DOE- STD- 1098-99, CN1, March 2005, *DOE Radiological Control* (the Radiological Control Standard - RCS). The Handbook is meant to assist those individuals within the Department of Energy, Managing and Operating contractors, and Managing and Integrating contractors identified as having responsibility for implementing training required by Title 10 Code of Federal Regulations Part 835 *Occupational Radiation Protection* (10 CFR 835) and training recommended by the RCS. This training is intended for auditors and assessors to assist in meeting the training requirements of 10 CFR 835 for the conduct of audits and assessments of occupational radiation protection programs. While this Handbook addresses many requirements of 10 CFR 835 Subpart B, it must be supplemented with facility-specific information to achieve full compliance.

This Handbook contains recommended training materials consistent with other DOE radiological safety training materials. The training material consists of the following five parts:

Program Management Guide - This part contains detailed information on how to use the Handbook material.

Instructor's Guide - This part contains lesson plans for instructor use, including notation of key points for inclusion of facility-specific information.

Overheads - This part contains overheads instructor use corresponding to the Instructor's Guide.

Student's Guide - This part contains student handout material and also should be augmented by facility-specific information.

Handouts - This part contains several student handouts that provide supporting information for various modules.

This training material is targeted for individuals with a basic knowledge of radiological protection concepts and provides material on how to conduct a radiological assessment.

This Handbook was produced in Microsoft Word and has been formatted for printing on a HP 4M (or higher) LaserJet printer. Overheads were produced in Powerpoint. Copies of this Handbook may be obtained from either the DOE Radiation Safety Training Home Page Internet site (http://www.hss.energy.gov/healthsafety/wshp/radiation/RST/rstmater.htm) or the Technical Standards Internet site (http://www.hss.energy.gov/nuclearsafety/techstds).

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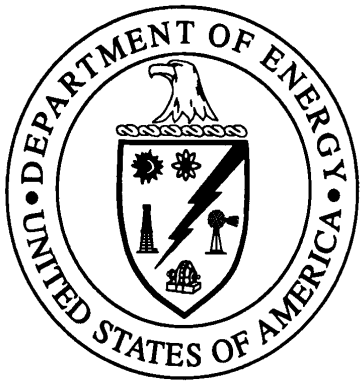
Program Management Guide



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Program Management Guide

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Introduction

Purpose and Scope

This handbook describes a Radiological Assessor Training program. It includes standards and policies as well as recommendations for material development and program administration. It is intended for use by DOE and DOE contractors for the development of facility-specific radiological assessor training. This material is intended for assessment of occupational radiation protection programs. This material does not address environmental radiation protection programs.

Compliance with 10 CFR 835-Subpart B

The DOE training materials for Radiological Assessor Training reflect the requirements identified in 10 CFR 835-Subpart B*, Management and Administrative Requirement*s, and recommendations identified in the DOE Implementation Guide G441.1-1B, *Radiation Protection Programs Guide,* and in DOE-STD-1098-99, *DOE Radiological Control Standard.* When implemented in its entirety and supplemented as noted with appropriate facility-specific information, this handbook provides an acceptable method to meet the requirements of 10 CFR 835-Subpart B for training of individuals (auditors and assessors) responsible for developing and implementing measures necessary for ensuring compliance with 10 CFR 835 (10 CFR 835.103).

However, it is incumbent on management of each facility to review the content of this handbook against the radiological hazards present to ensure that the training content is appropriate to each individual's prior training, work assignments, and degree of exposure to potential radiological hazards.

Training described in this handbook does not eliminate the need for additional training on facility-specific hazards. Notations throughout the program documents indicate the need for facility-specific information. If the noted section is not applicable to the facility, no information need be presented. The site Radiological Control Manager or designee should concur in facility-generated radiological training material.

Goal of Training Program

The goal of the training program is to provide a sufficient level of knowledge and skills in radiological assessment fundamentals commensurate with the assigned duties and potential radiological hazards encountered at DOE facilities using or possessing radioactive materials and/or radiation-producing devices.

Organizational Relationships and Reporting Structure

The DOE Office of Health, Safety and Security's Office of Worker Safety and Health Policy (HS-11) is responsible for approving and maintaining the training materials.

The establishment of a comprehensive and effective contractor site radiological control training program is the

responsibility of line management and their subordinates. The training function may be performed by a separate training organization, but the responsibility for quality and effectiveness rests with line management.

Training Program Descriptions

Overview of Training Program

Radiological Assessor Training may be provided to individuals (auditors and assessors) responsible for developing and implementing measures necessary for ensuring compliance with 10 CFR 835 at a DOE site or facility. The terminal objective is that, upon completion of this training, individuals with appropriate education and experience may conduct audits, assessments, appraisals and surveillances of occupational radiation protection programs at a DOE site or facility in accordance with 10 CFR 835.103 and in meeting other quality assurance requirements.

Prerequisites

The material is targeted for individuals with a baseline knowledge of radiological protection concepts and provides material on how to conduct a radiological assessment. DOE has developed training materials for radiation protection concepts as part of the Department's Technical Qualification Program. Students participating in the Radiological Assessors Training should be able to demonstrate competence of radiation protection concepts equivalent to the DOE Technical Qualification Program Topic Area *Radiation Protection.* The student Manual for the *Radiation Protection* Topic Area provides a good review of the competency topical expectations.

DOE has also provided guidance on qualifications of radiological assessors in DOE STD-1107-97 *Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities*. Students should be capable of meeting

	this standard prior to conducting independent technical evaluations/assessments of radiation protection programs (i.e. evaluations beyond simple surveillances of radiation protection program implementation). In accordance with 10 CFR 835-Subpart B, each individual shall have appropriate education, training and skills to discharge their responsibilities for ensuring compliance with 10 CFR 835. Refer to DOE Order 5480.20A, *Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities*, for qualification requirements for technical staff (this category frequently includes radiological assessors).
Proficiency Requirements	An examination or performance demonstration is recommended.
Retraining	Sites are encouraged to develop periodic training and retraining for radiological assessors and auditors. Retraining should focus on lessons learned and site specific events as necessary. Materials developed in support of training should be documented in accordance with 10 CFR 835.704, *Administrative Records*.
Instructor Training and Qualifications	All classroom instruction should be provided by instructors qualified in accordance with the contractor's site instructor qualification program. Training staff (contractor and subcontractor, if used) should possess both technical

knowledge and experience, and the developmental and instructional skills required to fulfill their assigned duties.

1.Training staff responsible for program management, supervision, and development should have and maintain the education, experience, and technical qualifications required for their jobs.

2.Instructors should have the technical qualifications, including adequate theory, practical knowledge, and experience, for the subject matter that they are assigned to teach.

3.Methods should be in place at each contractor site to ensure that individual instructors meet and maintain position qualification requirements.

4.Subject matter experts without instructor qualification may provide training in their area of expertise. However, if these subject matter experts are to be permanent instructors, they should be trained as instructors in the next practical training cycle.

DOE Order 5480.20A, *Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities*, discusses qualification requirements for instructors.

DOE has also provided guidance on qualifications of radiological instructors in DOE STD-1107-*97 Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities.*

Training Material Presentation

Training materials consist of lesson plans, overheads, student guides, and handouts. To ensure appropriate training, facility-specific materials must be added to the materials when necessary to adequately train individuals for facility-specific radiological hazards.

For example, facility-specific modules may be added to cover such topical areas as: reactors, breeder reactors, spent fuel storage, radwaste burial, radwaste storage, high level waste storage, tank farms, reprocessing plants, and vitrification plants.

Conversely, modules with no applicability to a facility or site may be omitted (e.g., a tritium facility may want to omit modules on uranium and plutonium).

It is estimated that this material could be presented in 44 hours. The Table of Contents in the Instructor's Guide provides a recommended breakdown of time per module.

Training Certificates

A training certificate that identifies the individual's current training status may be provided to qualified personnel. Each facility is responsible for determining the training status of employees. Facilities have the option of utilizing a certificate as proof of training.

Training Aids, References	Facility-specific training aids should be developed at the facility to suit individual training styles. Each facility may add information, activities, and/or view graphs to enhance the program.

Lectures, Seminars, Training Exercises, etc.	Radiological assessor training is designed to be delivered in a classroom setting. An alternate delivery method may be implemented with computer-based training (CBT) equipment or web-based training (WBT) equipment. The presentation of training should include DOE developed materials and facility-specific information.
Delinquent Training/Failure	Employees who are delinquent on initial training or retraining should lose their status of being qualified assessors or auditors until successful completion of the delinquent training requirement.
Exceptions and Waivers	Successful completion of the Radiological Assessor Training at one DOE site may be recognized by other DOE sites. However, the determination as to the adequacy of training as required by 10 CFR 835-Subpart B is the responsibility of the facility in which the individual will be conducting assessments.

Administration

Training Records	Training records and course documentation shall meet the requirements of 10 CFR 835.704 *Administrative Records*.
Training Program Development/Change Requests	All requests for program changes and revisions that are generic in nature may be submitted using DOE F 1300.3 *Document Improvement Proposal*. A copy of DOE F 1300.3 and instructions are included at the end of this document.
Audits (internal and external)	Internal verification of training effectiveness may be accomplished through senior instructor or supervisor observation of practical applications and discussions of course material. Results should be documented and maintained by the organization responsible for Radiological Control Training.

Evaluating Training Program Effectiveness

Verification of the effectiveness of Radiological Assessor Training should be accomplished by surveying a limited subset of former students in the workplace. This evaluation should include observation of practical applications and discussion of the course material. DOE/HSS has issued guidelines for evaluating the effectiveness of radiological training through the DOE Operations Offices and DOE Field Offices. These guidelines are available from the DOE Radiation Safety Training Home Page. (See the Foreword of this document.)

For additional guidance, refer to DOE STD 1070-94, *Guide for Evaluation of Nuclear Facility Training Programs*. The guidelines contained in these documents are relevant for the establishment and implementation of post-training evaluation programs.

References and Supporting Documents

U.S. Department of Energy, DOE Order 5480.20 change 1, Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities, July 2001.

U.S. Department of Energy, DOE STD-1098-99, Radiological Control, Reaffirmed December 2004.

U.S. Department of Energy, DOE STD-1107-97, Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities, January 1997.

U.S. Department of Energy, 10 CFR 835, Occupational Radiation Protection, June 2007.

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Radiological Assessor Training
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Instructor's Guide

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Regulatory Documents

Objectives:

Upon completion of this training, the participant will be able to:

1. Identify the hierarchy of regulatory documents.
2. Define the purpose of 10 CFR Part 835.
3. Define the purpose of the DOE Radiological Control Standard.
4. Define the terms “shall” and “should” as used in the above documents.
5. Describe the role of the Defense Nuclear Facilities Safety Board (DNFSB) at DOE sites and facilities.

Training Aids:

Overhead Transparencies (OTs): OT 1.1 – OT 1.17 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student’s Guide

References:

U.S. Department of Energy, 10 CFR Part 820, *Procedural Rules for DOE Nuclear Activities*, 2007.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, 2007.

U.S. Department of Energy, *Radiological Control*, DOE STD-1098-99, Reaffirmed December 2004.

U.S. Department of Energy, *Department of Energy Radiological Health and Safety Policy*, DOE P 441.1, April 1996.

I. Introduction

II. DOE radiological health and safety

A. Policy (some key points in summary)

- Establish and maintain a system of regulatory policy and guidance.
- Ensure appropriate training is developed and delivered and the technical competence of the DOE workforce.
- Establish and maintain, from the lowest to the highest levels, line management involvement and accountability for Departmental radiological performance.
- Ensure radiological measurements, analyses, worker monitoring results, and estimates of public exposures are accurate and appropriately made.
- Conduct radiological operations in a manner that controls the spread of radioactive materials and reduces exposure to the work force and the general public and utilizes a process that seeks exposure level as low as reasonably achievable (ALARA).
- Incorporate dose reduction, contamination reduction, and waste minimization features into the design of new facilities and significant modifications to existing facilities in the earliest planning stages.
- Conduct oversight to ensure Departmental requirements are being complied with and appropriate radiological work practices are being implemented.

Show OT 1.1 and OT 1.2.

State objectives.

Discuss that this is from DOE P 441.1

Show OT 1.3.

Show OT 1.4.

B. History

Show OT 1.5.

DOE has provided numerous written standards for on-site radiological protection, the most recent regulation being 10 CFR Part 835, *Occupational Radiation Protection*, Amended June 2007. This regulation was preceded by:

- DOE Notice 5480.6 of June 17, 1992, *Radiological Control*, which specified that the *DOE Radiological Control Manual* (DOE/EH-0256T) would supersede DOE Order 5480.11.
- DOE Order 5480.11, *Radiation Protection for Occupational Workers.* The purpose was to establish radiation protection standards and program requirements for DOE and DOE contractors for the protection of workers from ionizing radiation.

The establishment of DOE radiological protection standards did not start with these documents. A chronology of dose limits of DOE and its predecessor agencies, the Atomic Energy Commission (1946-1975) and the Energy Research and Development Administration (1975-1977), demonstrate a lowering of whole body dose limits over the last 50 years.

Discuss that there are different limit which will be discussed later (e.g., whole body, lens of the eye, and skin).

In the establishment of these dose limits, DOE has followed recommendations of national and international radiological protection groups, notably the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP).

C. Hierarchy of requirements

Currently within DOE there are two parallel hierarchies of requirements:

- Rules and/or regulations (these terms are used interchangeably in this training)
- DOE Orders

Show OT 1.6.

Obj. 1
Identify the hierarchy of regulatory documents.

Show OT 1.7.

III. Rules and regulations

In response to the enforcement authority in the Price-Anderson Amendments Act (PAAA) of 1988, DOE is converting its contractual requirement in orders to enforceable rules to enhance contractor accountability for safety.

A. DOE enforcement of rules under PAAA

10 CFR Part 820 (effective on September 16, 1993) sets forth the procedures to implement the provisions of the PAAA. Part 820 requires contractors to comply with DOE Nuclear Safety Requirements.

PAAA demands a “large stick” to enhance contractor accountability for safety. Rules provide authority for the assessment of civil and criminal penalties and thus provide the large stick.

B. Penalties under Part 820

1. Civil penalties

   DOE may assess civil penalties against any person subject to Part 820, for violations of:

   - Codified rules in the CFR
   - Compliance orders
   - Any program or plan required by a rule or compliance order

   Note: Certain nonprofit educational institutions and other listed institutions are exempt from assessment of civil penalties.

2. Criminal penalties

   If a person subject to the Atomic Energy Act of 1954, as amended, or Nuclear Safety Requirements, has by action or omission knowingly and willfully violated, caused to be violated, attempted to violate, or conspired to violate any section of the Atomic Energy Act of 1954, as amended, or applicable DOE Nuclear Safety Requirements, the person shall be subject to criminal sanctions.

3. The "carrot and stick" approach

   Discuss site-specific monetary incentives.

   DOE may provide monetary incentives in its management and operating (M&O) contracts for actions consistent with or exceeding requirements, and to penalize actions and activities that were not in compliance with requirements.

   Noncompliance with the Radiation Protection Program can subject a contractor to PAAA enforcement. There are provisions to mitigate penalties for self-identifying and reporting violations.

C. DOE Nuclear Safety Requirements

DOE Nuclear Safety Requirements are the set of enforceable rules, regulations, or orders relating to nuclear safety that have been adopted by DOE (or by another agency if DOE specifically identifies it).

Compliance orders are issued by the Secretary. They identify a situation that violates, potentially violates, or otherwise is inconsistent with the:

- Atomic Energy Act of 1954, as amended
- Nuclear statutes
- Nuclear Safety Requirements

Compliance orders:

- Mandate a remedy or other action
- States the reason for the remedy or other action

D. 10 CFR Part 835

Show OT 1.8.

On December 14, 1993, DOE published a final rule in the *Federal Register* (58 FR 65458) Title 10 Code of Federal Regulations Part 835, *Occupational Radiation Protection* (10 CFR 835). On November 4, 1998 an amendment to 10 CFR 835 was published in the *Federal Register* (63 FR 59663). On June 8, 2007 an amendment to 10 CFR 835 was published in the *Federal Register* (72 FR 31904).

Obj. 2
Define the purpose of 10 CFR Part 835.

The purpose of 10 CFR 835 is the codification of radiological protection requirements. It contains "shall" statements, which are legally binding. It also contains:

Define prescriptive language.

- Prescriptive language

- Added emphasis on ALARA
- Requirements for a Radiation Protection Program (RPP)

Show OT 1.9.

- Federal law
- Criminal and civil penalties for violations

E. Radiation Protection Program (10 CFR Part 835)

Each site, under Part 835, must submit a written Radiation Protection Program (RPP).

The RPP requires careful consideration because noncompliance may subject a contractor to PAAA enforcement

F. Guidance documents for 10 CFR Part 835

Show OT 1.10.

Two types of regulatory guidance documents have been developed:

- Guidance for implementing the provisions of 10 CFR Part 835.
- Guidance providing technical positions.

The above are available through the DOE HS-11 website at:

http://www.hss.energy.gov/healthsafety/wshp/radiation/

Unlike the requirements specifically set forth in 10 CFR Part 835, the provisions in guidance documents are not mandatory. They are intended solely to describe the rationale for, and the objectives of, regulatory requirements and/or to identify acceptable methods for implementing regulatory requirements.

Failure to follow a guidance document does not in itself indicate noncompliance with a specific requirement of the rule. A finding of noncompliance is found for a failure to satisfy the regulatory requirement.

Following a guidance document in the prescribed manner will ordinarily create a presumption of compliance with a related regulatory requirement.

1. Technical guidance

   Technical guidance describes and disseminates technical methods and techniques for fulfilling implementation and, in turn, the requirements in 10 CFR Part 835. Examples of this guidance are DOE Technical Standards and DOE Radiological Control Technical Positions (RCTPs).

   Refer students to website for RCTPs:
   Insert appropriate URL

   Review RCTPs and discuss as applicable to the site.

2. Implementation guides (IGs)

   Implementation guidance is intended to identify and make available to DOE contractors basic program elements and acceptable methods for implementing specific provisions of the final rule. Thirteen implementation guides have been condensed into one G441.1-1B, March 7, 2007.

   Refer students to website for IGs:
   Insert appropriate URL

G. Relationship between 10 CFR Part 835 and 10 CFR Part 20

   Show OT 1.11.

   10 CFR Part 20 is the occupational radiological regulation issued by the Nuclear Regulatory Commission (NRC).

   The question of consistency among federal agencies in their occupational radiological protection regulations became a major point of discussion during the rule making process.

While agreeing with the goal of consistency, DOE believes that it must promulgate its own regulations because of the unique nature and diversity of radiological activities within the DOE complex. The final rule allows DOE to establish more rigorous requirements in areas of particular concern. Overall 10 CFR Part 835 has many similarities as 10 CFR Part 20.

IV. DOE STD *Radiological Control* and Orders

Show OT 1.12.

A. *Radiological Control*

In January 1992, a memorandum was sent to the heads of DOE elements involved in managing radiological programs. In the memorandum, the Secretary directed a series of initiatives to enhance the conduct of radiological operations within the Department of Energy. Also in this memo, the Assistant Secretary of Environment, Safety and Health was directed to develop a comprehensive and definitive radiological control manual. The *DOE Radiological Control Manual* was developed to meet that directive and was approved by the Secretary and promulgated with DOE Notice 5480.6, *Radiological Control*, in July 1992.

Obj. 3
Define the purpose of the DOE Radiological Control Standard.

After the issuance of 10 CFR 835 as a final rule in December 1993, DOE Notice N441.1, *Radiological Protection for DOE Activities*, was issued on 9-30-95. This cancelled the notice which made the Radiological Control Manual a requirements document. However, the notice stated that "cancelled orders that are incorporated by reference in a contract shall remain in effect until the contract is modified to delete the reference.

N441.1 also retained some of the radiation protection requirements from the Radiological Control Manual that were not included in 10 CFR 835.

In July, 1999, the Radiological Control Manual was replaced by the standard, DOE-STD-1098-99, *Radiological Control*. Many DOE sites contractually must still adhere to the provisions of either the Radiological Control Manual or the Radiological Control Standard. Subsequent to the 1998 amendment to 10 CFR 835, the effective date of N441.1 has passed.

The DOE Radiological Control Standard is not regulatory in nature. It is a guidance document that describes DOE's policy and expectations for an excellent radiological control program**.**

1. Implementation

   If a site fully implements a provision of the DOE Radiological Control Standard, the user will have most likely complied with any related statutory, regulatory, or contractual requirements. Users are cautioned that they must review the source document (10 CFR 835) to ensure compliance.

2. Enforceability

   When incorporated into contracts, the provisions of the DOE Radiological Control Standard or Manual are binding requirements.

   If portions of the Site-Specific Radiological Control Manual are incorporated in the RPP under Part 835 and approved by DOE, they are also binding.

B. The Site-Specific Radiological Control Manual

- The DOE Radiological Control Standard states that a Site-Specific Radiological Control Manual should be written and followed.

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C. Relationship between 10 CFR Part 835 and the DOE Radiological Control Standard

Show OT 1.13.

1. Compliance

What is the relationship between Part 835 and the DOE Radiological Control Standard regarding compliance issues?

- The Office of Enforcement and Investigation (HS-40) will enforce 10 CFR Part 835. It can assess fines and penalties.

- The Program Offices will audit for both compliance with 10 CFR 835 and contractual agreements including the DOE Radiological Control Standard or Manual, Orders, etc. Results of these audits can affect the contractor's award fee.

2. What if there are conflicts?

Show OT 1.14.

10 CFR Part 835 takes precedence over requirements of the DOE Radiological Control Standard and orders. It is unlikely that there will be a conflicting requirement between the two documents, although one document may have a requirement that is not addressed in the other.

It is planned that all requirements for nuclear safety will be incorporated into rules.

3. "Shall" and "should" statements

   - 10 CFR Part 835 contains "shall" statements. "Shall" statements in Part 835 are legally binding.

     Processes for exemption relief from Part 835 are set forth in Subpart E to Part 820. If relief is requested from provisions of Part 835, the exemption must be considered and granted, if appropriate, by the Chief Health, Safety and Security Officer (HS-1).

   - The use of "should" in the DOE Radiological Control Standard recognizes that there may be site- or facility-specific attributes that warrant special treatment. It also recognizes that literal compliance with the elements and requirements of the provision may not achieve the desired level of radiological control performance.

Obj. 4
Define the terms "shall" and "should" as used in the above documents.

Refer students to website for exemption decisions: http://tis.eh.doe.gov/whs/rhmwp/exemption.html

Review exemption decisions and discuss as applicable to the site.

D. DOE Standards

DOE has developed several technical standards for occupational radiation protection. Depending on the site-specific application, some standards are required to be followed. For example, sites which need to monitor individual external exposures to ionizing radiation need to follow the DOE Laboratory Accreditation Program (DOELAP) standards. Other standards may be incorporated by reference in the site RPP.

Other standards provide technical guidance on specific applications, but adherence to the standard may not be required.

Prior to conducting an assessment, the site requirements documents must be reviewed to determine applicable requirements.

Show OT 1.15.
Refer students to website for technical standards:
Insert appropriate URL

Radiation protection standards are also on:
Insert appropriate URL

Review standards and discuss as applicable to the site.

V. Defense Nuclear Facilities Safety Board

A. Establishment

The Atomic Energy Act of 1954 was amended by adding Chapter 21, Defense Nuclear Facilities Safety Board (DNFSB). This amendment established an independent board in the executive branch to provide oversight of some DOE operations at DOE facilities and sites.

Obj. 7
Describe the role of the Defense Nuclear Facilities Safety Board (DNFSB) at DOE sites and facilities.

Show OT 1.16.

B. Members

The DNFSB consists of five members appointed by the President with consent of the Senate.

The Board shall:

- Review and evaluate standards
- Investigate any event or practice at a DOE defense nuclear facility that the Board determines has adversely affected or may adversely affect public health and safety.

The Board may:

- Establish reporting requirements for the Secretary of Energy

By evaluating how well DOE meets its objectives, the DNFSB helps DOE achieve and maintain excellence in radiological protection.

C. Secretary of Energy

The Secretary of Energy shall fully cooperate with the Board.

D. DNFSB Recommendations

DNFSB provides DOE with recommendations for improving safety at DOE defense nuclear facilities. Examples include:

DNFSB Recommendation 91-6 dealt with radiological protection concerns throughout the DOE defense nuclear facilities complex, and identified several actions to be taken by the Department to improve radiological protection performance.

DNFSB Recommendation 92-7 dealt with training and qualification at DOE sites and facilities.

DNFSB Recommendation 98-1 dealt with resolution of internal audit findings.

DNFSB Recommendation 99-1 dealt with safe storage of fissionable materials.

Implementation of DOE and site commitments made in response to DNFSB recommendations are areas to review during an assessment.

Show OT 1.17.

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: 10 CFR Part 835, Background and Focus

Objectives:

Upon completion of this training, the participant will be able to:

1. Describe the contents of 10 CFR Part 835.
2. Identify the site requirements of 10 CFR Part 835.

Training Aids:

Overhead Transparencies (OTs): OT 2.1 – OT 2.32 (may be supplemented or substituted with updated or site-specific information)

Handout - "Dosimetric Quantities in 10 CFR Part 835"

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

Handout - "Dosimetric Quantities in 10 CFR Part 835"

10 CFR 835

References:

U.S. Department of Energy, 10 CFR Part 820*, Procedural Rules for DOE Nuclear Facilities*, 2007.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, 2007.

U.S. Department of Energy, Order 5400.5, *Radiation Protection of the Public and the Environment,* 1990.

U.S. Department of Energy, DOE STD-1107-97 *Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities,* Reaffirmed June 2005.

U.S. Department of Energy, DOE G 441.1-1B, *Radiation Protection Programs Guide*, March 2007.

U.S. Department of Energy, DOE O 231.1-1A, Change 2, *Environment, Safety and Health Reporting,* 2004.

U.S. Department of Energy, DOE M 231.1-1A, Change 2, *Environment, Safety and Health Reporting Manual*, 2004.

I. Introduction

This module provides an overview of many of the provisions of 10 CFR 835. For completeness, individuals should always reference back to 10 CFR 835 for the complete text.

Show OT 2.1.

Emphasize that this lesson is an overview of major areas of 10 CFR Part 835. Not every provision is addressed in this module 10 CFR 835 should be reviewed in its entirety to ensure compliance.

Provide copies of 10 CFR 835 for reference.

State objectives.

II. Outline of 10 CFR Part 835

Show OT 2.2.

Part 835 is the codification of radiological protection requirements. Part 835 contains 14 subparts and five appendices. The outline consists of the following subparts:

Obj. 1
Describe the contents of 10 CFR Part 835.

A — General Provisions
B — Management and Administrative Requirements
C — Standards for Internal and External Exposure
D — Reserved
E — Monitoring of Individuals and Areas
F — Entry Control Program
G — Posting and Labeling
H — Records
I — Reports to Individuals
J — Radiation Safety Training
K — Design and Control
L — Radioactive Contamination Control
M — Sealed Radioactive Source Control
N — Emergency Exposure Situations

Show OT 2.3.

Under 10 CFR Part 835, each site must submit a Radiation Protection Program (RPP).

Obj. 2
Identify the site requirements of 10 CFR Part 835.

Part 835 helps to ensure that DOE facilities are operated in a manner such that occupational radiological exposure to workers is maintained within acceptable limits and as low as is reasonably achievable (ALARA).

A. Subpart A - General Provisions

Subpart A contains the scope of the rule. The rule in this part establishes radiological protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from the conduct of DOE activities.

It also includes activities excluded from the provisions of the rule. Activities that are excluded include the following (summarized):

Show OT 2.4.

- Activities regulated through a license by the Nuclear Regulatory Commission (NRC) or a state under an agreement with the NRC.
- Activities conducted under the authority of the Director, Naval Nuclear Propulsion Program.
- Specified activities conducted under the Nuclear Explosives and Weapons Surety Program.
- Radioactive material transportation.
- DOE activities in other countries with acceptable radiation protection program.
- Background radiation.

Discuss radioactive material transportation definition.

Occupational doses received as a result of excluded activities and radioactive material transportation, as listed above, shall be considered when determining compliance with the occupational dose limits (835.202 and 835.207), and with the limits for the embryo/fetus (835.206).

Show OT 2.5.

Subpart A also addresses:

- Definitions
- Radiological units (Curie, rad, roentgen, rem, and multiples)

B. Subpart B - Management and Administrative Requirements

Show OT 2.6.

The RPP shall:

- Include formal plans and measures for applying the ALARA process to occupational exposures.
- Specify the existing and/or anticipated operational task.
- Address, but not be limited to, each requirement in Part 835.
- Include plans, schedules, and other measures for achieving compliance.

DOE may direct or make modifications to an RPP. An initial RPP or update shall be considered approved 180 days after its submission unless rejected by DOE at an earlier date.

Internal Audits (10 CFR 835.102)

Internal audits of the radiation protection program, including examination of program content and implementation, shall be conducted through a process that ensures that all functional elements are reviewed no less frequently than every 36 months. This training material and DOE G 441.1-1B, *Radiation Protection Programs Guide*, provide guidance on DOE's expectations.

Discuss again DOE's series of Implementation Guides and their purpose.

Education, Training and Skills (10 CFR 835.103)

Individuals responsible for developing and implementing measures necessary for ensuring compliance with the requirements of this part shall have the appropriate education, training, and skills to discharge these responsibilities. DOE STD-1107-97, Reaffirmed June 2005, *Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities,* provides guidance on DOE's expectations.

Written Procedures (10 CFR 835.104)

Written procedures are required, as necessary, to ensure compliance with 835, commensurate with radiological hazards and education, training and skills of exposed individuals.

C. Subpart C - Standards for Internal and External Exposure

Show OT 2.7.

This subpart addresses limits for:

- General employees (occupational)
- Embryos/fetus of declared pregnant worker (i.e., A woman who has voluntarily declared to her employer, in writing, her pregnancy for the purpose of being subject to the occupational dose limits to the embryo/fetus. This declaration may be revoked, in writing, at any time by the declared pregnant worker.)
- Occupationally exposed minors
- General public in a controlled area

It also addresses:

- Planned special exposures
- Nonuniform exposures of the skin
- Concentrations of radioactive material in air

1. Summary of dose limits

10 CFR Part 835 employs the rem unit for several different physical quantities. For information about these quantities refer participants to page 1 of handouts, "Dosimetric Quantities in 10 CFR Part 835."

Show OT 2.8 and OT 2.9.

Exposed Individual	Annual Limit
General Employee: Whole Body (internal and external) (TED)	5.0 rem
General Employee: Lens of Eye (ED)	15.0 rem
General Employee: Extremity (below elbow and knees) and skin (SED)	50.0 rem
General Employee: Any Organ or Tissue (other than lens of eye) (DED + CED)	50.0 rem
Declared Pregnant Worker: Embryo/Fetus (gestation period) (ED)	0.5 rem
Occupationally Exposed Minors (under age 18): (TED)	0.1 rem *
Members of the Public in Controlled Areas: (TED)	0.1 rem

- And 10% of other general employee limits.

2. Planned special exposures (PSEs)

It is acknowledged that unusual conditions can arise in which higher-than-normal doses can be justified. In these well-planned, well-controlled, and highly infrequent and unusual conditions operating management would be permitted to allow specified individual doses exceeding the occupational limit, such as 5 rem per year.

The term "unusual conditions" is made clear by specifying that alternatives which would preclude exposures higher than the prescribed dose limits must be either unavailable or impractical.

Show OT 2.10.

10 CFR 835.204 specifies requirements for annual and lifetime dose from PSEs. It also specifies requirements for determining previous individual exposures prior to allowing a PSE.

Every PSE must be approved in advance by DOE and requires the informed consent of the employee involved.

3. Concentration of radioactive material in air

Appendices A and C contain the derived air concentration (DAC) values used in the control of occupational exposure to airborne radioactive material.

Show OT 2.11.

DACs are listed in appendices A and C of 10 CFR 835. For intakes (appendix A), they are the airborne concentration that equals the annual limit on intake (ALI) divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m^3).

Define DAC in terms of dose equivalent.

The ALI is the smaller value of intake of a given radionuclide in a year by a standardized man that would result in a CED of 5 rems or a $H_{T,50}$ of 50 rems to any individual organ or tissue.

Appendix C contains DACs for controlling external dose from being immersed in a cloud of airborne radioactive material.

Estimation of internal dose shall be based on bioassay data rather than air concentration values unless bioassay data are:

- Unavailable (e.g., radon or very short lived radioisotopes)
- Less accurate than internal dose estimates based on representative air concentration values
- Inadequate

E. Subpart D - Reserved

E. Subpart E - Monitoring of Individuals and Areas

Show OT 2.12.

This subpart addresses:

- General requirements
- Instrumentation
- Individual monitoring - external
- Individual monitoring - internal
- Air monitoring
- Receipt of packages containing radioactive material

1. General requirements (10 CFR 835.401)

   Monitoring of individuals and areas shall be performed to:

   - Demonstrate compliance with Part 835.
   - Document radiological conditions.
   - Detect changes in the radiological conditions.
   - Detect the gradual buildup of radioactive material.
   - Verify the effectiveness of engineering and process controls in containing radioactive material and reducing radiation exposure.
   - Identify and control potential sources of individual exposure to radiation and/or radioactive material.

2. Instrumentation

   Instruments and equipment used for monitoring and contamination control shall be:

   - Periodically maintained and calibrated on an established frequency.
   - Appropriate for the type(s), levels, and energies of the radiation(s) encountered.
   - Appropriate for existing environmental conditions.
   - Routinely tested for operability.

Show OT 2.13.

3. Individual monitoring - external (10 CFR 835.402)

   For the purpose of monitoring individual exposure to external radiation, personnel dosimetry shall be provided to and used by:

   - Radiological Workers likely to receive:
     – An effective dose to the whole body of 0.1 rem (100 mrem) or more in a year
     – A shallow equivalent dose to the skin or to any extremity of 5 rem or more in a year
     – A lens of the eye equivalent dose of 1.5 rem or more in a year
   - Declared Pregnant Workers who are likely to receive from external sources an equivalent dose to the embryo/fetus in excess of 10 percent of the applicable limit.

Show OT 2.14.

- Members of the public in a controlled area and occupationally exposed minors likely to receive, in one year, from external sources, a dose in excess of 50 percent of the applicable limits.

- Individuals entering a High or Very High Radiation Area.

DOE Laboratory Accreditation for Personnel Dosimetry is required for external dose monitoring programs implemented to demonstrate compliance with 10 CFR 835.

4. Individual monitoring - internal (10 CFR 835.402)

   Show OT 2.15.

   Internal dose evaluation programs (including routine bioassay programs) shall be conducted for:

   - Radiological Workers who, under typical conditions, are likely to receive 0.1 rem or more committed effective dose from all occupational radionuclide intakes in a year.

   - Declared Pregnant Workers likely to receive an intake or intakes resulting in an equivalent dose to the embryo/fetus in excess of 10 percent of the limit.

   - Members of the public in a controlled area and occupationally exposed minors who are likely to receive a committed effective dose in excess of 50 percent of the limit from all intakes in a year.

DOE Laboratory Accreditation for Radiobioassay is required for internal dose monitoring programs implemented to demonstrate compliance with 10 CFR 835.

Compliance due date 1-1-02.

5. Air monitoring (10 CFR 835.403)

   Measurements of radioactivity concentrations in the ambient air of the workplace shall be performed as follows:

   - Air sampling shall be performed in occupied areas where an individual is likely to receive an exposure of 40 DAC-hrs or more in a year (i.e. an annual intake of 2 percent or more of the specific ALI value) for the mixture of isotopes.

   - Samples shall be taken as necessary to characterize the levels or concentration of airborne radioactive material when respirators are worn for radiation protection purposes.

   - Real-time air monitoring shall be performed when there is a need to alert potentially exposed individuals to unexpected increases in airborne radioactivity levels such that immediate action is necessary in order to minimize or stop inhalation exposures.

6. Receipt of Packages Containing Radioactive Material (10 CFR 835.405)

   Establishes requirements to monitor certain types of packages and sets a time limit of not later than 8 hours after the beginning of the working day following receipt of the package.

Show OT 2.16.

F. Subpart F - Entry Control Program (10 CFR 835.501)

Show OT 2.17.

Subpart F addresses entry into:

Discuss different types of radiological areas.

- Radiological Areas
- High Radiation Areas
- Very High Radiation Areas

1. Radiological Areas

   The degree of control shall be commensurate with existing and potential radiological hazards within the area.

One or more of the following methods shall be used to ensure control:

Show OT 2.18.

- Signs and barricades
- Control devices on entrances
- Conspicuous visual and/or audible alarms
- Locked entrance ways
- Administrative controls

"No control(s) shall be installed at any radiological area exit that would prevent rapid evacuation of personnel under emergency conditions."

Show OT 2.19.

2. High Radiation Areas

Show OT 2.20.

A High Radiation Area is an area where radiation levels exist such that an individual could exceed a deep equivalent dose to the whole body of 0.1 rem in any one hour at 30 centimeters from the source or from any surface that the radiation penetrates.

If an individual receives a deep equivalent dose exceeding 1.0 rem in an hour (at 30 cm), a High Radiation Area shall have one or more of the following:

- A control device that prevents entry to the area when high radiation levels exist or that, upon entry, causes the radiation level to be reduced below that level that defines a High Radiation Area.
- A device that functions automatically to prevent use or operation of the radiation source or field while individuals are in the area.

- A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the High Radiation Area and the supervisor of the activity are made aware of the entry.

- Entryways that are locked. During periods when access to the area is required, positive control over each entry is maintained.

- Continuous direct or electronic surveillance that is capable of preventing unauthorized entry.

- A control device generating audible and visual alarm signals to alert personnel in the area before use or operation of the radiation source and in sufficient time to permit evacuation of the area or activation of a secondary control device that will prevent use or operation of the source.

3. Very High Radiation Areas

Show OT 2.21.

A Very High Radiation Area is an area in which an individual could receive a dose in excess of 500 rad in one hour at 1 meter from the radiation source or from any surface that the radiation penetrates.

Show OT 2.22.

In addition to the requirements for a High Radiation Area, additional measures shall be implemented to ensure individuals are not able to gain unauthorized access to Very High Radiation Areas.

"No control(s) shall be established in a High or Very High Radiation Area that would prevent rapid evacuation of personnel."

G. Subpart G - Posting and Labeling

Show OT 2.23.

Subpart G addresses the general requirements for signs:

- Yellow background
- Black or magenta radiation symbol
- Clear and conspicuous signs

In addition, Subpart G addresses specific posting requirements for:

- Controlled Areas
- Radiation Areas
- High Radiation Areas
- Very High Radiation Areas
- Airborne Radioactivity Areas
- Contamination Areas
- High Contamination Areas
- Radioactive Material Areas

Discuss posting and labeling exceptions.

This subpart also addresses exceptions to posting and labeling.

H. Subpart H - Records

Show OT 2.24.

Subpart H addresses requirements for records documenting compliance with Part 835 and with the Radiation Protection Program.

Records that are specifically required include those necessary to demonstrate compliance with the ALARA provisions of the rule.

10 CFR 835 also requires that certain records be maintained, including records of:

- Individual monitoring
- Sealed source inventory and control
- Results of surveys for the release of material and equipment
- Results of specified monitoring for radiation and radioactive material
- Maintenance and calibration of radiation monitoring instruments
- Internal audits

Each individual's training as a general employee and as a Radiological Worker must be recorded. Where appropriate, demonstration and documentation of proficiency is required.

Refer to 10 CFR 835 Subpart H for a complete listing of required records.

DOE M 231.1-2, Change 2, *Environment, Safety and Health Reporting Manual* specifies radiation protection reporting requirements that may be applicable to the site or facility being assessed.

I. Subpart I - Reports to Individuals (10 CFR 835.801)

Subpart I addresses reports to individuals and their accessibility to reports, including:

Discuss applicability of O 231.1 to the site or facility.

Show OT 2.25.

On an annual basis, each DOE or DOE contractor-operated site or facility must provide each individual monitored for occupational exposure a radiation dose report of his/her occupational exposure at that site or facility.

Upon the request from an individual terminating employment, records of exposure shall be provided to that individual as soon as the data are available, but not later than 90 days after termination. A written estimate of the radiation dose received by that employee based on available information shall be provided at the time of termination, if requested.

J. Subpart J - Radiation Safety Training

Show OT 2.26.

This subpart addresses radiation safety training. The tailored approach to training requirements are based on:

- Unescorted access to or receiving occupational dose in controlled areas (e.g., General Employees)
- Unescorted access to radiological areas or unescorted assignment as Radiological Workers

Requirements of Part 835 include:

- Verification by examination for certain training (e.g., Radiological Worker Training)
- Intervals of training not to exceed twenty four months
- List of topics which must be included in training
- Provisions for limited use of escorts in lieu of training

K. Subpart K - Design and Control

Subpart K addresses added emphasis on facility and equipment design and administrative controls to maintain radiological exposures ALARA.

Show OT 2.27.

1. Facility design and modifications (10 CFR 835.1001)

   During the design of new facilities or modification of old facilities, the following objectives shall be adopted:

   - Optimal methods shall be used to assure ALARA
   - Maintain exposure levels below an average of 0.5 mrem/hr
   - Avoid release of radioactivity to the workplace atmosphere
   - The design or modification of a facility and the selection of materials shall include features that facilitate operations, maintenance, decontamination, and decommissioning

2. Workplace controls (10 CFR 835.1003)

   During routine operations, the combination of physical design features and administrative control shall provide that:

   - The anticipated occupational dose to general employees shall not exceed the limits
   - The ALARA process is utilized for personnel exposures to ionizing radiation

Show OT 2.28.

L. Subpart L - Radioactive Contamination Control

1. Control of material and equipment

   This section addresses the requirements for release of materials and equipment from radiological areas to controlled areas. Releases to uncontrolled areas are addressed in DOE O 5400.5. Some of the provisions:

   - Specifies conditions for material and equipment in contamination areas (CAs), high contamination areas (HCAs), and airborne radioactivity areas (ARAs) to be released to a controlled area
   - Addresses movement of material and equipment with removable surface contamination, on-site from one radiological area for immediate placement in another radiological area
   - Specifies conditions for material and equipment with fixed contamination to be released for use in controlled areas outside of radiological areas

Show OT 2.29.

Control of Areas (10 CFR 835.1102) addresses

- Prevention of inadvertent transfer or removal of contamination to locations outside radiological areas under normal conditions
- Where contamination levels exceed values in Appendix D, the area is controlled commensurate with hazards
- Areas with fixed contamination exceeding radioactivity values may be located outside radiological areas, provided certain controls, conditions, or provisions are met
- Personnel monitoring for contamination upon exiting CAs, HCAs, or ARAs
- Use of protective clothing in CAs and HCAs

M. Subpart M - Sealed Radioactive Source Control

Show OT 2.30.

Sealed radioactive sources shall be used, handled and stored in a manner commensurate with the hazard.

Specifies values (Appendix E) for sources which must be inventoried and leak tested at intervals not to exceed six months.

N. Subpart N - Emergency Exposure Situations

Show OT 2.31.

This subpart addresses:

- Employees who have exceeded dose limits as result of authorized emergency exposure
- Nuclear accident dosimetry

Individuals whose occupational exposures have exceeded any limits as a result of an authorized emergency exposure may be permitted to return to work provided that certain conditions are met.

Nuclear accident dosimetry

Show OT 2.32.

Nuclear accident dosimetry involves installations possessing sufficient quantities of fissile material to constitute a critical mass, and shall include;

- Method to conduct initial screening of personnel involved
- Method and equipment for analysis of biological materials
- A system of fixed nuclear accident dosimeter units
- Personal nuclear accident dosimeters

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Overview of the *DOE Radiological Control Standard*

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Describe the managerial responsibilities in the *DOE Radiological Control Standard*.
2. Describe the contents of the *DOE Radiological Control Standard*.

Training Aids:

Overhead Transparencies (OTs): OT 3.1 – OT 3.12 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

U.S. Department of Energy, O 440.1B*, Worker Protection Program for DOE (Including the National Nuclear Security Agency) Federal Employees*, May 2007.

I. Introduction

Show OT 3.1.

State objectives.

II. *DOE Radiological Control Standard*

Obj. 1
Describe the managerial responsibilities in the *DOE Radiological Control Standard.*

The DOE Radiological Control Standard is written for line management. It is designed to assist line managers in fulfilling their duties and responsibilities for implementing an occupational radiation protection program.

Discuss site commitments to follow the Radiological Control Standard or Manual.

It is also designed to assist site/facility workers in having the information they need to be responsible for their own radiological exposures and to help ensure that the controls are in place to eliminate any releases, unplanned exposures or uptake, and to apply ALARA principles. The emphasis is on teamwork and support from line management.

Emphasize the need to review site requirements documents prior to conducting an assessment.

The Radiological Control Standard may be considered as an occupational radiation protection good practices document. Individual sites may have contractual commitments to implement sections of the standard.

III. Chapter 1, Excellence in Radiological Control

Show OT 3.2.

Obj. 2
Describe the contents of the *DOE Radiological Control Standard*.

This chapter defines the roles of DOE and the contractors in achieving the goal of radiological control excellence. It consists of the following five sections:

- *DOE Radiological Control Standard*
- Leadership in Radiological Control
- Improving Radiological Control Performance
- Contractor Radiological Control Organization
- DOE Management

A. *DOE Radiological Control Standard*

The contractor is responsible for implementing an occupational radiation protection program. To assist this effort, they may develop a Site Radiological Control Standard Implementation Plan. The Site-Specific Radiological Control Standard, which is developed from the Implementation Plan, does not require DOE approval.

Show OT 3.3.

B. Leadership in Radiological Control

Commitment of senior management to radiological control is defined in this section of the Standard.

The responsibilities and accountability of each individual for ALARA and radiological excellence is emphasized.

Worker responsibilities and the concepts of conduct of radiological operations are clearly defined.

Show OT 3.4.

C. Improving Radiological Control Performance

The use of critiques as a management tool, rather than as a method to "fix blame" or "shoot the messenger," and the importance of real root cause identification are emphasized. Over 20 radiological performance indicators are identified that are tools designed to assist managers in focusing their priorities and attention on radiological control performance.

Show OT 3.5.

D. Contractor Radiological Control Organization

This section discusses the contractor's radiological control organization and the qualifications of the Radiological Control Manager.

E. DOE Management

This section discusses the roles and responsibilities of DOE management for providing guidance and performance evaluation of radiological control programs.

Show OT 3.6.

IV. Chapter 2, Radiological Standards

This chapter deals with administrative control dose limits, contamination control and control levels, and posting.

A. Administrative Control Levels (ACLs) and Dose Limits

Discuss site specific ACLs and other limits.

Lifetime control levels and dose limits for Radiological Workers, members of the public, embryos/fetuses, and special control levels are discussed in this section.

For most facilities an ACL of 500 millirem or less will be challenging for Radiological Workers. Individual occupational doses, in rem, should be kept below the individual's age in years.

B. Contamination Control and Control Levels

In this section, personnel contamination control, removable and fixed contamination control levels, and airborne radioactivity control levels are given.

C. Posting

Discuss non-regulatory posting used at the site.

Posting requirements are presented in this section and include several non-regulatory areas including: Radiological Buffer Areas, Underground Radioactive Material Areas, and Soil Contamination Areas.

V. Chapter 3, Conduct of Radiological Work

Show OT 3.7.

The planning of radiological work, work preparation (e.g., Radiological Work Permits), and the requirements for the entry to and exit from the various types of controlled areas are contained in this chapter. Also covered are: radiological work performance, the aspects of radiological work in different operations with radiation-generating equipment, and construction and restoration projects.

A. Planning Radiological Work

This section emphasizes that the conduct of radiological work is a line responsibility. Worker responsibility, along with systematic planning, provides the necessary information for safe radiological work. Of fundamental importance is the requirement to plan work with an emphasis on ALARA principles.

B. Work Preparation

In this section, the Radiological Work Permit (RWP) is discussed. This chapter states that the RWP is the key to any particular radiological operation, and preplanning is essential.

C. Entry and Exit Requirements

The minimum requirements for entry into and exit from defined radiological areas and other non-regulatory areas are discussed in this section.

D. Radiological Work Controls

This section discusses radiological work as a team effort involving the Radiological Workers, their supervisors, and Radiological Control personnel. The DOE Radiological Control Standard discusses stop-radiological work authority for Radiological Control Technicians (RCTs), their supervisors, line supervision, and workers through their supervisors because of:

- Inadequate radiological controls
- Radiological controls not being implemented
- A radiological control hold point not being satisfied

DOE O 440.1B*, May 2007, Worker Protection Program for DOE (Including National Nuclear Security Administration)Federal Employees* specifies that individuals have the authority to stop work due to hazardous conditions.

This stop work authority is not limited to just radiological hazards. Workers may "stop work when they discover employee exposures to imminent danger conditions or other serious hazards." Contractors are required to have procedures addressing stop work authority.

Discuss that, per O 440.1A, stop work authority is not limited to radiological hazards.

E. Evaluation of Performance

Show OT 3.8.

Evaluation of performance, critiques, post job reviews, and lessons learned are discussed in this section.

F. Special Applications

This section examines the special aspects for the control of radiological work when working with the following:

- Plutonium
- Uranium
- Tritium
- Accelerators
- Radiation Generating Devices

G. Radiological Design Criteria

This section addresses design objectives for design of new facilities and modification of existing facilities.

VI. Chapter 4, Radioactive Materials

Show OT 3.9.

The requirements for labeling, storage, control, release, and transportation of radioactive materials, and the control of radioactive sources, are discussed in this chapter. This chapter also deals with the management of solid and liquid radioactive wastes, and airborne radioactivity. Support activities such as personnel protective clothing and equipment, laundry, decontamination and vacuum cleaners, and portable air-handling equipment are also discussed.

VII. Chapter 5, Radiological Health Support Operations

Show OT 3.10.

This chapter discusses the requirements for external dosimetry, internal dosimetry, a respiratory protection program, the handling of contaminated personnel, radiological monitoring and surveys, and instrumentation and calibration.

VIII. Chapter 6, Training and Qualification

Show OT 3.11.

The requirements that ensure personnel have the training and qualifications needed to safely work in and around radiological areas and to maintain their own doses and those of others (ALARA) are discussed in this chapter.

A. General Radiological Training

Within these sections, training and qualification standards are discussed for:

- General Employees
- Radiological Workers I and II
- Radiological Control Technicians and Supervisors

B. Other Radiological Training

This section addresses training and qualification for:

- Managers/supervisors
- ALARA training for:
  - Engineers
  - Schedulers
  - Procedure writers
- Radiological control personnel
  - Dosimetry technicians
  - Instrument technicians
  - Medical personnel
  - Records clerk
  - Whole body counter technicians
  - Laboratory personnel
- Radiographers
- Radiation-generating device operators
- Emergency response personnel

C. Training for Special Applications

This section addresses training for the following facilities:

- Plutonium
- Uranium
- Tritium
- Accelerators

IV. Chapter 7, Radiological Records

Show OT 3.12.

The requirements for employee and visitor records, radiological control procedures (policies, procedures, Radiological Work Permits (RWPs), ALARA, and quality assurance records), radiological surveys, instrumentation and calibration records, records management, and radiological reporting are presented in this section.

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Elements of a Radiological Control Program

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Identify factors that influence the scope and magnitude of a Radiological Control Program at any nuclear facility.
2. Identify typical elements of a Radiological Control Program.

Training Aids:

Overhead Transparencies (OTs): OT 4.1 – OT 4.5 (may be supplemented or substituted with updated or site-specific information)

Handouts - "List of Radiological Control Program Elements"

"Elements of a Radiological Control Program"

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

U.S. Department of Energy, 10 CFR Part 820*, Procedural Rules for DOE Nuclear Facilities*, 2007.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, 2007.

I. Introduction

Show OT 4.1.

State objectives.

II. Radiological Control Program

A. Overall program

The Radiological Control Program consists of the commitments, policies, and procedures that are administered by a site or facility to meet the EH Health and Safety Policy.

The Radiation Protection Program required by 10 CFR Part 835 is an element of the overall Radiological Control Program.

Show OT 4.2.

The Radiological Control Program should address the following:

Obj. 1
Identify factors that influence the scope and magnitude of a Radiological Control Program at any nuclear facility.

- Requirements
- Responsibilities
- Programs/procedures
- Assessments

- What to do?
- Who does it?
- How is it done?
- Is it being done, and how well?

B. Size of the program

Radiological Control Programs vary in size.

There are several factors that may affect the magnitude of a Radiological Control Program. The specific mission, types and quantities of radioactive material, and the radiation-generating devices that will be used at the site are just a few.

Ask participants what factors may affect program size–list on flip chart.

Encourage participants to write responses in their Student's Guide.

Responses should include the following:

- The specific facility mission

- The radiation-generating devices at the site
- The types and quantities of radioactive materials in use at the site
- The physical and chemical forms of the radioactive materials in use at the site
- The physical location of the site in relation to the population centers
- The size of the work force
- The age of the facility
- The original facility design criteria

Ask participants how a site would determine what had to be included in their program.

Encourage participants to write responses in their student's guide.

III. Elements of a radiological control program

A. Requirements

Responses should include:

- Hazard assessment/ characterization
- Requirements/ commitments
  - Contract
  - RPP (10 CFR Part 835)
  - Other federal regulations
  - State regulations
  - Site RadCon Manual Implementation Plan
  - Orders
  - Other

B. Responsibilities

Ask participants how a site should address and document these responsibilities.

Responses should include:
- Organization and administration
  - Upper management commitment
- Personnel training and qualification

C. Programs/procedures

Ask participants what type of subprograms should be included or what areas should be addressed in the responsibilities.

Responses should include:
- Work controls (engineered, administrative, personal protective equipment)
- Posting and labeling
- Entry controls
- Radioactive materials controls
- Criticality controls
- Radiation-generating devices
- Contamination controls
- Respiratory protection
- ALARA

- Dosimetry
  - External
  - Internal
- Instrumentation and alarms
- Monitoring
  - Workplace
  - Environmental
  - Air
- Radioactive waste management
- Transportation and receipt of radioactive material
- Emergency response
- Reporting
- Records

Ask participants what types of subprograms should be established to monitor and improve program performance.

D. Assessments

Responses should include:
- Internal audits and investigations
- Trend analysis
- Performance indicators

IV. List of Radiological Control Program Elements

- Organization and administration
- Personnel training and qualification
- Quality assurance
- ALARA
- Radiological Work Control
  - Procedures
  - Radiological Work Permits
- Posting and labeling
- Radioactive material control
  - Source control
  - Release of materials
  - Receipt and transportation
- Radiation-generating devices
  - Sealed source
  - X-ray machines
- Entry control
- Contamination control
- Instrumentation/alarms
- Monitoring
  - Workplace
  - Effluent
  - Environmental

Show OT 4.3.

Obj. 2
Identify typical elements of a Radiological Control Program.

Refer participants to page 4 of handouts, "List of Radiological Control Program Elements," which has different element names, but similar functions.

Show OT 4.4.

Show OT 4.5.

- Dosimetry
  - External
  - Internal
    - Program management (e.g., staffing, technical basis, procedures, quality assurance)
    - Individual monitoring (e.g., air monitoring, contamination monitoring, bioassay)
    - Internal dose evaluation
- Respiratory protection
- Facility specific features
  - Uranium
  - Plutonium
  - Tritium
  - Accelerators
- Radioactive waste management
- Emergency response
- Records
- Assessments/performance indicators

Refer participants to page 10 of handouts, "Elements of a Radiological Control Program." These provide a more detailed listing/breakdown of elements. As time allows, review selected elements.

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Technical Safety Requirements

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Describe the purpose of DOE Order 5480.22 and its relationship to 10 CFR 830.205.
2. Describe the purpose of Technical Safety Requirements (TSRs) in regard to facility operations/activities.
3. Identify the source(s) of information required to develop reasonable and appropriate TSRs.
4. Describe the responsibilities for the development and use of TSRs.
5. List the criteria for identifying problems in meeting TSRs.
6. List areas in TSRs which could be reviewed as part of a radiological assessment.

Training Aids:

Overhead Transparencies (OTs): OT 5.1 – OT 5.13 (may be supplemented or Substituted with updated or Site-specific information)

Handouts - "Typical Safety Analysis Report (SAR) Contents"

"Technical Safety Requirement (TSR) Format and Content"

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

U.S. Department of Energy, 10 CFR 830, *Nuclear Safety Management*, 2000.

U.S. Department of Energy, Operation Procedure *Identifying, Reporting, and Tracking Nuclear Safety Noncompliances*, June 1998.

I. Introduction

Show OT 5.1 and OT 5.2.

State objectives.

II. Purpose of 10 CFR 830.205

Obj. 1
Describe the purpose of DOE Order 5480.22 and its relationship to 10 CFR 830.205.

On October 10, 2000 an Interim final rule was published in the Federal Register for 10 CFR 830, "Nuclear Safety Management". The Interim Final Rule was effective December 11, 2000, and codifies requirements for TSRs in 10 CFR 830.205. The new rule required contractors to develop and submit TSRs to DOE for approval by April 10, 2003.

This material may need to be updated to reflect final implementation guidance for 10 CFR 830 when it is finalized.

TSRs are a critical element in the overall DOE safety program.

A. Definitions (Paragraph 6)

- Technical Safety Requirements are those requirements that define the conditions, safe boundaries, and the management or administrative controls necessary to ensure the safe operation of nuclear facilities and to reduce the potential risk to the public and facility workers from uncontrolled releases of radioactive materials or from radiation exposure due to inadvertent criticality. Technical Safety Requirements consist of safety limits, operating limits, surveillance requirements, administrative controls, use and application instructions, and the bases thereof.

Show OT 5.3.

- A controlled document is content maintained uniformly among the copies by an Administrative Control System (paragraph 6, Item e).

Basis: Summary statements of the reasons for the operating limits and associated surveillance requirements. It shows how the numerical value, condition, or the surveillance fulfills the purpose from the safety documentation.

Show OT 5.4.

B. Policy (Paragraph 7)

Obj. 2
Describe the purpose of Technical Safety Requirements (TSRs) in regard to facility operations/activities.

It is the policy of the Department that nuclear facilities operate Cognizant Secretarial Officer (CSO)-approved Technical Safety Requirements, which prescribe the bounds for safe operation of these facilities in order to protect the health and safety of the public and reduce risk to workers.

Show OT 5.5.

The TSRs constitute a contract between the operating contractor and DOE management of the methods that will be utilized or constraints to be applied to minimize the potential risk of operating the proposed facility or conducting the proposed activity.

NOTE: TSRs apply to actions by specific facility personnel and their commitments to responsible DOE managers.

The Technical Safety Requirements document is to be a controlled document.

TSRs are <u>not</u> based upon maintaining worker doses below some acceptable level following an uncontrolled release of hazardous material or inadvertent criticality; rather, the risk to workers is reduced through controls that reduce the <u>likelihood</u> and <u>potential</u> <u>impact</u> of such events.

C. Source for bases (justification) of TSRs

In the development of limits, set-points, staffing requirements, and other parameters for input into the individual TSRs, the facility/operation-specific Safety Analysis Report (SAR), particularly the accident analyses contained therein, is normally the primary basis.

Obj. 3
Identify the source(s) of information required to develop reasonable and appropriate TSRs.

Show OT 5.6.

The limitations that are included in the TSRs should be derived from the facility-specific safety analysis, which considers all credible accidents. This includes the most significant possible releases of radioactive and hazardous materials, criticality scenarios, and the accidental releases expected during the life of the facility.

SAR text of interest
- Principal Safety Criteria
- Accident Analysis
- Deviation of TSRs

Show OT 5.7.

Careful and thorough examination of these accident analyses will provide values for defining the operational limits necessary to ensure that facility operations do not occur outside the bounds assumed in the analyses. Such an examination will also identify parameters and operating conditions that should be limited in order to reduce, provide warning of, and mitigate the uncontrolled releases of hazardous materials and to prevent inadvertent criticality.

Show OT 5.8.

Examples of requirements expected to be developed include:

- Operating limits for principal process parameters
- Technical and administrative conditions that must be met
- Availability of safety equipment and systems
- Critical functions of instrumentation and controls

Operations within the boundaries of the resulting requirements will provide reasonable assurance that the nuclear facility will not:

- Threaten the health and safety of the public
- Pose an undue risk to workers from the uncontrolled releases of radioactive or other hazardous materials and inadvertent criticality

Refer participants to page 24 of handouts, "Typical Safety Analysis Report (SAR) Contents."

For facilities that do not have an approved SAR, the technical input into the TSRs must be derived from existing documents/analyses that specifically demonstrate the limiting conditions that the facility is expected to experience during normal operations and potential accident conditions.

In order to serve as the basis for the TSRs, these studies must systematically evaluate:

Show OT 5.9.

- All potential off-normal conditions that could occur during the life of the facility
- What could be considered design basis accidents

D. Responsibilities for TSRs

Show OT 5.10.

- Prepare → Contractor
- Review → DOE Field Office
- Approve → CSO

Obj. 4
Describe the responsibilities for the development and use of TSRs.

Refer participants to page 26 of handouts, "Technical Safety Requirement (TSR) Format and Content."

E. Identification of violations

Violations of a TSR occur as the result of four circumstances:

- Exceeding a Safety Limit (SL)
- Failing to take the necessary actions within the required time limit following:
  - Exceeding a Limit Control Setting (LCS)
  - Failing to meet Limiting Conditions for Operations (LCO)
  - Failing to successfully meet a Surveillance Requirement (SR)
- Failing to perform a surveillance within the required time limit
- Failing to comply with an Administrative Control (AC) requirement

As stated previously, compliance with TSRs is required by 10 CFR 830.205, violations may be enforceable under PAAA.

Show OT 5.11.

Note that the violation relates to failure to comply with an Action Statement. The actions required to be taken when LCSs are exceeded, or when operations outside an LCO occur, are intended to provide compensatory protection for the same safety concerns for which the limit was established. Thus, exceeding the limit by itself is not considered a violation but is a reportable event as an Off-Normal Occurrence.

Obj. 5
List the criteria for identifying problems in meeting TSRs.

F. Reporting Requirements (DOE Order 231.1A,Change 1

Show OT 5.12.

A, Chg 1) *Occurrence Reporting and Processing of Operations Information,* June 2004

- Categorization
  - Operational Emergency
  - Significance Category 1 - 4
- Notification
- Follow-up notification
- Occurrence Report preparation

TSR ACs may impose additional facility- or operations-specific reporting requirements, which must also be carefully and fully followed.

Violations of TSRs may need to be reported as part of the Noncompliance Tracking System (NTS). For guidance on NTS reports, refer to Operation Procedure *Identifying, Reporting, and Tracking Nuclear Safety Noncompliances*, June 1998, prepared by the DOE Office of Enforcement (HS - 40).

G. Ancillary guidance

The TSR document shall be kept current at all times so that it reflects the facility as it exists and is analyzed in the SAR. The TSR must be approved prior to changes in the facility or facility practices.

TSRs are the primary source of the more important safety requirements that are imposed upon any facility operations/activities. The bases for the TSRs can be found in the Safety Analysis Report, principally in the chapters on Safety Criteria and Accident Analysis.

TSRs should be written in a clear and concise manner, in language that is understandable by those in the facility operating organization. The TSR should not contain excessive details that belong more appropriately in the SAR.

The scope and content of TSRs are to be limited to only the most critical nuclear safety areas. This serves to make TSR Documents more useful for controlling facility safety.

H. Radiological Assessment of TSR Compliance

Obj. 6 List areas in TSRs which could be reviewed as part of a radiological assessment

TSRs typically specify requirements for several areas that may be reviewed as part of a radiological assessment. These areas include:

Area monitors:

- Criticality monitors
- Area Radiation Monitors
- Air Monitors (i.e., real time air monitors, fixed head air samplers)

Show OT 5.13.

Surveillance requirements for area monitors

HEPA ventilation systems and their surveillances

Shift Staffing
- Facility staff qualification, training and retraining

Audits and reviews

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Radiological Aspects of Uranium

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Identify the radiological properties of uranium.
2. Describe the toxicological properties and behavior of uranium.
3. Identify appropriate instrumentation, measurement techniques, and special radiological survey methods for uranium.
4. Describe personnel protection requirements, external dose control techniques, and internal dose control techniques.
5. Describe special controls and considerations required for uranium operations.

Training Aids:

Overhead Transparencies (OTs): OT 6.1 – OT 6.11 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

ICRP Publication 30, *Limits for Intakes of Radionuclides by Workers*, 1979.

U.S. Department of Energy, DOE-STD-1136-2000, *Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities*, 2004.

U.S. Department of Energy, DOE-STD-1121-98, *Internal Dosimetry*, Reaffirmation May 2003.

U.S. Department of Energy, DOE-HDBK-1113-98*, Radiological Safety Training for Uranium Facilities*, Reaffirmation May 2005.

U.S. Department of Energy, DOE-STD-1098-99 Chg 1, *Radiological Control*, March 2005.

U.S. Environmental Protection Agency, *Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration, and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, EPA-520/1-88-020, 1988.

I. Introduction

The guidance in DOE-STD-1136-2000, *Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities, 2004* should be reviewed in detail prior to conducting an assessment of uranium facilities. The following is a brief overview of the radiological aspects of uranium.

Show OT 6.1 and OT 6.2.

State objectives.

Show OT 6.3.

II. Radiological aspects of uranium

Obj. 1
Identify the radiological properties of uranium.

A. Radiological properties of uranium

Review DOE-STD-1136-2000, *Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities, 2004.*

Fifteen radioisotopes exist, but the three of most concern to the uranium industry are:

Uranium-238:
99.7% abundant in natural uranium;
half-life = 4.5 billion yrs,
specific activity = 3.3 E-7 Ci/g

Uranium-235:
0.72% abundant;
half-life = 710 million yrs,
specific activity = 2.1 E-6 Ci/g

Uranium-234:
0.006% abundant;
half-life = 247 thousand yrs,
specific activity = 6.2 E-3 Ci/g

Enriched uranium has a higher content of Uranium-235 than found in nature. Typical enrichment values are:

- 2%-3% Uranium-235: power reactor grade fuel
- >90% Uranium-235: weapons grade material

Specialized reactor fuel may have enrichments other than those listed above.

The uranium byproduct of enrichment is reduced in Uranium-235 content and is called depleted uranium. Its typical composition is as follows:

- 99.75% Uranium-238
- 0.20% Uranium-235
- 0.0007% Uranium-234

As a result of the differences in specific activities, Uranium-234 may account for a significant fraction, or even the majority, of the radioactivity for enriched uranium.

For example, for 3% enriched uranium (i.e., 3% Uranium-235), the Uranium-234 (with an abundance of 0.03%) would have approximately 6 times the activity as Uranium-238 and approximately 30 times the activity as Uranium-235.

Uranium-238 and Uranium-234 are part of the uranium decay series, while Uranium-235 is part of the actinium series. Therefore, following chemical separation, decay products will continue to grow in. The most significant of these are Thorium-234 and Protactinium-234m from the uranium series and Thorium-231 from the actinium series.

Other small amounts of radioactive material may be present as the result of reprocessing uranium. These include Neptunium, Plutonium, Technetium-99, and other radioisotopes of uranium, including Uranium-232 and Uranium-236.

B. Radioisotopes

Show OT 6.4.

The primary radioisotopes of uranium are all long-lived alpha-emitters. The specific activity (Ci/g) of uranium increases as enrichment increases; therefore, enriched uranium is a more serious radiation hazard.

In most uranium facilities, the inhalation hazard from alpha particles released in the respiratory tract is the predominant radiological hazard associated with the alpha emitting uranium isotopes. In addition, uranium decay products are primarily beta-emitters. For external exposure, the major concern is the high-energy beta particle from Protactinium-234m (2.29 MeV). As a result of beta radiation, the typical contact dose with a block of uranium is approximately 200 mrad/hr.

Trace contaminants such as Technetium-99 and Uranium-232 may result in additional external radiation dose when present.

As a result of the alpha-neutron reaction, casks of enriched uranium hexafluoride may also emit neutrons. Typical dose rates are on the order of a few mrem/hr.

C. Criticality

Uranium-235 and Uranium-233 are both fissile materials; therefore, facilities handling enriched uranium and/or Uranium-233 have the potential for criticality accidents, generating large amounts of neutron and gamma radiation.

D. Toxicological properties of uranium

Obj. 2
Describe the toxicological properties and behavior of uranium.

See Table 2-13 of DOE-STD-1136-2000

Uranium is a heavy metal poison and is toxic in much the same way lead or mercury is. For soluble compounds of low enrichments (< 5% Uranium-235), the toxic properties of uranium override the radiological hazards. The kidney is the primary organ of concern.

For insoluble compounds of any enrichment or all compounds of highly enriched uranium, the radiological hazards are limiting.

III. Detection, measurement, and survey techniques

Show OT 6.5.

Obj. 3
Identify appropriate instrumentation, measurement techniques, and special radiological survey methods for uranium.

A. Monitoring program

A radiation protection monitoring program in a uranium facility must ensure the detection of typical ionizing radiations over wide energy ranges.

To detect alpha radiation from the uranium isotopes surveys using photon-sensitive portable and fixed alpha detectors such, as zinc sulfide or gas proportional counters, should be used.

Appropriate beta detection instrumentation should be available to measure decay products such as Protactinium-234m. If Technetium-99 is suspected, special low-energy beta particle detection equipment should be available.

If large quantities of uranium hexafluoride are present, appropriate neutron survey instruments should be available to measure the neutron radiation.

If the facility contains enriched uranium and/or Uranium-233, appropriate criticality safety alarm systems shall be in place and appropriate neutron and gamma survey instruments available.

Continuous air monitors (CAMs), sample extraction lines that go to CAMs, and continuous radiation dose monitors should be placed outside glove boxes and fume hoods.

B. Survey Techniques

Show OT 6.6.

Monitoring practices include, but are not limited to, the following:

- Contamination surveys of the workplace
- Release surveys
- External exposure surveys
- Airborne contamination surveys
- Routine surveillance by a Radiological Control Technician

All work areas must be monitored for contamination levels on a regularly scheduled basis. The frequency of such surveys will depend on the potential for dispensability of the radioactive material. During these routine surveys, all work enclosures, work surfaces, floors, and equipment within the workplace should be surveyed.

C. Workplace characterization

Show OT 6.7.

At the time a program is established, measurements of external dose should be made

at all locations where it occurs to delineate the levels involved (workplace characterization). Additional measurements should be made at the same frequency as the contamination surveys to identify the buildup of uranium in HEPA filters and glove boxes.

Airborne contamination surveys should be performed for:

- Prompt detection of airborne contamination for worker protection
- Personnel dose assessment
- Monitoring of trends within the workplace
- Special studies

IV. Personnel protection requirements

Show OT 6.8.

Obj. 4
Describe personnel protection requirements, external dose control techniques, and internal dose control techniques.

Review DOE-HDBK-1113-98, *Radiological Safety Training for Uranium Facilities*, 1998.

Workers in uranium facilities need to be appropriately trained on the hazards. DOE has developed DOE-HDBK-1113-98*, Radiological Safety Training for Uranium Facilities*, Reaffirmation May 2005. This handbook provides DOE's guidance on expectations for training of uranium workers.

A. Personnel air sampling

The use of personnel air sampling programs should be considered in monitoring individual Radiological Workers.

B. Protective clothing

As a minimum, personnel who perform operations in controlled areas should wear coveralls – protective clothing is required in contamination areas, not controlled areas. No personal outer clothing should be permitted under coveralls. For inspections or visits, lab

coats, gloves, and shoe covers may be permissible.

Protective clothing should be removed at the step-off pad, and personnel monitoring for contamination shall be performed. If this is not practical, strict control of the movement of personnel shall be maintained from the step-off pad to a location where protective clothing can be removed. Personnel wearing protective clothing shall not be allowed to mingle with individuals wearing personal street clothing. Protective clothing shall not be allowed in uncontrolled areas such as offices, lunchrooms, or control rooms.

C. Respiratory protection

Respiratory protection should be readily available. Respiratory protective equipment should be used for all bag-out operations, bag and glove changes, and any situation involving a potential or actual breach of confinement.

V. External dose control

Show OT 6.9.

A. Beta radiation

Beta radiation is usually the dominant external radiation hazard in work with unshielded forms of uranium. The primary concern is Protactinium-234m, though other radionuclides may be present. Particular care should be taken in operations such as melting and casting, where decay products could be separated and concentrated. Appropriate measurements should be made of the material and appropriate extremity dosimetry worn by workers handling the material.

B. Gamma radiation

Gamma radiation is normally not the controlling factor at uranium facilities. However, gamma fields can exist in areas where large quantities of uranium are stored. Appropriate actions including time, distance, and shielding considerations should be taken to maintain radiation doses ALARA.

C. Neutron radiation

Neutron radiation from enriched uranium fluoride compounds should also be considered in determining potential external radiation hazards.

VI. Internal dose control

Show OT 6.10.

Intakes

In most uranium facilities, the primary radiological hazard is the potential for internal intakes of uranium. This hazard must be controlled by appropriate facility and equipment design, contamination control procedures, and protective clothing.

Inhalation is the primary route of concern. Uranium transported from the lungs is deposited in the bone (22%), kidney (12%), or other tissues (12%), or excreted (54%), according to International Commission on Radiological Protection (ICRP) Publication 30.

Control must be verified by a bioassay program. Urinalysis is the most common technique, but fecal analysis and *in vivo* monitoring may also be appropriate.

DOE-STD-1121-98, *Internal Dosimetry,* Reaffirmation May 2003*,* provides technical guidance on internal dosimetry programs, including evaluation of occupational internal doses from exposure to radon and thoron. This standard should be reviewed prior to conducting assessments of internal dosimetry programs.

Review DOE-STD-1121-98, *Internal Dosimetry. Reaffirmation May 2003*

VII. Special controls and considerations at uranium operations

Show OT 6.11.

Obj. 5
Describe special controls and considerations required for uranium operations.

A. Criticality alarm systems (gamma or neutron) shall be provided in each area where an accidental criticality is possible. Site requirements documents relating to criticality alarms should be reviewed prior to the assessment, if applicable. These requirements may include: ANSI/ANS 8.1, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*; ANSI/ANS 8.3 *Criticality Accident Alarm* Systems; ANSI/ANS 8.7, *Nuclear Criticality Safety in the Storage of Fissile Materials*; ANSI/ANS 8.15, *Nuclear Criticality Control of Special Actinide Elements*; and ANSI/ANS 8.19, ANS *Administrative Procedures for Nuclear Criticality*.

B. All DOE facilities that possess sufficient quantities and kinds of fissile material to constitute a potentially critical mass shall provide nuclear accident dosimetry (fixed and personal). The number of dosimeters needed and their placement will depend on the nature of the operation, structural design of the facility, and accessibility of areas to personnel. An analysis of the dosimeters and their placement should be conducted and documented.

Reference 10 CFR 835.1304.

C. Uranium metal in finely divided form is pyrophoric; therefore, any grinding or milling operations must be carefully conducted to avoid fires.

   Uranium hexafluoride is commonly found in many uranium operations. This material is a solid at room temperatures but volatilizes readily at elevated temperatures. As a gas, it is extremely hazardous, forming hydrofluoric acid when it comes in contact with water. Operations involving uranium hexafluoride must be conducted very carefully to prevent release of the gas.

D. External radiation hazards from uranium are primarily associated with decay products; therefore, operations in which the decay products can separate and concentrate must be monitored carefully. For example, crucibles used to melt depleted uranium and casks used to ship uranium hexafluoride are sometimes more radioactive after they are emptied than when they are full. The reason is that the decay products are left in the emptying process and are no longer self-shielded by the uranium.

Summarize lesson.

Review objectives.

Answer questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Radiological Aspects of Tritium

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Describe the radiological properties of tritium.
2. Identify personnel protection requirements and dose control techniques.
3. Identify the biological effects of internally deposited tritium.
4. Describe appropriate instrumentation, measurement techniques, and special radiological survey methods for tritium.
5. Identify special controls and considerations required for the use of tritium.

Training Aids:

Overhead Transparencies (OTs): OT 7.1 – OT 7.14 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1121-98, *Internal Dosimetry*, Reaffirmation May 2003.

U.S. Department of Energy, DOE-HDBK-1129-99, *DOE Handbook Tritium Handling and Safe Storage*, Reaffirmation 2007.

U.S. Department of Energy, DOE-HDBK-1105-96*, Radiological Training for Tritium Facilities*, Reaffirmation 2002.

U.S. Department of Energy, DOE-HDBK-1079-94, *Primer on Tritium Safe Handling Practices*, 1994.

U.S. Department of Energy, Radiological Control Technical Position, RCTP 01 - 02, *Acceptable Approaches for Developing Air Concentration Values for Controlling Exposures to Special Tritium Compounds,* 2001.

U.S. Environmental Protection Agency, *Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration, and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, EPA-520/1-88-020, 1988.

ICRP Publication 30, *Limits for Intakes of Radionuclides by Workers*, 1979.

ICRP Publication 66, *Human Respiratory Tract Model for Radiological Protection*, 1994.

I. Introduction

Show OT 7.1 and OT 7.2.

State objectives.

II. Radiological aspects of tritium

Show OT 7.3.

A. There are three primary sources of tritium. These are:

1. Environmental sources - Reactions between cosmic rays and the upper atmosphere

$^{14}N + {}^{1}n \rightarrow {}^{3}H + {}^{12}C$

$^{2}H + {}^{2}H \rightarrow {}^{3}H + {}^{1}H$

2. By-product of power reactors

- Ternary fission - A fission event resulting in fission fragments, one of which is tritium. Occurrence typically has a 0.1% yield.

B-10 (n, 2 alpha) ^{3}H

Li-7 (n, n alpha) ^{3}H

3. DOE production of tritium (Hanford, Savannah River reactors) is by the following reaction:

$^{6}Li + {}^{1}n \rightarrow {}^{3}H + \text{alpha}$

B. Chemical and radiological properties of tritium

1. Chemical forms

Show OT 7.4.

- Elemental tritium (tritium gas, HT, DT, T_2)
- Tritiated water (tritium oxide, HTO, DTO, T_2O)
- Special tritium compounds (STCs): created by intentional combination of tritium with the desired materials or by inadvertent contamination of a material that has been subjected to the presence of tritium for a period of time.

  These are classified in a number of ways, depending on their host material (metal or organic), rate of tritium release (stable or unstable), and physical form (particulate or non-particulate). They include:

  - Organically bound tritium (OBT); the main types of OBT encountered in the DOE complex are solvents, oils, and solid particulates (e.g., plastics, nylon, and organic dust forms).
  - Particulates; stable or insoluble forms are referred to as stable tritiated particulates (STPs).

2. Radiological properties

- $^3H \rightarrow {}^3He$ + beta minus and anti-neutrino
- E_{max} = 18.6 keV, E_{avg} = 5.69 keV
- Half-life = 12.32 years
- Specific activity = 9619 Ci/gram
- ALI_{water} = 3000 MBq = 8 E4 μCi (inhalation and ingestion)
- DAC_{water} = 0.8 MBq/m^3 = 2 E-5 μCi/cm^3
- $DAC_{elemental}$ = 2 E4 MBq/m^3 = 0.5 μCi/cm^3
- f_1 = 1
- Committed dose equivalent per unit intake = 1.73 E-11 Sv/Bq = 6.4 E-2 mrem/μCi
- $DAC_{elemental}/DAC_{water}$ = 25,000

Obj. 1
Describe the radiological properties of tritium.

Show OT 7.5.

In addition, DOE has issued guidance on radiological protection for special tritiated compounds in Radiological Control Technical Position, RCTP 0 1 - 02, *Acceptable Approaches for Developing Air Concentration Values for Controlling Exposures to Special Tritium Compounds.* DOE has also issued RCTP 06-01, *Acceptable Approaches for Developing Sealed Radioactive Sources and Posting and Labeling Requirements for Special Tritium Compounds* (*STCs*).

Review Radiological Control Technical Position, RCTP 01 - 02, *Acceptable Approaches for Developing Air Concentration Values for Controlling Exposures to Special Tritium Compounds.*

DOE has also developed a technical standard, *Radiological Control Programs for Special Tritium Compounds*,
DOE- HDBK-1184-2004, Change Notice 1 May 2006.

Review *Radiological Control Programs for Special Tritium Compounds*,
DOE- HDBK-1184-2004

C. Potential exposure pathways of tritium

Show OT 7.6.

Dose pathways and biological effects

- Inhalation
  - Elemental tritium (tritium gas) - Limiting condition is exposure to the lung
  - Approximately 0.005% of HT inhaled is converted to HTO prior to exhalation
  - Nearly 100% of inhaled HTO is incorporated into body fluids/tissues.

- Ingestion
  - Tritiated water
    - Assumed to be instantaneous
    - Biological half-life is normally ten days, but may be reduced by a factor or two-three with increased fluid intake

- Skin absorption of HTO through intact skin ≈50% of that inhaled.

For different modes of entry of STCs:

- STPs behave with the characteristics of the particle to which they are attached.

- Soluble OBT distributes throughout the body causing a whole body dose. Insoluble OBT can be taken into the body by inhalation when in particulate form. Airborne droplets of insoluble components of oils may be treated as stable particulates.

D. General sources of tritium releases

Show OT 7.7.

1. Gaseous releases - ventilation exhaust systems
2. Liquid wastes
   - Aqueous
   - Organic (e.g., oils)
3. Solid wastes
   - Contaminated wastes
   - Treatment residues

E. Exposure controls for tritium

Show OT 7.8.

Obj. 2
Identify personnel protection requirements and dose control techniques.

The personnel protection requirements for tritium include:

- Airborne contamination controls
- Surface contamination controls

1. Airborne controls
   - Differential room pressure zones
   - Dilution ventilation
   - Room-air detritiation systems
   - Local exhaust ventilation

2. Contamination controls

   - Good housekeeping
   - Good work practices

3. Personnel protective equipment

   - Air supplied respirators
   - Protective clothing

F. Metabolism of tritium

Obj. 3
Identify the biological effects of internally deposited tritium.

The tritium beta lacks sufficient energy to penetrate the dead cell layer in skin. Therefore, it is of little consequence as an external hazard. The beta particles can produce Bremsstrahlung radiation when they interact with matter, although the tritium Bremsstrahlung is extremely low energy. It is remotely possible that the Bremsstrahlung exposure could become significant around materials with very high specific activities and little or no shielding.

Tritium can deliver a radiation dose if it gets inside the body. Modes of entry include:

Show OT 7.9.

- Inhalation
- Ingestion
- Absorption

1. Inhalation

   Tritium gas (HT) is only slightly incorporated into the body when inhaled. Approximately 0.005% of HT inhaled is converted to tritiated water prior to being exhaled. Depending upon the rate at which HT converts to HTO *in vivo,* it is possible that some dissolved HT may be excreted in urine.

Tritiated water (HTO) is much more radiologically hazardous than tritium gas. Inhaled HTO enters the body through the lung fluids with 100% efficiency, and mixes rapidly with body water. Nearly 100% of tritiated water (HTO) inhaled is incorporated into body fluids and tissues.

2. Ingestion

   Ingested HTO is assumed to be completely and instantaneously absorbed from the gastrointestinal tract and mixes rapidly with the body fluids so that following ingestion, the concentration in sweat, sputum, urine, blood, perspiration and expired water vapor is the same.

3. Absorption

   There is negligible skin absorption for tritium gas. Some HT can be absorbed through the skin from contact with surface contamination. This uptake is probably in the form of HTO, resulting from the oxidation of HT. Some tritium may be retained in the skin in the form of organics, presumably resulting from exchange reactions with HT on or in the skin.

   HTO can be readily absorbed through the skin. It will be uniformly distributed in all biological fluids within one to two hours.

   Most exposures are to HTO, which rapidly enters the body water via absorption through the lungs and/or skin. A small amount of HT can dissolve in lung fluids, convert to HTO, and enter the body fluids. Exposures to HTO are approximately 10,000 to 25,000 times more hazardous than exposure to HT. HTO has an effective half-life in the body in the range of 4 to 18 days, with a mean effective half-life of about 9 or 10 days.

Most tritium leaves the body either in urine or through evaporation from the lungs and skin. The dose commitment from an uptake of one curie of HTO is approximately 63 rem.

For the above 3 discussed modes of entry: STPs and insoluble components of tritiated oils behave with the characteristics of the particle to which they are attached.

For dose calculations for STPs, ICRP Publication 66 uses absorption types; slow, medium, and fast (S, M, F). These are used in place of the lung retention classes (day, week, and year; D, W, Y) used in ICRP Publication 30. Depending on the absorption type of the compound, the dose per intake will be different than HTO.

Review Types S, M, F

For example: The air concentration value (which could be used in assessing dose per intake) for Type S STP is 10 times more restrictive than HTO, while the air concentration value for Type F STP is 5 times less restrictive than HTO.

Soluble OBTs act somewhat similar to HTO, however a larger percentage of nuclear transformations occur in the stomach. The dose per intake is approximately twice that of HTO.

Skin absorption is also a valid intake pathway for tritiated oil components and solvent OBT.

G. Methods of tritium containment

Show OT 7.10.

1. Primary - Process equipment and piping

2. Secondary

   - Glove boxes
   - Temporary vented enclosures

3. Tertiary - Room and associated ventilation systems

    - Effluent recovery systems
    - Emergency containment systems

H. Airborne tritium controls

Show OT 7.11.

1. Differential room pressure zones - The air ventilation system plays a key role in controlling the spread of contamination. In addition to providing the necessary humidity and temperature control for a building, differential pressure zones should be established within a building to ensure that the air flows from areas with lower hazardous contamination potential to areas with more hazardous contamination potential.

2. Dilution ventilation - Dilution ventilation is the once-through flow technique of exchanging outside air for inside air for comfort and basic contamination control.

3. Room-air detritiation systems - Such a system uses tritium monitors located in the room exhaust to activate (close) fast acting dampers. The dampers then route the exhaust through a special oxidation/drying system and return the air to the room.

3. Local exhaust ventilation - The primary advantage of local exhaust ventilation techniques is the removal of airborne tritium, regardless of its evolution rate or chemical or physical form. In addition, these techniques use relatively low flow rates compared to normal ventilation requirements.

I. Measurement techniques for tritium

1. Air monitoring - Fixed and portable ionization chambers most widely used.

2. Differential monitoring - Separate monitoring of HT and HTO components through the use of bubblers in conjunction with desiccants or catalysts.

3. Discrete sampling - Samples collected with a bubbler or "cold finger" type sampler, then later analyzed by liquid scintillation counting techniques.

4. Process monitoring

   - Stack, room, hood, glove box

   - Mass spectroscopy, gas chromatography, calorimetry

5. Surface monitoring

   - Difficult to measure directly due to low-energy emission

   - May have some success with thin window GM (pancake style probe), thin window sodium iodine, or gas flow proportional counters

   - Smears taken for loose contamination, and measured by dissolution and analysis by liquid scintillation counting techniques

6. Liquid Monitoring - Liquid scintillation counting techniques

Show OT 7.12.

Obj. 4
Describe appropriate instrumentation, measurement techniques, and special radiological survey methods for tritium.

Flow-through ionization chambers

Typical example - TRITON radioactive gas monitors

Explain how the ionization chamber works.

J. Bioassay program for tritium workers

An adequate bioassay program for tritium workers would test for chronic and acute exposure.

1. Chronic exposure - Periodic urinanalysis for tritium (daily to biweekly identified in Tritium Good Practices Manual)

2. Acute exposure

   - Wait one to two hours.
   - Void bladder.
   - Collect sample as soon as possible thereafter.
   - Continue to collect daily to determine individual half-life.

Dose from exposure to STCs may need to be assessed based on air monitoring results, see RCTP 99-02.

DOE-STD-1121-99, *Internal Dosimetry*, 1999, provides guidance on internal dosimetry programs including monitoring and assessing dose from tritium.

Show OT 7.13.

Obj. 5
Identify special controls and considerations required for the use of tritium.

Review DOE-STD-1121-99, *Internal Dosimetry*, 1999, for tritium applications.

K. Tritium effluent recovery systems

1. Purpose - Reduce tritium available for release

2. Method - Tritium gas converted to HTO and ultimately a stable waste form

Show OT 7.14.

L. Inventory control and accountability for tritium

1. Nuclear materials, including tritium, need to be controlled and have material accountability.

2. Appendix D to the Tritium Good Practices Manual discusses inventory control and defines it to consist of:

   - Measurements
   - Measurement controls
   - Determination of holdup in systems
   - Development of predictors
   - Establishment of accounting practices

Summarize lesson.

Review objectives.

Ask for questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Radiological Aspects of Plutonium

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Identify the radiological properties of plutonium.
2. Identify the biological effects of plutonium.
3. Identify special controls and considerations required for plutonium operations.
4. Describe appropriate instruments, measurement techniques, and special radiological survey methods for plutonium.
5. Describe personnel protection requirements and dose control techniques for plutonium.

Training Aids:

Overhead Transparencies (OTs): OT 8.1 – OT 8.12 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

References:

American National Standards Institute, ANSI/ANS*, Criticality Accident Alarm Systems*, 1986.

American National Standards Institute, ANSI/ANS 8.1, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors,* 1983.

American National Standards Institute, ANSI/ANS 8.19, *ANS Administrative Procedures for Nuclear,* 1984.

ICRP Publication 30 Part 4, *Limits for Intakes of Radionuclides by Workers: an Addendum*, 1988.

U.S. Department of Energy, DOE-STD-1128-98, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities*, Change Notice 2, December 2006.

U.S. Department of Energy, DOE-STD-1121-98, *Internal Dosimetry*, Reaffirmation May 2003.

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Change Notice 1, March 2005

U.S. Department of Energy, Radiological Control Technical Position 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*, January 2001.

I. Introduction

Show OT 8.1 and OT 8.2.

State objectives.

The guidance in DOE-STD-1128-98, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities,* Change Notice 2 December 2006 should be reviewed in detail prior to conducting an assessment of plutonium facilities. The following is a brief overview of the radiological aspects of plutonium.

Review DOE-STD-1128-98, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities* Change Notice 2 December 2006.

II. Background

Plutonium was first synthesized in the winter of 1940-41 by a team of scientists at the University of California. Its potential use in weapons was quickly identified, and much of the effort of the Manhattan Project was in the production of sizable quantities of plutonium. Other uses for plutonium include use as:

- Reactor fuel
- Heat sources in thermoelectric generators to power satellites
- Components in portable neutron sources

Plutonium is a silvery-white metal that readily oxidizes to a dull gray color. It can be found in a variety of physical and chemical forms. Several of the chemical forms (including the pure metal) are pyrophoric, so care must be exercised in handling the material. Because of the pyrophoric nature of plutonium and its alloys, the preferred form for storing, shipping, and handling is as plutonium oxide.

Pyrophoric = able to ignite spontaneously

III. Radiological properties of plutonium

A. Isotopes

There are 15 isotopes of plutonium, all radioactive, beginning with Plutonium-232 and ending with Plutonium-246. The radioisotopes of primary interest are Plutonium-238, Plutonium-239, and Plutonium-240, all of which are primarily alpha-emitters.

Obj. 1
Identify the radiological Properties of plutonium.

Show OT 8.3.

1. Plutonium-238 (half-life = 87.7 yrs) is most commonly used as a heat source in thermoelectric generators. Because of its heat production, care must be taken in handling gram or larger quantities, as it could melt plastic or ignite other materials.

2. Plutonium-239 (half-life = 24,000 yrs) is the primary component of plutonium reactor fuel (>85%) and weapons grade plutonium (>90%), with Plutonium-240 (half-life = 6,560 yrs) constituting most of the remainder in both cases.

3. Plutonium radioisotopes emit relatively few high-energy gamma rays, so kilogram quantities can often be processed without serious gamma dose problems. However, small amounts of some radioisotopes or decay products can increase external dose. For example, Plutonium-241 decays by beta emission to Americium-241, which emits a 60-keV gamma ray. This can be a significant source of dose to hands in glove boxes.

4. Neutron dose rates from spontaneous fission and from alpha-neutron reactions with light elements may be significant (e.g., 1 kg of $Pu\text{-}F_4$ (Pu-238) would have a contact neutron dose equivalent rate of 4800 rem/hr).

B. Biological effects of internally deposited plutonium

Show OT 8.4.

Obj. 2
Identify the biological effects of plutonium.

The primary hazards from the most common chemical form of plutonium (PuO_2) are inhalation and ingestion. This chemical form is relatively insoluble. Therefore, uptake through the gastrointestinal (GI) system following an ingestion is small.

Inhaled plutonium can remain in the lungs for a considerable time before being removed through the lymph system.

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Plutonium is difficult to remove from the body. The primary method is through the administration of chelating agents as soon after the intake as possible. Trained medical personnel are needed to administer chelating agents.

The plutonium that enters the systemic system is mostly translocated to the liver and the bone (as is discussed in the following section). Accordingly, development of cancer in these organs and in the lungs are of particular interest in evaluating long-term effects from intakes of plutonium.

C. Survey techniques

Show OT 8.5.

Obj. 3
Identify special controls and considerations required for plutonium operations.

A radiation protection program in a plutonium facility shall ensure the detection of all types of radiation (i.e., alpha, beta, gamma, x-ray, and neutron) over large energy ranges. Alpha-sensitive instruments are necessary for most contamination control surveys.

Continuous air monitors (CAMs), sample extraction lines that go to CAMs, and continuous radiation dose monitors should be placed outside the glove boxes and hoods.

Neutron surveys become important when processing tens of grams of Plutonium-238 or hundreds of grams of mixed isotopes of plutonium, particularly compounds (i.e., PuO_2, PuF_4). The neutron survey is important in instances where photon shields, such as leaded glass, are used. Such shields normally stop all of the charged particles, most of the low-energy photons, and essentially none of the neutrons. Under these circumstances, neutron radiation is likely to be the major contributor to whole body dose.

Exposure rate surveys are normally conducted with photon-sensitive instruments with known energy responses for photons with energies $\geq$ 10 keV.

Monitoring practices include, but are not limited to, the following:

Show OT 8.6.

- Contamination surveys of the workplace
- Release surveys
- External exposure rate surveys
- Airborne radioactivity surveys (both real time (CAMs) and historical (fixed air head))
- Routine surveillance by a Radiological Control Technician

All workplaces shall be monitored for contamination levels on a regularly scheduled basis. The frequency of such surveys will depend on the potential for dispensability of the radioactive material. As a minimum, all gloves, work surfaces, floors, and equipment within the workplace should be surveyed.

Airborne radioactivity surveys should be performed for:

- Prompt detection of airborne contaminants for worker protection
- Personnel dose assessment
- Monitoring of trends within the workplace
- Special studies

Intakes

In most plutonium facilities, the primary radiological hazard is the potential for internal intakes of plutonium. This hazard must be controlled by appropriate facility and equipment design, contamination control procedures, and protective clothing/equipment.

Plutonium transferred from the initial entry site is assumed to be translocated to the liver (45%) and the bone (45). Retention half-life in the liver is 20 yrs and in the bone is 50 yrs, according to International Commission on Radiological Protection (ICRP) Publication 30.

Per ICRP Publication 48, studies have indicated an average partitioning of plutonium between liver and bone of 30% and 50%. However, due to high individual variability, use of the 45% liver and 45% bone partitioning is still recommended.

Control must be verified by a bioassay program. Urinalysis is the most common technique, but fecal analysis and *in vivo* monitoring may also be appropriate.

DOE-STD-1121-98, *Internal Dosimetry,* Reaffirmation May 2003 provides technical guidance on internal dosimetry programs, including enhanced workplace monitoring for instances where there is a technology shortfall, such as for plutonium. This standard should be reviewed prior to conducting assessments of internal dosimetry programs.

Review DOE-STD-1121-98, *Internal Dosimetry,* Reaffirmation May 2003.

Discuss technology shortfall - routine bioassay cannot reliably detect exposures of 100 millirem.

The standard also discusses appropriate evaluation of bioassay results.

D. Monitoring instruments

Show OT 8.7.

Obj. 4
Describe appropriate instruments, measurement techniques, and special radiological survey methods for plutonium.

DOE-STD-1128-98, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities*, Change Notice 2 December 2006 has additional guidance on monitoring instrumentation.

Facilities that deal with unencapsulated plutonium should have continuously operating effluent monitors to determine whether or not plutonium is being released to the environment.

Criticality alarm systems (gamma or neutron) should be provided in each area where an accidental criticality is possible.

E. Sources of external dose

External dose control for plutonium is primarily concerned with photon dose rates from handling plutonium in a glove box and from the neutron dose rate from some mixtures of plutonium.

Show OT 8.8.

While significant high-energy penetrating photons are not commonly associated with plutonium, low-energy photons (x- and gamma-rays) can create significant dose rate problems to extremities. This is particularly a concern when large amounts of Plutonium-238, Plutonium-241, or Americium-241 (from the decay of Plutonium-241) are present.

Neutrons can also represent a potentially significant dose due to spontaneous fission (alpha, neutron) reactions or neutron induced fission. The neutron dose is largely determined by the radioisotope and other materials near the source.

F. Control of external dose

Show OT 8.9.

External dose control is accomplished with traditional dose reduction techniques:

- Time (minimize)
- Distance (maximize)

Long-handled tongs, for example.

- Shielding (use as needed)

Other work practices, including good housekeeping and specialized tool and equipment design, can reduce external dose, as well.

G. Techniques for internal dose control

Show OT 8.10.

The confinement system is a series of physical barriers that, together with a ventilation system, minimizes the potential for release of radioactive material into work areas and the environment under normal and abnormal conditions, thereby minimizing internal dose.

The term "containment" is also used for "confinement."

Generally, three confinement systems are used to achieve the confinement system objectives at plutonium handling facilities. They consist of the following:

- Primary confinement is provided by piping, tanks, glove boxes, encapsulating material, and the like, and any off-gas system that controls effluent from within the primary confinement. It provides confinement of the area immediately surrounding the hazardous material.

- Secondary confinement is provided by the walls, floor, roof, and associated ventilation exhaust systems of the cell or enclosure surrounding the process material or equipment. Except in the case of glove box operations, the area inside this barrier is usually unoccupied; it provides protection for operating personnel.

- Tertiary confinement is provided by the walls, floor, roof, and associated ventilation exhaust system of the facility. It provides a final barrier against release of hazardous material to the environment.

Different devices may be used to confine and control radioactive material. The selection of the appropriate device will depend on the quantity of material, its form, and the operations to be performed.

Fume hoods may be used for some operations with plutonium, depending on the quantity and dispersability of the material. In general, plutonium fume hood operations shall be limited to wet chemistry processes and less than 100 mg of plutonium.

Higher levels of plutonium are generally handled in glove boxes. Care should be taken in the design of the glove box to ensure confinement of the material and any fire.

Ventilation may also be employed to confine plutonium, although it usually is used in conjunction with other measures.

H. Personnel protection

Show OT 8.11.

Obj. 5
Describe personnel protection requirements and dose control techniques for plutonium.

Workers in plutonium facilities need to be appropriately trained on the hazards. DOE has developed *Radiological Safety Training for Plutonium Facilities*, DOE-HDBK-1145-2001, Reaffirmation January 2007. This document provides DOE's guidance on expectations for training of plutonium workers.

The use of personal air sampling programs should be considered to monitor individual workers for exposure to airborne plutonium. Section 4.4.4 of DOE-STD-1121-98, *Internal Dosimetry*, Reaffirmation May 2003 discusses use of breathing zone or personal air monitoring when there is a technology shortfall (i.e., the derived investigation level is less than the minimum detectable activity). Technology shortfalls are common for routine plutonium bioassay programs.

In addition, DOE has issued guidance on use of air monitoring results when there is a technology shortfall in Radiological Control Technical Position (RCTP) 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*.

Review Radiological Control Technical Position 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*

In part, RCTP 2001-01 states that, when there is a technology shortfall for bioassay and air monitoring results indicate exposures greater than 100 millirem in a year are likely, one should assess dose based on the air monitoring results.

As a minimum, personnel who perform operations in controlled areas should wear coveralls and shoe covers. For inspections or visits, lab coats and shoe covers may be permissible. When contaminated wet areas are to be entered, water-repellent (plastic or rubber) clothing shall be worn. No personal outer clothing should be permitted under coveralls.

Hands should be protected by a minimum of two barriers; for example, at least one pair of surgeon's gloves and one pair of rubber gloves should be worn.

Protective clothing should be removed at the step-off pad, and personnel monitoring for contamination shall be performed.

Respiratory protection equipment shall be readily available. Respiratory protection equipment should be used for all bag-out operations, bag and glove changes, and any situation involving a potential or actual breach of confinement. Protection, in the form of air-purifying or atmosphere-supplying respirators, shall be used whenever concentrations of radionuclides in the air are likely to exceed the applicable DACs.

DAC = Derived Air Concentration, a 10 CFR 835 limit for airborne radioactivity.

I. Inventory control and accountability requirements

Show OT 8.12.

Real-time or near real-time accountability systems should be incorporated if possible.

J. Criticality safety considerations

Criticality alarm systems (gamma or neutron) shall be provided in each area where an accidental criticality is possible.

Criticality safety requirements may include: ANSI/ANS 8.3-1986*, Criticality Accident Alarm Systems*; ANSI/ANS 8.1-1983, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*; and ANSI/ANS 8.19-1984, *ANS Administrative Procedures for Nuclear Criticality.*

It is important to review site requirements documents prior to conducting the assessment.

All DOE facilities that possess sufficient quantities and kinds of fissile material to potentially constitute a critical mass shall provide nuclear accident dosimetry.

Reference 10 CFR 835.1304.

Summarize lesson.

Review objectives.

Ask for questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Radiological Work Permits

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Identify types of job hazards that are not addressed by Radiological Work Permits (RWPs).
2. Describe the two basic types of RWPs.
3. Determine the types of jobs that may and may not be worked under the controls imposed by RWPs.
4. Identify typical time limits for the two basic types of RWPs.
5. List essential elements of an effective RWP.
6. List RWP program elements that may be included in a radiological assessment.

Training Aids:

Overhead Transparencies (OTs): OT 9.1 – OT 9.11 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Change Notice 1, March 2005.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, Amended June 2007.

U.S. Department of Energy, Order 440.1-1A, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees Guide for Use with DOE O 440.1B* March 2007.

I. Introduction

Show OT 9.1 and OT 9.2.

State objectives.

Review Chp 3, Part 2 of DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

10 CFR Part 835.501(d) requires written authorizations to control entry and perform work in radiological areas, commensurate with the radiological hazards. DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004, Chapter 3, Part 2, provides guidance on DOE's expectations for such written authorizations.

These written authorizations may take a variety of forms tailored to the work processes involved. Often, the form will be that of a Radiological Work Permit (RWP), discussed in detail below.

II. Radiological Work Permits (RWPs)

Obj. 1
Identify types of job hazards that are <u>not</u> addressed by Radiological Work Permits (RWPs).

A. Purpose

The RWP is designed to document the radiological conditions and associated controls in a work area. The RWP should be integrated with other work authorizations that address safety and health issues, such as those for industrial safety and hygiene, welding, and confined space entry.

Articles 311 and 312 of DOE-STD-1098-99 provide guidance on preparing work control procedures consistent with the principles of Integrated Safety Management. This includes use of multidiciplinary teams to prepare work control procedures for tasks involving significant types of hazards and referring to U.S. Department of Energy, Order 440.1-1A, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees Guide for Use with DOE O 440.1B* March 2007.

B. Typical RWP process

Show OT 9.3.

The process may be different at your site or facility.

1. Requester submits an RWP request form.

2. Radiological Control Supervisor accepts form, collects additional job information as necessary, and assures that completion of appropriate radiological surveys to be performed in the work area.

3. Radiological Control Technicians, or other appropriately trained and authorized personnel, perform surveys, analyze samples, and report results.

4. RWP controls are established based on the results of the surveys.

5. Radiological Control personnel, in consultation with relevant technical staff, complete, distribute and implement the RWP.

6. Radiological Workers and Radiological Control personnel review completed RWP, prior to start of job, during pre-job briefs, and/or ALARA reviews.

Show OT 9.4.

7. Radiological Worker/Supervisor advises Radiological Control personnel when job is complete (so RWP can be terminated).

8. Radiological Control personnel maintain surveys and RWP documentation.

C. Types of RWPs

Show OT 9.5.

There are two basic types of Radiological Work Permits:

Obj. 2
Describe the two basic types of RWPs.

- Job-specific RWP
- General RWP

The job-specific permit is used for jobs which present a greater potential for significant radiation dose, airborne radioactivity, or spread of contamination, and which involve "hands on" work.

Examples of jobs that would likely require job-specific RWPs include those where work is:

- Performed with detailed, specific, written work procedures, approved in advance by Radiological Control personnel

- "Hands-on" work performed infrequently on radiological systems (e.g., valve replacement in process buildings)

- Performed in areas in which the radiological conditions have no history of remaining stable

Obj. 3
Determine the types of jobs that may and may not be worked under the controls imposed by RWPs.

The general RWP typically is used for jobs with less potential for health physics concerns and for routine, repetitive jobs that do not involve "hands on" work.

Examples of jobs that may be worked under a general RWP include:

- Routine tours, inspections, inventories, valve lineups, equipment tagouts, surveys, and equipment operation.

- Work routinely performed on nonradiological systems (e.g., fire protection systems in shut-down process buildings).

- Routine operations involving radioactive material for which the radiological conditions have a history of remaining stable.

Keep in mind that there may be a need for other (nonradiological) permits or authorizations to safely perform these jobs. For example permits may be needed to address nonradiological hazards, such as: electrical, confined space, asbestos, hazardous materials, respiratory protection, fire, heavy equipment and scaffolding.

D. Time limits

The job-specific RWP usually remains in effect only for the duration of the job (typically less than 30 days).

The general RWP typically is approved for a period of time of one year or less.

Show OT 9.6.

Obj. 4
Identify typical time limits for the two basic types of RWPs.

E. Elements of an RWP include:

- Description of work (detailed)
- Radiological conditions (contamination, airborne, radiation levels) in the work area
- Dosimetry (TLD badge, self-reading dosimetry, special dosimetry) requirements
- Requirements for a pre-job briefing, if necessary
- Radiological Control Technician coverage (start of job, continuous, intermittent)
- Training requirements to work in the area
- Protective clothing requirements
- Respiratory protection equipment requirements
- Stay time requirements
- Radiological conditions that may limit work or void the RWP
- Special dose reduction (ALARA) or contamination reducing measures to be considered

Show OT 9.7.

Obj. 5
List essential elements of an effective RWP.

"Valve work" is not a detailed work description.

Briefings are needed most for elevated radiation or contamination levels: workers in High Contamination Areas need briefings more than workers in Contamination Areas.

Show OT 9.8.

Discuss stay time, accidents, and alarms.

Discuss staff rotation, alarming dosimetry, planning, and shielding.

- Special personnel contamination monitoring requirements
- Work document number (if used)
- Unique RWP identification number

Show OT 9.9.

- Date of permit issue and expiration date
- Signatures of Radiological Worker and supervisor (attesting to their understanding of RWP requirements and agreement to follow) and Radiological Control staff

If time allows, show examples of contemporary RWPs, highlighting required information and radiological controls.

F. RWP Elements for Radiological Assessment

Obj. 6
List RWP program elements that may be included in a radiological assessment.

The following are RWP program elements which may be reviewed as part of a radiological assessment:

Show OT 9.10.

- RWPs appropriately required for activities and areas
- Completeness of information on RWPs
- Adequacy of radiological surveys to support RWP
- Worker adherence to RWP requirements
- RWP appropriately reviewed and approved

Show OT 9.11.

- Adequacy of worker monitoring (TLDs, bioassay, air monitoring RCT coverage) specified on RWP
- ALARA considerations included in RWP
- RWP program implemented in accordance with written procedures

Summarize lesson.

Review objectives.

Ask for questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Contamination Containment and Temporary Control Measures

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Describe what temporary engineered radiological controls can be used to reduce or eliminate contamination spread.
2. Describe why engineered and administrative controls are needed.

Training Aids:

Overhead Transparencies (OTs): OT 10.1 – OT 10.5 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, Amended June 2007.

U.S. Department of Energy, DOE-STD-1121-98, *Internal Dosimetry*, Reaffirmation May 2003.

U.S. Department of Energy, Radiological Control Technical Position 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*, 2001.

I. Introduction

10 CFR Part 835, *Occupational Radiation Protection*, specifies contamination control requirements in Subpart L. Chapters 3 and 4 of DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004 provides guidance on meeting the requirements and additional information for implementing an effective contamination control program. All of these documents should be reviewed prior to conducting an assessment.

Show OT 10.1.

State objectives.

Review
10 CFR Part 835, *Occupational Radiation Protection*

DOE-STD-1098-99, *Radiological Control,* Reaffirmed December 2004

II. Contamination containment and temporary control measures

Minimization of internal dose

The minimization and control of internal dose should be conducted in accordance with the following hierarchy of controls:

Show OT 10.2.

1. Engineered controls, including containment of radioactive material at the source wherever applicable, should be the primary method of minimizing airborne radioactivity and internal dose to workers.

   Engineered controls are devices such as glove boxes, glove bags, portable filtration units, and containment tents. They should be used to prevent worker inhalation of radionuclides.

   Portable and fixed/permanent shielding using dense materials (lead) or portable plastic interlocking fluid filled containers are also engineered features, used to minimize external radiation dose.

Obj. 1
Describe what temporary engineered radiological controls can be used to reduce or eliminate contamination spread.

The use of these devices reduces the spread of contamination, cleanup time, and decontamination costs. These measures help maintain doses ALARA. In addition, they can reduce the need for respirators and the impact on work in nearby areas.

Obj. 2
Describe why engineered and administrative controls are needed.

Engineered controls should be used in accordance with technical instructions, proper training, and effective administrative controls

Site-specific manuals should contain generic instructions on the design, controls, training, and use of engineered controls.

2. Administrative controls, including access restrictions and the use of specific work practices designed to minimize airborne contamination, should be used as the secondary method to minimize worker internal dose.

Show OT 10.3.

3. Only when engineered and administrative controls have been applied and the potential for airborne radioactivity still exists, should personnel protective equipment, including use of respiratory protection, be considered.

   Chapter 3 of DOE-STD-1098-99 discusses:
   Access controls for Contamination Areas
   Controlling the spread of contamination
   Monitoring for contamination.

   Appendix 3 C*, Contamination Control Practices*, includes recommended selection of protective clothing, and a recommended sequence for donning and doffing.

   Use of respiratory protection should be considered under the following conditions:

   - Entry into posted Airborne Radioactivity Areas
   - During breach of contaminated systems or components
   - Work in areas or on equipment with removable contamination levels greater than 100 times the values in Table 2-2 of DOE-STD-1098-99
   - During work on contaminated or activated surfaces with the potential to generate airborne radioactivity

   The selection of respiratory protection equipment should include consideration of worker safety, comfort, and efficiency. The use of positive pressure respiratory protection devices is recommended wherever practicable to alleviate fatigue and increase comfort.

Show OT 10.4.

Air-supplied respirators, for example

Respirators can provide adequate protection for workers in an airborne radioactivity environment, but engineered controls may be more practical. By using engineered controls instead of respirators, the worker is not subjected to the stresses created by wearing a respirator. It is more difficult to breath and communicate when wearing a respirator. Vision is impaired, and the respirator is not comfortable. Productivity can therefore be improved by using engineered features instead of respirators.

To minimize intakes of radioactive material by personnel, smoking, eating, or chewing shall not be permitted in Contamination, High Contamination, Airborne Radioactivity Areas, or Radiological Buffer Areas established for contamination control purposes.

Contamination should be contained at its source. The principle is to prevent contamination spread from occurring. The most effective methods based on sound ALARA principles should be used. All controls should be documented and clearly controlled by RWPs.

Respirators may be appropriate for simple, straightforward jobs.

In specific situations the use of respiratory protection may be contraindicated due to physical limitations or the potential for significantly increased external dose.

Show OT 10.5.

Example: Work in high radiation fields and airborne radioactivity.

In such situations, written authorization should be obtained from the line organization manager and the Radiological Control Manager prior to incurring internal dose. Specific justification of the need to accept the dose, including a description of measures taken to mitigate the intake of airborne radioactivity, should be documented as part of the radiological work documentation.

The use of personal air sampling programs should be considered to monitor individual workers for exposure to airborne radioactive material, especially when the use of respiratory protection is contraindicated. This is particularly important when there is a bioassay program technology shortfall (i.e., the derived investigation level is less than the minimum detectable activity). Section 4.4.4 of DOE-STD-1121-98, *Internal Dosimetry*, discusses use of breathing zone or personal air monitoring.

In addition, DOE has issued guidance on use of air monitoring results when there is a technology shortfall in Radiological Control Technical Position (RCTP) 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*.

Review Radiological Control Technical Position 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*

In part, RCTP 2001-01 states that, when there is a technology shortfall for bioassay and air monitoring results indicate exposures greater than 100 millirem in a year are likely, one should assess dose based on the air monitoring results.

Summarize lesson.

Review objectives.

Ask for questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Radiological Work Site Mockup Demonstration
Objectives: Upon completion of this lesson, the participant will be able to: 1. Identify poor radiological work practices, in and around a mock radiological work site. 2. Inspect a typical contamination containment (glove bag). 3. Develop field assessment notes to support findings (hands-on exercise).	
Training Aids: Overhead Transparencies (OTs): OT 11.1 (may be supplemented or substituted with updated or site-specific information) Materials needed for this exercise are listed on the following pages.	
Student Materials: Student's Guide	
References: U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmation December 2004.	

Radiological Work Site Mockup Demonstration Checklist for Module 11

The exercise is a mock-up demonstration that is performed by the instructors to give the participants an opportunity to assess and identify poor radiological work practices.

The participants should be instructed to identify and make notes of the poor radiological practices during the demonstration. After the demonstration, ask the participants to:

- Identify poor radiological practices
- Make recommendations for improvement

Radiological Work Site Mockup Demonstration Checklist for Module 11 (continued)

Description of Mock-up Demonstration Area

The area is intended to simulate an actual, posted area where radiological work is performed.

White plastic PVC pipes and junctions are used to create a support structure for a heavyweight clear plastic contamination containment (glove bag). The glove bag measures approximately 2 ft wide x 2 ft high x 3 ft long.

The glove bag has four glove ports, which allow the installation of four sets of heavy rubber gloves for Radiological Workers #1 and #2. The bag is suspended from the PVC pipes by "bungee" cords.

Inside the glove bag is a valve, with two shutoff valves installed on both sides. The valves are installed on PVC pipe, which penetrates the glove bag. The penetrations are taped, to ensure a good seal.

Normally a polyethylene (poly) bottle would be connected to the glove bag, to collect any liquid released inside the bag. In this exercise, the poly bottle is intentionally not installed.

Radiological rope barrier and standard signs (which intentionally contain improper wording or incorrect color combinations) surround the posted area, which measures about 15 ft x 15 ft square. One exit, with step-off pad, is provided, through which the actors enter the area.

Directly beneath the glove bag is a simulated area of high radiation called a "hot spot," with a standard label filled-in to indicate the dose rate. A yellow lead blanket is provided to cover (shield) the "hot spot."

The simulated job, which is controlled by a Radiological Work Permit (RWP), is valve removal by Radiological Workers #1 and #2, supported by a Radiological Control (DOE RadCon) Technician, a Quality Inspector, and a DOE Representative.

Radiological Work Site Mockup Demonstration Checklist for Module 11
(continued)

Supplies and Equipment for Mock Exercise

This item is needed:	To:
rubber mallet	install and dismantle PVC pipe support
standard screwdriver	tighten glove hose clamps
pipe wrench	tighten valve connections
"hot spot" blank labels	enter field information on dose rates
"bogus'" radiological signs (RADIATION AREA signs with incorrect wording and/or colors)	simulate erroneous posting of radiological area
step-off pad	simulate radiological area exit
razor knife	cut glove penetrations into bag
yellow tape	seal valve-to-glove bag surfaces
yellow lead blanket	shield "hot spots"
yellow poly bottle	stage in background, outside radiological area
stanchions ("rad rope")	simulate radiological area boundaries
office trash can	serve as a "prop"

Radiological Work Site Mockup Demonstration Checklist for Module 11
(continued)

Setup for Mock Exercise

Complete the following tasks prior to the implementation of the mock-up exercise:

- ❑ Install PVC containment supports, pipe with valve and glove bag.
- ❑ Place a tear in one finger of a glove attached to a glove bag (large enough to stick a finger through).
- ❑ Open both isolation (green-handled) valves.
- ❑ Prepare a "hot spot" label and write "500 mrem/hr" on the label.
- ❑ Stick label onto mock hot spot and place yellow lead blanket over it.
- ❑ String yellow and magenta poly rope through stanchions to establish mock radiological area.
- ❑ Place defective signs (wrong color or wording) onto the rope; for example, "Radiation Zone."
- ❑ Place poly bottle in background (5 ft behind containment supports).
- ❑ Place a yellow plastic waste bag just outside the radiological area.
- ❑ Prepare RWP for this job showing High Radiation Area, Radiological Buffer Area, thermoluminescent dosimeters (TLDs) and pocket dosimeters, continuous Radiological Control Technician coverage, and pre-job briefing required (instructor reviews with the class members in an earlier session).
- ❑ Brief players before mock exercise (see Module 11 of Instructor's Guide).
- ❑ Dress players (include "maternity padding" for DOE Representative).
- ❑ Paint simulated cut on right hand of Worker 2.

I. Introduction

Show OT 11.1.

State objectives.

II. Mockup demonstration

Refer to previous pages for instructions on setting up for the mockup demonstration.

A. Storyboard

Ask participants to observe the demonstration and watch for poor radiological work practices. Encourage participants to write down poor work practices in their student's guide for discussion after demonstration.

Player(s)	Action	Dialogue
Workers #1 and #2	Approach posted radiological area.	
Worker #2	Chews gum and rubs the open cut on his hand.	
Worker #1	Asks Worker #2:	"Do you have the RWP?"
Worker #2	Replies:	"I thought you had it."
Worker #2	Asks Worker #1:	"Where is that RadCon Technician?"
Worker #1	Replies:	"I haven't seen him."
Worker #1	Pulls out his pocket dosimeter, raps it on the pipe, and reads it.	
	Asks Worker #2:	"Where is your dosimeter?"

Player(s)	Action	Dialogue
Worker #2	Replies:	"I'll just use your reading."
Worker #1	Asks Worker #2:	"Are you ready to get started?"
Worker #2	Replies: Takes a sip from his soft drink and places the cup on the floor.	"In a minute..."
Workers #1 and #2	Enter radiological area.	Engage in small talk: what happened over the weekend, hunting, children.
Worker #2	Sticks used chewing gum to pipe support. Notices green isolation valves are open. Calls out to Worker #1:	"Hey, these valves are open."
Worker #1	Replies to Worker #2:	"So, close them."
Worker #2	Closes only one valve. Comments to Worker #1:	"I wish we had been trained to work on this valve. It sure would be easier if we knew what we were doing and had received a pre-job briefing."
Worker #1	Replies: Sticks finger through a hole in a torn glove bag.	"No big deal, we can wing it."

Player(s)	Action	Dialogue
Worker #1	Works a short minute. Asks Worker 2:	 "Have you seen the replacement valve?"
Worker #2	Points to the valve outside the area and replies: Leaves the area to get the replacement valve.	 "It's over there, I'll get it."
Worker #1	Loiters in area, close to "hot spot."	
RadCon Technician	Enters the scene and walks around the area, but does not provide much assistance to the workers. Demonstrate his contamination survey instrument (with a pancake probe).	
DOE Representative and Quality Inspector	Enter the area and engage in small talk with Worker #1.	
Worker #1	Resumes work.	
DOE Representative	Relocates lead blanket, then sits over "hot spot."	
Worker #2	Returns with replacement valve and knocks over his soft drink.	

Player(s)	Action	Dialogue
Worker #1	Continues working.	
Worker #2	Shakes hands because they have become wet.	
	Complains:	"Hey, there is rusty water in this glove bag."
Worker #1	Turns to Worker #2 and replies:	"Well, shut the valve."
Worker #2	Shuts the valve off.	
Worker #1	Opens the glove bag's zipper and places the replacement valve in the bottom of the glove bag.	
Quality Inspector	Complains:	"My mouth is sure dry."
Worker #2	Reaches into his pocket and offers the Quality Inspector a stick of gum.	"Would you like a stick of gum."
Quality Inspector	Replies: Takes the gum.	"Sure, thanks."
Quality Inspector	Moves the poly bottle into area and sits on it.	
Quality Inspector	Reaches into area to "help" Workers #1 and #2 with the job.	
Worker #2	Asks the Quality Inspector:	"How many of these jobs have you done?"
Quality Inspector	Replies:	"None, I'm new. Matter of fact, I'm scheduled for GERT next Tuesday."

Player(s)	Action	Dialogue
Worker #1 and Worker #2 Worker #1	Remove the defective valve. Look around for the bag to place the valve in. Complains:	 "Where's the bag to put this thing in?"
RadCon Technician	Leaves the controlled area. Returns with the yellow bag and prepares to receive the defective valve from Workers #1 and #2.	
Worker #2	Fumbles about and misses the yellow bag, dropping the valve on the floor.	"OOPS"
RadCon Technician	Picks up the valve and puts it into the plastic bag, laying it on the floor. He leaves the area without monitoring	
Quality Inspector Worker #1 Quality Inspector	Drops his pen into the area of the spill. Picks up the pen and hands it to the Quality Inspector. Accepts the pen and does not request it to be monitored or decontaminated.	
Quality Inspector and DOE Representative	Leave the area.	

Player(s)	Action	Dialogue
Worker #1	Asks Worker #2:	"What should we do about the spill?"
Worker #2	Replies:	"It's almost breaktime. RadCon will take care of it later."
Worker #2	Places lead blanket over the spill.	
Worker #1	Picks up bagged valve and throws it into a nearby trash can.	
Workers #1 and #2	Leave the area.	

B. Deliberate errors from mock exercise

- Workers #1 and #2 are dressed differently for the same job
- Protective clothing worn by Worker #1 is not taped at wrists, ankles
- Bearded Worker #1 wearing respirator
- Half-face respirator used (type not recommended for radioactive materials)
- Wrong (yellow) canisters installed in mask
- Worker #2 chews gum
- No RWP copy at work site
- No RadCon Technician present (RWP calls for continuous coverage)
- Worker #1 abuses pocket dosimeter
- Worker #2 has no pocket dosimeter
- Quality Inspector, RadCon Technician, and DOE Representative have no TLD badges
- Worker #2 drinks soft drink in area
- Green isolation valves not closed prior to beginning work
- No pre-job briefing (based on dialogue)
- No training for this job (based on dialogue)
- Torn glove (glove bag not inspected for integrity prior to job start)
- No corrective action to torn glove

Ask participants to identify errors observed during the demonstration. Encourage participants to write down the errors in their student's guide, then discuss each of the errors.

- Replacement valve not taken into area
- Worker #1 loiters in high radiation area while #2 gets replacement valve
- RadCon Technician not actively involved in job assistance
- RadCon Technician does not have proper survey instrument for measuring radiation levels
- DOE Representative moves lead blanket without replacing it to original position
- DOE Representative (pregnant) sits over unshielded hot spot
- Worker #2 has open cut on hand
- Worker #2 creates liquid spill (knocks over soft drink)
- Inappropriate response to spill (covers with lead blanket, no notice to RadCon)
- Quality Inspector is given gum in area and chews it
- Poly bottle not installed for glove bag
- Quality Inspector is in area without having received General Employee Radiological Training (GERT)
- No yellow plastic bag in area to receive old valve dropped onto floor
- Worker #2 drops old valve onto floor (creating another spill)
- RadCon Technician does no monitoring after valve dropped onto floor
- Quality Inspector drops pen into contamination and there is no monitoring or decontamination of the pen
- Worker #1 puts used, contaminated valve into ordinary trash can

NOTE: Participants will detect other errors that are not listed.

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Radiation-Generating Devices

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Identify radiation-generating devices.
2. Describe the basic components of an x-ray machine.
3. Identify the most common use of x-rays.
4. Identify the potential hazards associated with x-rays.
5. Identify the most common use of sealed gamma ray sources and the potential hazards.
6. Identify the most common use of beta and neutron sources and the potential hazards.

Training Aids:

Overhead Transparencies (OTs): OT 12.1 – OT 12.11 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, Amended June 2007.

ANSI N43.2-1989a, *Radiation Safety for X-ray Diffraction and Fluorescence Analysis Equipment*, 1989.

ANSI N43.3-1993, *Installations Using Non-Medical X-ray and Sealed Gamma Ray Sources Energies up to 10 MeV*, 1993.

U.S. Nuclear Regulatory Commission, 10 CFR Part 34, *Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations*, 1992.

Update to DOE G 441.1-1B, *Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*.

Section 7.0 Radiation Generating Devices.

Section 15.0 Sealed Radioactive Source Accountability and Control.

U.S. Department of Energy, DOE HDBK-1109-97*, Radiological Safety Training for Radiation-Producing (X-Ray) Devices*, Reaffirmation January 2007.

I. Introduction

Update to DOE G 441.1-1B, Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection. Section 7.0 Radiation Generating Devices, includes provisions for exposure to ionizing radiation from DOE activities. Included in the 10 CFR 835 definition of a radiological worker is "operation of radiation producing devices". 10 CFR 835 also specifies requirements for sealed radioactive sources.

Show OT 12.1 and OT 12.2.

State objectives.

Review 10 CFR 835 radiological worker definition.

Show OT 12.3.

II. *DOE* Guidance

Update to DOE G 441.1-1B, Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection. Section 7.0 Radiation Generating Devices, provides guidance on DOE's expectations for controlling exposure from radiation generating devices (RGD). The IG includes a definition of a RGD as "a collective term for devices which produce ionizing radiation including, certain sealed radioactive sources, small particle accelerators used for single purpose applications which produce ionizing radiation (e.g., radiography), and electron generating devices that produce x-rays incidentally."

Review Update to DOE G 441.1-1B, Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection, Section 7.0 Radiation Generating Devices.

Show OT 12.4.

Obj. 1
Identify radiation generating devices.

For sealed radioactive sources, refer to DOE Update to DOE G 441.1-1B, Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection, Section 15.0 Sealed Radioactive Source Accountability and Control.

Update to DOE G 441.1-1B, Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection, Section 15.0 Sealed Radioactive Source Accountability and Control.

Article 365 of DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004 provides additional guidance, including the use of ANSI N43.3, ANSI N43.2, and 10 CFR Part 34 for meeting its requirements covering RGDs.

Review DOE-STD-1098-99, *Radiological Control, Reaffirmed December 2004* (Article 365).

DOE HDBK-1109-97*, Radiological Safety Training for Radiation-Producing (X-Ray) Devices*, provides guidance on DOE's expectations for radiation safety training for individuals using RGDs.

Review DOE HDBK-1109-97*, Radiological Safety Training for Radiation-Producing (X-Ray) Devices*

III. X-ray machines

A. Components

X-ray devices have been in existence for about 100 years. Although there are many different designs of x-ray machines, they all have the same basic components. These include a source of electrons, an electrical potential difference to accelerate the electrons, and an anode, or target for the accelerated electrons to strike.

Show OT 12.5.

Obj. 2
Describe the basic components of an x-ray machine.

Usually, the source of electrons in an x-ray machine is a thin wire filament from which electrons are emitted when it is heated by a large electrical current. Controlling the current through the filament, then, becomes a way to control the number of electrons available for acceleration.

The number of electrons moving across the x-ray tube, or the tube current, is adjusted on the x-ray machine control panel with the milliAmpere (mA) control. In some x-ray machines, the mA may be fixed, and not adjustable by the operator.

The electrical potential difference between the cathode (filament) and the anode (or target) is the force that accelerates the electrons. The larger the potential difference, the more kinetic energy the electrons will acquire. The potential difference is measured in units of kilovolts (kV). The energy of the electrons is measured in units of kilo electron volts (keV), with one electron volt being the amount of energy required to move one electron through a potential difference of one volt.

Electrons interact in the target by one of the following mechanisms:

- Excitation
- Ionization
- Bremsstrahlung

The accelerated electrons then strike the anode (or target). The target may consist of various materials, depending on the purpose and design of the x-ray tube. X-ray production is most efficient in high atomic number targets, like tungsten.

When electrons strike and excite target atoms, the kinetic energy of the electrons is deposited in the target as heat. When electrons ionize target atoms, characteristic x-rays will be emitted as electrons from outer shells fill vacancies created by ejected electrons.

When the accelerated electrons simply decelerate (brake) as they come near the large, positively charged nucleus of a target atom, the change in energy resulting from the deceleration is emitted as a bremsstrahlung photon. If the accelerated electron loses all of its energy and essentially comes to rest, then the energy of the bremsstrahlung photon will be equal to the initial kinetic energy of the electron.

Show OT 12.6.

Bremsstrahlung is German for "braking radiation."

B. X-ray energy spectrum

The energy of the x-ray photons coming out of the x-ray machine is of interest to the users of the machine. The typical energy spectrum from an x-ray machine consists of the characteristic x-rays from the target, which have discrete energies, and the bremsstrahlung photons which have a whole range of energies, the maximum energy depending on the potential difference across the tube. For a typical x-ray machine, the bremsstrahlung photons far outnumber the characteristic x-rays.

C. Design features

The cathode and anode of the x-ray tube are enclosed in an evacuated glass tube or envelope. The vacuum is necessary to ensure that the accelerated electrons will interact in the target, and not with gas molecules.

The x-rays are produced in all directions in the target. However, only x-rays directed toward the exit port, or window, will comprise the useful beam.

Several devices are used to control the size of the useful x-ray beam. A lead diaphragm is a sheet of lead with a hole in it. It is placed near the exit port, and restricts the size of the useful beam by absorbing x-rays that don't pass through the hole. The size of the beam is not adjustable with this type of device unless another diaphragm with a different-size opening is used.

For some operations, the size of the useful beam must be adjusted by the operator. An adjustable collimator is essentially a set of movable lead sheets. Two sheets restrict the width of the beam, and two sheets restrict the length of the beam. The operator can then adjust the size of the beam to any desired combination of length and width.

Often, the lowest energy x-rays are not desired in the beam. The low energy x-rays can be filtered out by placing absorbing material (called filters) in the path of the beam. Aluminum or copper is commonly used, depending on the energy of the machine. The addition of filters increases the average energy of the beam, since the lower energy x-rays are removed from the beam when they are absorbed by the filters.

The anode is usually encased in copper, which serves to dissipate the heat. In many x-ray machines, the anode rotates at a high speed, which increases the area of bombardment and therefore is also useful in dissipating heat.

The x-ray tube housing is an insulated metal casing around the glass envelope that provides both electrical and radiation shielding. The housing will intercept most of the x-rays produced in the target that are not part of the useful beam.

D. Common uses and hazards

X-ray machines are most commonly used for radiography, or the examination or inspection of the structure of materials by non-destructive means.

Obj. 3
Identify the most common use of x-rays.

The energy of the x-rays required will depend on the density, thickness, and atomic number of the objects or structures to be imaged, or examined. Dense, thick, high atomic number objects or structures require more energetic x-rays.

X-ray machines used in medicine are fairly standardized in appearance, and in the way they are installed. That is not true of x-ray machines used for industrial applications. X-ray machines may be fixed installations, mobile units, or completely enclosed cabinet systems. The cabinet x-ray systems are commonly used for security applications (e.g., baggage inspection units).

Show OT 12.7.

Obj. 4
Identify the potential hazard associated with x-rays.

The major hazard from x-ray machines is the external dose hazard to machine operators and other people in the vicinity. No one should ever be exposed to the primary (or useful) beam. Exposure to leakage radiation (from the housing) and scatter radiation should be reduced by appropriate controls.

IV. Analytical x-ray machines

Show OT 12.8.

A. Fluorescence analysis

Characteristic x-rays that result from ionization of atoms can be used to identify atoms, since the characteristic x-rays will have energies that are unique to that element. This forms the basis for x-ray fluorescence spectroscopy. A sample to be analyzed is irradiated by a beam of high-intensity x-rays. The x-rays ionize atoms in the sample, which emit characteristic x-rays when the electron shell vacancies created by ionization are filled.

The characteristic x-rays can be analyzed by determining their energy, or by determining their wavelength. Either way, the result leads to information about the elemental composition of the sample.

These instruments are usually completely enclosed. Access doors are provided for changing samples, and the doors are equipped with interlocks to prevent access to the x-ray beam.

The hazard is primarily an external dose hazard to scattered radiation from the components and the sample, and is typically fairly low.

B. X-ray diffraction

When x-rays are scattered by a crystalline solid, they are scattered from the different atoms, but only in certain directions. This technique is used for crystal structure research.

Collimated = focused

The primary beam and the diffracted beams are very small and well collimated. In some types of diffraction equipment, the sample cannot be enclosed in a structure. The primary beam is controlled by a shutter that opens and closes. The major hazard associated with diffraction units is intense, localized exposure from the primary beam to the hands or eyes that can occur during sample changing or beam alignment procedures with the shutter inadvertently open. The primary beam is very small, but may have an intensity of up to 40,000 R/min. At this exposure rate, even short exposures of the hands and fingers could result in severe injury, and potential loss of fingers.

V. Sealed gamma ray sources

Show OT 12.9.

Sealed gamma ray sources are used for a variety of applications in industry. Gamma ray sources are the most common sealed source encountered, although others are used and are discussed later. Radiography is probably the most common use, and may be performed with the gamma rays from sealed sources of Cobalt-60, Cesium-137, or Iridium-192.

Obj. 5
Identify the most common use of sealed gamma ray sources and the potential hazards.

Other uses of sealed gamma ray sources are thickness gauges (e.g., to determine the thickness of sheet metal), level gauges (e.g., to determine a fluid level in a container), and density gauges (e.g., to measure the geologic formation porosity during oil and mineral logging).

The hazard from these sources is primarily an external dose hazard. The most common cause of overexposure incidents with gamma radiography sources results from radiographers failing to perform radiation surveys to verify that the gamma source is back in the shielded position. Also, if mechanical damage to the source encapsulation occurs, radioactive material contamination will be a hazard as well.

VI. Other sealed sources

Show OT 12.10.

Sealed sources of beta particles may be used as thickness gauges (e.g., measurement of dust on filter paper, or gauging thickness of thinner plastics).

Obj. 6
Identify the most common use of beta and neutron sources and the potential hazards.

Neutron sources have a variety of applications and are commonly used in moisture gauges (e.g., determining moisture content in raw materials such as gravel, wood chips, etc.). The fast neutrons emitted by the source are moderated by the hydrogen atoms in the material being measured, and can then be detected with a neutron detector. Of course, the more moisture contained in the material, the more hydrogen atoms will be present.

Fast neutrons moderated (slowed down) to slow neutrons, which are detected.

Neutron sources are also used to some extent for radiography of very dense materials like lead or steel, which otherwise would require very high energy photons to radiograph.

Californium-252 emits neutrons after undergoing spontaneous fission, and therefore serves as a neutron source. Neutrons can also be produced fairly easily by nuclear reactions in certain materials such as beryllium.

When an alpha-emitting material is combined with beryllium, the alpha/beryllium reaction results in the formation of Carbon-12 and a neutron. Some common sources of this type are combinations of Americium-241 and Beryllium (AmBe sources) and Plutonium-239 and Beryllium (PuBe sources). Another nuclear reaction that can produce neutrons is the photo-neutron reaction. For this reaction to occur, a gamma-emitting material is combined with beryllium, resulting in the production of neutrons. An example of this type of neutron source is the combination of Antimony-124 and Beryllium (SbBe source).

The primary hazard from beta and neutron sources is from the external radiation fields they generate. These sources would only become an internal hazard should the source rupture or leak and radioactive material subsequently is inhaled or ingested. An additional hazard of neutron activation exists around neutron sources.

Neutron activation can produce gamma-emitters (external dose concern).

10 CFR 835 Subpart M "Sealed Radioactive Source Control" establishes requirements for accountable sealed radioactive sources. Requirements include provisions for (at intervals not to exceed 6 months):

Review definition of accountable sealed radioactive source.

inventory

posting

leak testing

Discuss 10 CFR 835.3(e) provision to allow 30 day grace period for certain time intervals.

VII. Other radiation-generating devices

Other radiation-generating devices (RGDs) that may be encountered are small particle accelerators (<10 MeV) used for radiography, ion implantation, or the production of incidental photons or particles (neutron generators).

Some RGDs produce radiation incidental to their primary purpose. Examples of devices that produce radiation incidentally are electron beam welders, electron microscopes, and pulse generators.

VIII. Categorizing RGD installations

Show OT 12.11.

The ANSI standards referenced earlier categorize RGD installations into the following categories for radiation safety purposes.

Each category is discussed briefly. The ANSI standards and other referenced documents should be consulted for complete information and requirements for each category.

A. Exempt shielded installations

The RGD and all objects exposed to the source of radiation shall be within a permanent enclosure that, under all circumstances of use, possesses sufficient inherent shielding and prevents inadvertent entry to any part of the body. The exposure at any accessible region 5 cm from the outside surface of the enclosure shall not exceed 0.5 mrem in any one hour.

B. Shielded installation

The RGD and all objects exposed to the source are within a permanent enclosure from which persons are excluded during the irradiation. Some of the requirements for shielded installations include mandatory interlocks, audible and visual warning devices, a "crash" button, and posting of warning signs.

Skyshine is the term used to describe radiation emerging more or less vertically from a shielded enclosure, which then scatters from air molecules to produce radiation at some distance from the source.

C. Unattended installation

The RGD is installed in a single-purpose shielded enclosure, and the design shall ensure that individuals are not exposed to doses exceeding 100 mrem in a year.

D. Open installation

Open installations must be conspicuously posted, and have a conspicuously defined perimeter. The perimeter must delimit the area in which the exposure can exceed 5 mrem in any one hour. The operational staff shall provide constant surveillance. Other requirements include use of survey meters, personnel dosimetry, and temporary shielding.

Summarize lesson.

Review objectives.

Ask for questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Radiological Aspects of Accelerators

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Identify the general characteristics of accelerators.
2. Identify the types of particles accelerated.
3. Identify the two basic types of accelerators.
4. Identify uses for accelerators.
5. Define prompt radiation.
6. Identify prompt radiation sources.
7. Define radioactivation.
8. Explain how contaminated material differs from activated material with regard to radiological concerns.
9. Identify activation sources.
10. Identify engineered and administrative controls at accelerator facilities.
11. Identify the special radiological concern and recommended instrument for each type of accelerator radiation survey.

Training Aids:

Overhead Transparencies (OTs): OT 13.1 – OT 13.12 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

Stanford Linear Accelerator Center, *Health Physics Manual of Good Practices for Accelerator Facilities*, SLAC-327, 1988.

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, Amended June 2007.

DOE G 441.1-1B, Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection, Section 7.0 Radiation Generating Devices.

U.S. Department of Energy, DOE HDBK-1108-2002*, Radiological Safety Training for Accelerator Facilities*, Reaffirmed January 2007.

U.S. Department of Energy, DOE O420.2B, *Safety of Accelerator Facilities,* July 2004.

I. Introduction

10 CFR Part 835, *Occupational Radiation Protection*, includes provisions for exposure to ionizing radiation from DOE activities, which includes exposures from accelerator operations.

Show OT 13.1, OT 13.2, and OT 13.3.

State objectives.

II. *DOE* Guidance

DOE G 441.1-1B, Radiation Protection Programs for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection, Section 7.0 Radiation Generating Devices provides guidance on DOE's expectations for controlling exposure from accelerators.

Review DOE G441.1-1B,

Review DOE O 420.2B, Safety of Accelerator Facilities.

Article 364 of DOE-STD-1098-99, *Radiological Control*, Reaffirmation December 2004 provides similar guidance, and includes guidance to use the *Health Physics Manual of Good Practices for Accelerator Facilities*, SLAC-327, in meeting occupational radiation protection requirements for accelerators.

Review DOE-STD-1098-99, *Radiological Control* (Article 364).

Review *Health Physics Manual of Good Practices for Accelerator Facilities*, SLAC-327.

DOE HDBK-1108-2002, *Radiological Safety Training for Accelerator Facilities*, Reaffirmation January 2007 provides guidance on DOE's expectations for radiation safety training for individuals using accelerators.

Review DOE HDBK-1108-2002, Reaffirmation January 2007 *Radiological Safety Training for Accelerator Facilities.*

III. General characteristics of accelerators

Accelerators are devices that increase the speed and thus the energy of charged particles.

Obj. 1
Identify the general characteristics of accelerators.

A. Accelerator energy

Accelerators are normally rated by the maximum energy to which the particles are accelerated.

The energy imparted to the charged particles is determined by the potential difference measured in volts (V) in the electrical field. At all but the

smallest accelerators, the acceleration is accomplished by directing the charged particles repeatedly through regions containing radiofrequency electromagnetic fields.
One electron volt (eV) is the energy gained by an electron accelerated through an electric potential of 1 volt.

An electron accelerated across a gap by means of a 10,000 volt, or 10 kilovolt (kV), potential difference is said to have gained 10 kilo electron volts (10 keV) of energy after crossing the gap.

Other energy units commonly encountered at accelerators are: MeV (1 million, or 10^6 electron volts), GeV (1 billion, or 10^9 electron volts), and TeV (1 trillion, or 10^{12} electron volts). These units of energy are commonly used not only for electrons, but for all charged particles.

B. Types of particles accelerated

Show OT 13.4.

Obj. 2
Identify the types of particles accelerated.

Particles accelerated include:

- Electrons
- Protons
- Nuclei of various elements

C. Types of accelerators

Show OT 13.5.

Obj. 3
Identify the two basic types of accelerators.

The accelerated charged particle may move in either a linear (straight line) or in a circular (curved) path as the result of moving perpendicular to a magnetic field; these are the two basic types of accelerators.

1. Linear accelerators

   Straight-line accelerators suffer from the disadvantage that the finite length of flight path limits the particle energies that can be

achieved.

Linear accelerators include:

- Van de Graaffs
- Cockcrott-Waltons

2. Circular-path accelerators

   In circular-path accelerators, magnets guide the particle along a spiral path, allowing a single electric field to apply many cycles of acceleration.

   Circular-path accelerators include:

   - Cyclotrons
   - Betatrons
   - Synchrotrons

Until the 1980's, all accelerators used for both physics research and in practical applications, such as in medicine and in materials science operated in a so-called "fixed target" mode. In this mode the accelerated energetic particles are delivered to a target made of some material at rest in the laboratory.

Since that time, research facilities have been constructed in which counter-circulating accelerated beams of particles collide with each other, rather than with targets at rest in the laboratory. The use of accelerated particles in this "colliding beam" mode has been done to take advantage of the fact that the total energy of the colliding particles, including both their kinetic energies and the energy included in their masses at rest, becomes available in the collision process. This condition is not true for fixed target collisions.

Such colliders are not nearly as numerous as other types of accelerators, but represent important research facilities in which basic physics research is conducted.

D. Purpose and uses

Show OT 13.6.

Obj. 4
Identify uses for accelerators.

Accelerators were originally designed to study the structure of matter. Accelerators today are used not only for basic research purposes, but for many other applications as well. Examples include:

- Production of radioisotopes
- Generation of bremsstrahlung for radiography
- Induction of fusion
- Pumping for lasers
- Detoxification of hazardous waste
- Production of synchrotron radiation

E. Facility size/complexity

Small accelerators/facilities usually mean simpler controls, less staff to coordinate, smaller areas to monitor, and fewer points of access to control. However, small accelerators (lower energy) can produce very intense levels of radiation.

As the size and complexity of the installation increases, so does the importance of clear and concise communication channels and a detailed formality of operations.

IV. Radiological concerns

Show OT 13.7.

A. Prompt radiation

Obj. 5

Prompt radiation results from the accelerator beam or the interaction of the beam with matter only while the accelerator is operating. Prompt radiation components include:

Define prompt radiation.

1. Primary beam

   The primary beam consists of accelerated charged particles prior to any interactions that may decrease the beam's energy or intensity.

   It is the most intense form of radiation present at an accelerator facility and is made inaccessible to personnel through engineered and administrative controls.

Obj. 6
Identify prompt radiation sources.

2. Secondary beam

   The secondary beam is produced by interaction of the primary beam with matter such as targets or beamline components. The secondary beam may consist of:

   - Electromagnetic radiation
   - Neutrons
   - Charged particles

3. Skyshine

   Skyshine is the term used to describe radiation emerging more or less vertically from a shielded enclosure, which then scatters from air molecules to produce radiation at some distance from the source.

4. Electromagnetic radiation (photons)

   Prompt photons may include those produced by:

   - Bremsstrahlung: Photons emitted through the deceleration of charged particles in the beam

- Electromagnetic cascades: Multiple photons emitted through initial high-energy interactions

- Synchrotron radiation: Photons emitted as charged particles are accelerated in a curved path (a dramatically more significant effect for electrons than it is for protons having the same kinetic energy)

- Thermal neutron capture: Photons can be emitted as a result of nuclear reactions in which materials present in the accelerator enclosure absorb thermalized neutrons produced by the accelerated beams.

5. Neutrons

   Neutrons can be produced through nuclear interactions of the primary and secondary beams with matter. They can also be produced by interaction of high energy photons with matter (photonuclear reaction).

   Neutron radiation is a concern within any area where the beam can interact with physical objects.

6. Muons

   Muons are particles that are physically similar to electrons, but are about 200 times heavier.

   Energies in excess of 212 MeV are required to produce muons by means of pair production at electron accelerators. At proton and ion accelerators, muons cannot readily be produced at energies below about 140 MeV since charged pions or kaons, which decay into muons, must first be produced. Due to the short ranges of low energy muons in matter, they are not normally of concern for accelerators of less than 500 MeV kinetic energy.

Muons travel mainly in the direction of the beam that produced them, with very little deviation from the beam path. They are a concern directly downstream of targets and beam dumps.

B. Residual radioactivity (radioactivation)

Radioactivation is the process by which materials become radioactive. It is commonly referred to as "induced radioactivity" or simply "activation." Generally energies above 10 MeV are needed to activate materials.

Show OT 13.8.

Obj. 7
Define radioactivation.

Activated materials will continue to emit radiation after shutoff of the beam. The length of time depends on the half-life and quantity of the activated element.

1. Contaminated materials versus activated materials

   Contaminated materials are considered to be items with removable surface contamination. Activated materials are considered to be volume contamination, meaning the radioactive materials are dispersed throughout the items.

   Obj. 8
   Explain how contaminated material differs from activated material with regard to radiological concerns.

   Activated materials normally do not present a potential loose contamination hazard except during activities such as:

   - Grinding
   - Burning
   - Machining
   - Handling filters of coolant water

   Activated materials are normally controlled based on the residual external radiation dose rate.

2. Activated materials

   Materials that may become radioactive include:

   - Any material within the accelerator enclosure
   - Beamline components
   - Air
   - Liquids

   Accelerators used to produce radioisotopes present special problems because of the variety of target materials used, and because the parameters of machine and target are deliberately optimized to produce radioactive materials.

- Beamline components

  Items that intercept a portion of the beam are most likely to be activated. Among those items which have the highest probability for activation are:
  – Targets
  – Beam dumps or stops
  – Collimators and scrapers
  – Septa and other magnets
  – Cavities and beamline

- Air

  Air and other gases in the accelerator enclosure may be activated. Typically, the activation products are short-lived gaseous radionuclides of the elements in the air. Examples are Oxygen-15 from Oxygen-16.

Obj. 9
Identify activation sources.

The two major concerns of air activation products are:
– Worker (delays entry)
– Environmental (releases from enclosures)

- Liquids

  Tritium is frequently produced in water used to cool the target and/or experimental equipment. As this water supply is usually a closed system, the concentration of the tritium in the water will slowly increase.

  Other activated liquids may include:
  – Oil in vacuum pumps
  – Cryogenic fluids

C. Ancillary sources

Accelerators employ devices to either impart energy to particles, or redirect them during the acceleration process. The following devices may emit ionizing radiation while they are operating.

1. Klystrons

   Klystrons provide power to accelerate charged particles. They emit x-rays during operation.

2. Radiofrequency (RF) cavities

   These devices accelerate charged particles using electromagnetic fields. Trace gases within the RF cavity cause photons to be emitted by the accelerated particles.

3. Electrostatic separators/septa

   These devices split a particle beam into two beams using static electric fields. The high voltages associated with these devices cause electrons to accelerate in the vacuum within

the beamline. They emit x- or gamma rays.

V. Radiological and other controls

Controls are used at accelerator facilities to protect personnel from exposure to ionizing radiation and other hazards, which include:

- Electrical
- Mechanical
- Cryogenic
- Nonionizing radiation

The design of an effective safety program incorporates a combination of engineered and administrative controls.

A. Engineered controls

Show OT 13.9.

Engineered controls are the primary controls at an accelerator facility.

Show OT 13.10.

1. Active engineered controls

Obj. 10
Identify engineered and administrative controls at accelerator facilities.

Active engineered controls include devices that sense changing conditions and can trigger a safety action. Examples may include:

- Status lights
- Alarms
- Interlocks
- Scram buttons

2. Passive engineered controls

Once installed, passive engineered controls are used to prevent personnel entry or reduce

radiation dose and require no further action to perform their intended function. Passive engineered controls may include:

- Barriers
- Shielding

B. Administrative controls

Show OT 13.11.

Administrative controls require human interaction in order to be effective.

Key administrative controls include:

- Signs/postings
- Search and secure (sweep) procedures
- Controlled access procedures
- Configuration control procedures
- Radiological Work Permits (RWPs)

VI. Monitoring

Show OT 13.12.

Monitoring for radiation at accelerators can be complicated. Special techniques and instrumentation may be necessary due to the existence of:

- Mixed radiation fields (photons, protons, neutrons)
- Pulsed beams
- Very high-energy radiation
- High dose rates

A. Prompt radiation

Measurements of prompt radiation fields are required for occupational and environmental monitoring and for accident dosimetry and calibration of dosimeters, as well as for research purposes. In selecting measurement techniques and instruments, it is important to consider the purpose of the measurement and the radiation field's parameters.

Obj. 11
Identify the special radiological concern and recommended instrument for each type of accelerator radiation survey.

1. Mixed radiation fields

   The complexity of the radiation field and the radiation measurements increase with the energy of the accelerator.

2. Pulsed radiation

   Prompt pulsed radiation must be measured with specialized survey instruments. Ion chambers are typically used and are recommended.

3. Neutrons

   Neutron monitoring is complicated and must be conducted by highly trained individuals with specialized instruments.

B. Environmental monitoring

Environmental sampling/monitoring may include:

- Prompt radiation (neutrons, skyshine, muons)
- Sampling exhausted air from beam housings
- Surface/groundwater (on and off site)
- Monitoring of radiation levels at site boundary (from storage areas)

C. Personnel monitoring

Simple dosimeters, such as those used in personal dosimetry and simple survey instruments, should be calibrated when possible in radiation fields that are similar to those in which they will be used. To interpret measurements made with these instruments, one must know as much as possible about the radiation field that is being measured.

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Assessment Techniques

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Describe the difference between structured and unstructured assessments.
2. Describe the difference between vertical and horizontal reviews.
3. List the documents needed in order to perform a radiological assessment.
4. Define the term assessment.
5. Describe how to evaluate a contractor assessment program.
6. Describe the desired characteristics of performance goals.
7. List five performance indicators used in assessing Radiation Protection Program effectiveness.

Training Aids:

Overhead Transparencies (OTs): OT 14.1 – OT 14.13 (may be supplemented or Substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, 1999.

U.S. Department of Energy, 10 CFR Part 835, *Occupational Radiation Protection*, 1998.

U.S. Department of Energy, DOE G441.1-1, *Management and Administration of Radiation Protection Programs Guide,* 1999.

U.S. Department of Energy, Order 232.1A*, Occurrence Reporting and Processing of Operations Information*, 1997.

U.S. Department of Energy, DOE-EM-STD-5505-96*; DOE Limited Standard Operations Assessments,* 1996.

DOE-STD-1070-94; *DOE Standard Guidelines for Evaluation of Nuclear Facility Training Programs,* Reaffirmed 1999.

I. Introduction

Show OT 14.1 and OT 14.2.

State objectives.

Self assessment is part of an effective worker health and safety program. As such, there are many requirements related to conducting self assessments and maintaining quality assurance programs, such as those required under 10 CFR 830.120 ,or as part of an effective Integrated Safety Management program. This module focuses on the radiation protection required assessments and audits.

10 CFR Part 835, *Occupational Radiation Protection*, requires, in 10 CFR 835.102, that internal audits of the Radiation Protection Program be conducted at least every 36 months. The audits shall include all radiation protection functional elements.

Section 4.1.4 of DOE G441.1-1, *Management and Administration of Radiation Protection Programs Guide,* provides guidance on meeting the 10 CFR 835 requirement for audits. Section 4.2 of the Guide includes a listing of radiation protection functional elements and associated DOE guidance documents.

Review DOE G441.1-1, *Management and Administration of Radiation Protection Programs Guide*.

Article 134 of DOE-STD-1098-99, *Radiological Control*, provides additional guidance on radiological control assessments.

Review Article 134 of DOE-STD-1098-99, *Radiological Control.*

II. Types of assessments

It can be extremely damaging if we, as overseers, facility representatives, and assessors, violate the high standards of performance and rules that we are to assess. It is important to understand that we are constantly being monitored and that we must set the example with regard to radiological protection.

It is very important to understand that we are dealing with people and that we have some of the same human tendencies that they do.

Follow all health physics rules.

The methods used to gather or capture information can detract from the effectiveness of the assessment process.

Good interpersonal skills are essential.

Assessment techniques can be enhanced through training and practice. These techniques will improve the ability to see, observe, and better understand.

There are two types of assessments: unstructured and structured. "Unstructured" reviews means "not looking for one specific area or thing." "Minimum preparation" method is accomplished through going with workers on routines. These could be described as general assessments.

Show OT 14.3.

Obj. 1
Describe the difference between structured and unstructured assessments.

The more preparation put into the assessment, the more effective it is, no matter what type of assessment is conducted.

The second type of assessment is "structured," which involves looking specifically at one issue and reviewing it from every angle.

Two traditional methods within the structured inspection are the vertical and horizontal review.

Obj. 2
Describe the difference between vertical and horizontal reviews.

Vertical review is the assessment of a narrow subject area in great detail, for example, assessing the Radiological Control Organization from top to bottom.

Show OT 14.4.

Horizontal review is the assessment of a broad

range of related subjects in generally less detail, for example, assessment of radiological protection across all organizations at a nuclear facility.

III. Assessment guidance

A. Documents

Ask why the documents are needed.

Obj. 3
List the documents needed in order to perform a radiological assessment.

IMPORTANT: Put the burden of producing documents on the site. If the site personnel state that it is not appropriate that they comply, they must provide DOE with written support for that position.

Show OT 14.5.

The DOE and site basic documents an assessor should have for radiological compliance include (determine the extent of applicability and site commitments to adhere to the documents):

- 10 CFR Part 835
- Site Radiation Protection Program
- DOE-STD-1098-99, *Radiological Control*
- Other applicable federal regulations
- Applicable DOE orders

- State regulations
- DOE Implementation Guides
- Site DOE contract
- Site commitments (corrective actions, DNFSB recommendation responses)
- Site reports (deficiency, occurrence)
- Site-Specific RadCon Manual
- Approved exemptions
- Peer group/industry group standards/recommendations
  - DOE standards
  - ANSI standards
  - NRC Regulatory Guides

Show OT 14.6.

B. Compliance issues

1. Compliance is only the tip of the iceberg.
2. What are the issues?
   - What happened?
   - Why did it happen?
   - Will corrective action prevent recurrence?
   - How can we ensure it will not happen again?

What can you use to support the findings?

3. Determine the degree of consequence of noncompliance effects and ramifications of noncompliance.

4. Procedural compliance is only part of the overall commitment to excellence in radiological control.

   - Acknowledge good practices

     The DOE radiological control policy is that "continuing improvement is essential to excellence in radiological control."

   - Encourage what is good.

5. Need to distinguish between requirements ("shall" statements) and recommendations ("should" statements).

What is site management doing to encourage excellence in radiological protection?

Differentiate between requirements and good practices.

C. Compliance orders

Compliance orders are issued by the Secretary. They identify a situation that violates, potentially violates, or otherwise is inconsistent with the:

- Atomic Energy Act of 1954 as amended
- Nuclear statutes
- Nuclear Safety Requirements

Compliance orders mandate a remedy or other action, and state the reason for the remedy or other action.

Examine orders and responses to orders for:

- Timelines
- Accuracy
- Completeness (Was the problem solved?)

IV. Assessing radiological performance

Show OT 14.7.

A. Internal audits, inspections, reviews, investigations, and self-assessments comprise "assessments" and are part of the numerous checks and balances needed in an effective Radiation Protection Program.

Obj. 4
Define the term assessment.

Internal audits of the Radiation Protection Program shall be conducted such that over a three-year period, all functional elements are assessed for program performance, applicability, content, and implementation. These should be performed by individuals who are organizationally independent from the organization responsible for developing and implementing the Radiation Protection Program.

Reference 10 CFR 835.102.

B. DOE-EM-STD-5505-96*; DOE Limited Standard Operations Assessments,* contains very good methodology for performing assessments.

Show OT 14.8.

Obj. 5
Describe how to evaluate a contractor assessment.

There are three major components of an effective assessment program: management assessments, operational assessments, and quality assurance assessments. For each of these, functional areas are identified that represent specific areas of managerial or technical activity. Within each functional area, performance objectives are defined that represent essential characteristics or conditions of an effective safety program. The criteria associated with each performance objective are intended to serve as guidelines for the assessments.

Review DOE-EM-STD-5505-96*; DOE Limited Standard Operations Assessments.*

Provide an example of a fundamental area and associated performance objectives and criteria.

Both management and operational assessments are operationally focused and performance-oriented. They deal with the safety culture of the facility, how safely it is being operated, and the condition of its documentation and equipment. The design of the facility and its process systems is presumed, for purposes of the management and operational assessments, to permit safe operation. This is based on the presumption of an appropriate selection and application of design standards by the architect-engineer and the operating contractor, and of appropriate independent reviews by DOE or its predecessor agencies of the design, the construction activities, and the Safety Analysis Report.

The criteria listed do not address every activity that might be relevant to a performance objective. Therefore, meeting all criteria does not necessarily ensure that the performance objective is fully met. Conversely, a specific facility might achieve the performance objective without meeting all criteria.

In part, because of the various ways in which the performance objectives can be met, effective assessments emphasize the performance objectives rather than the criteria. The methods for determining whether a criterion is met are not given. Consequently, considerable expertise and judgment are required to be exercised in conducting the assessments.

Although the quality assurance assessments have a broad perspective, covering the overall quality assurance program of the facility, they are relevant to assessing radiological protection performance.

DOE-STD-1070-94; *DOE Standard Guidelines for Evaluation of Nuclear Facility Training Programs,* provides guidance on evaluating training programs at nuclear facilities.

Review DOE-STD-1070-94; *DOE Standard Guidelines for Evaluation of Nuclear Facility Training Programs.*

C. Radiation Protection Program deficiencies

Show OT 14.9.

Managers should encourage the positive view that identifying even minor deficiencies represents an opportunity for further improvement.

Radiological work practices should be continually scrutinized and questioned so that opportunities for improvement can be identified, assessed, and incorporated into the Radiation Protection Program.

The type of deficiency must also be considered. For example, sites with a more aggressive program to identify deficiencies would tend to have more.

The number of deficiencies, alone, does not measure the overall quality of the Radiation Protection Program.

D. Critiques

Show OT 14.10.

One assessment method is the critique. An honest review and establishment of facts, which are in chronological order, is necessary to arrive at the truth.

This is a formal process established to obtain pertinent facts following an unusual radiological situation or at the satisfactory conclusion of a new or unusual operation involving radiological controls.

The process should be used to quickly establish facts in chronological order so that the underlying reasons or causes for the success or failure are well understood. Work force participation should be encouraged. Critiques are a management tool and should not be used to "fix blame" or "shoot the messenger." This process complements the *Occurrence Reporting and Processing* of DOE Order 232.1A.

In developing corrective action plans, managers should address basic underlying reasons for the identified deficiencies or concerns, not just the specific symptoms identified by the reviewer.

E. Radiation Protection Assessment Program

To accurately assess the performance of the Radiation Protection Program, an assessment program should be formalized, created, and implemented.

Elements of a Radiation Protection Assessment Program

Hold open discussion on elements of a Radiation Protection monitoring and assessment program. List responses on the flip chart.

Encourage participants to write responses in their Student's Guide. Responses should include:

- Problem areas
- Reportable occurrences
- Critiques
- Performance indicators
- Goals

Stress why these responses are important to the effectiveness of the program.

F. Radiation Protection Program Performance

The contractor senior site executive should establish, approve, and maintain a radiological performance goals program. The performance goals should be measurable, achievable, auditable, challenging, and meaningful in promoting improvement. Chapter1, part 3 of DOE-STD-1098-99, *Radiological Control*, provides guidance on appropriate radiological goals.

Show OT 14.11.

Obj. 6
Describe the desired characteristics of performance goals.

Goals need to be developed primarily by those responsible for performing the work. Forming a Radiological Awareness Committee that includes the active participation of the work force is encouraged.

Show OT 14.12.

Review chapter 1, part 3 of DOE-STD-1098-99, *Radiological Control.*

Radiological performance goals should be reviewed at least annually and revised as appropriate. Normally, more stringent goals should be set annually to reflect the improved radiological performance at the facility. Occasionally, the goals may be made less stringent to accommodate changes in work load or mission.

G. Performance indicators

Obj. 7
List five performance indicators used in assessing Radiation Protection Program effectiveness.

To evaluate performance, one needs to be able to measure change. This means dimensions must be identified. One must be able to track, trend, post, paint, count, look at, and assign numbers. What gets measured, gets done.

Show OT 14.13.

Ask participants for performance indicators. Hold open discussion. List responses on the flip chart. Encourage participants to write responses in their Student's Guide.

Refer to Table 1-1 of DOE-STD-1098-99, *Radiological Control.*

Responses should include:

1. Exposure control
   - Collective dose
   - Average worker dose
   - Maximum dose to worker
   - Number of unplanned doses greater than the administrative control level
   - Number of dose assessments for lost or damaged dosimeters
   - Maximum neutron dose to a worker
2. Personnel contamination
   - Number of skin and personal clothing contaminations
   - Number of contaminated wounds
   - Number of facial contaminations
3. Control of internal exposure
   - Number of positive bioassays
   - Number of airborne events
   - Number of alarms on airborne monitors (actual and false)
   - Number of Airborne Radioactivity Areas
   - Area of Airborne Radioactivity Areas in square feet

4. Control of Contamination Areas
   - Number of Contamination and High Contamination Areas
   - Area of Contamination Areas in square feet
   - Area of High Contamination Areas in square feet
   - Number of spills
5. Minimization of radioactive waste
   - Volume and activity of radioactive waste in cubic feet and curies, respectively
   - Cubic feet of waste not subject to volume reduction by incineration, compaction, or other means
6. Control of radioactive discharges
   - Volume and activity of radioactive discharges in cubic feet and curies, respectively
   - Number of unplanned or accidental releases

Summarize lesson.

Review objectives.

Ask for questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Planning and Conducting Assessments

Objectives:

Upon completion of this lesson, the participant will be able to:

1. List 10 of the 19 elements of a Radiation Protection Program.
2. Identify five deficiencies in a Radiation Protection Program that point to the need for an assessment.
3. Describe the preparations needed to conduct a Radiation Protection Program assessment.
4. Describe how to conduct a Radiation Protection Program assessment.
5. Describe two qualifying conditions for a follow-up assessment.
6. Describe what actions should be taken when assessments indicate marginal radiological control performance.

Training Aids:

Overhead Transparencies (OTs): OT 15.1 – OT 15.24 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE G441.1-1B, *Management and Administration of Radiation Protection Programs Guide,* 2007.

I. Introduction

Show OT 15.1 and OT 15.2.

State objectives.

II. Assessments

A. Reasons for conducting assessments include the following:

Ask for reasons for conducting an assessment. List responses on flip chart.

Ensure that responses include four reasons listed in lesson plan.

- Determine regulatory compliance.
- Formally document Radiation Protection Program strengths and weaknesses.
- Investigate a specific incident.
- Document conditions that need a follow-up assessment.

B. Basic elements of a Radiation Protection Program

Show OT 15.3.

Obj. 1
List 10 of the 19 elements of a Radiation Protection Program.

- Organization and administration
- Personnel training and qualification
- Quality assurance
- ALARA
- Radiological work control
  - Procedures
  - RWPs
- Posting and labeling
- Radioactive material control
  - Source control
  - Release of materials
  - Receipt and transportation

Explain the essential functions of each element in contributing to an effective program.

- Radiation-generating devices
  - Sealed source
  - X-ray machines
- Entry control
- Contamination control
- Instrumentation and alarms
- Monitoring
  - Workplace
  - Effluent
  - Environmental
- Dosimetry
  - External
  - Internal (bioassay)
- Respiratory protection
- Facility-specific features
  - Uranium
  - Plutonium
  - Tritium
  - Accelerators
- Radioactive waste management
- Emergency response
- Records
- Assessments/performance indicators

Show OT 15.4.

Show OT 15.5.

C. Indications that an assessment is needed

Show OT 15.6.

- Exceeding administrative dose control levels or regulatory limits
- Loss of control of radioactive material

Obj. 2
Identify five deficiencies in a Radiation Protection Program that point to the need for an assessment.

- Unmonitored/excessive release of radioactive material to the environment
- Excessive numbers of skin contamination incidents
- Uptakes of radioactive material by employees
- Excessive numbers of radiological incidents
- Inadequate training

Show OT 15.7.

- Ineffective work control systems
- Incomplete or inaccurate radiological surveys
- Incomplete or inaccurate records

III. Preparing for the assessment

Show OT 15.8.

To adequately prepare for the assessment:

Obj. 3
Describe the preparations needed to conduct a Radiation Protection Program assessment.

- Review operating history
- Examine previous assessment reports
- Collect input from person(s) assessed
- Determine applicability of industry issues
- Review policies and procedures
- Assemble regulations and guidance documents
- Prepare an assessment plan

A. Operating history

Show OT 15.9.

Review the operating history. The following documents can be extremely helpful in preparing for the assessment:

- Occurrence reports
- Radiological deficiency reports
- Violations/citations
- Facility design changes

B. Previous assessments

Show OT 15.10.

Examine previous assessment reports. Documents that could be helpful are:

- DNFSB Recommendations
- Self-assessments
- Corporate quality assurance reports
- External audits

C. Input from person(s) to be assessed

Show OT 15.11.

- Management
- Radiological Control Manager
- Radiological Control Organization's "customers"

D. Industry issues

Show OT 15.12.

- Emerging technical issues
- Application of best industry standards to site program

E. Policies and procedures

- Operating procedures
- Radiological control policies

Show OT 15.13.

F. Regulations and guidance documents

- Federal
- State
- Site
- Industry or peer group

Show OT 15.14.

G. Assessment plan

- Identify elements to be assessed.
- Generate specific questions and/or standards against which to measure performance.
- Develop record sheet for assessment responses, data, and field notes.
- Allocate time for each assessment activity.
- Intentionally leave unscheduled time.

Show OT 15.15.

Have a backup plan for slack time. Preparation time should equal or exceed time spent conducting the assessment.

IV. Conducting the assessment

A. General guidance

Remember the assessment is a positive activity, designed to help those being appraised. Follow the plan, but be flexible.

Include nothing in the assessment findings that is not based on fact, requirement, or commitment. If in doubt, leave it out (but raise it, informally as a matter deserving a closer look).

Obj. 4
Describe how to conduct a Radiation Protection Program assessment.

Share the findings with the point(s) of contact each day. There should be no surprises at the daily Radiological Control Manager debriefing or at the final debriefing.

B. Announced versus unannounced assessments

Show OT 15.16.

1. Announced assessments are scheduled through a pre-assessment memorandum. The following information should be addressed:

   - Assessment objectives
   - Assessor(s)
   - Assessment duration
   - Request for a site point of contact
   - Any special needs
   - Recommended time and place for pre- and post-assessment conferences

2. Unannounced assessments

   - Used to determine "real" program performance
   - Back-shift, off-hours tours may reveal relaxation in program standards
   - Vary the assessment schedule

   Note: Contact the Radiological Control Manager and line management immediately if there is a serious problem.

3. Available methods for conducting an assessment include:

   - Document reviews
   - Personnel interviews
   - Field observations

Show OT 15.17.

4. Recommended assessment approach (in order)

   - Review upper-tier procedures describing the Radiation Protection Program.
   - Conduct a short (one hour or less) tour of the site/facility.
   - Interview Radiological Control Organization staff and "customers."
   - Conduct detailed and follow-up tours, interviews, and document reviews.

Show OT 15.18.

5. Perform document reviews of:

   - Operating procedures
   - Records for:
     - Dosimetry
     - Work control Radiological Work Permit
     - Surveys (contamination, radiation level, air, special)
     - Occurrence, deficiency reports, and critiques
     - Regulatory reports
     - Radioactive effluent reports
     - Training and qualification
     - Instrument calibration and response testing
   - Special studies

6. Site/facility tour

    - Tour the site/facility, preferably with an experienced individual from the site.

    - Make notes of housekeeping and facility condition. Items to look for include:
        – Leaks, spills
        – Dirt, rust, and clutter
        – Poor equipment maintenance
        – Radiological control posting
        – Radiological Control Technician and Radiological Worker interface
        – Employee morale

7. Conduct interviews with the following:

    Show OT 15.19.

    - Radiological Control Manager

    - Radiological Control Supervisor(s)

    - Radiological Control Technical Leads

    - Qualified Radiological Control Technicians

    Show OT 15.20.

    - Radiological Control Organization's "Customers"

    - DOE Site Representatives

    - Facility Manager

    The following are the details:

    Attempt to determine the information for each of the positions interviewed.

    - Radiological Control Manager
        – Knowledge of current radiological control regulations, industry standards
        – Identification of program deficiencies and priorities
        – Obstacles to improving program performance

- Radiological Control Supervisor(s)
  - Level of support given Radiation Protection Program and Radiological Control Manager
  - Identification of program deficiencies and priorities
  - Obstacles to improving program performance

  Note: Compare responses to those from Radiological Control Manager.

- Radiological Control staff members responsible for major technical functional areas.

  Examples of these functional areas include:
  - Organization and administration
  - Personnel training and qualification
  - Quality assurance
  - ALARA
  - Radiological work control
    + Procedures
    + RWPs
  - Posting and labeling
  - Radioactive material control
    + Source control
    + Release of materials
    + Receipt and transportation
  - Radiation-generating devices
    + Sealed source
    + X-ray machines
  - Entry control
  - Contamination control
  - Instrumentation alarms
  - Monitoring
    + Workplace
    + Effluent
    + Environmental
  - Dosimetry
    + External
    + Internal (bioassay)
  - Respiratory protection

  - Facility-specific features
    + Uranium
    + Plutonium
    + Tritium
    + Accelerators
  - Radioactive waste management
  - Emergency response
  - Records
  - Assessments/performance indicators

  Document their responses to incidents in their technical area.

  Discuss impediments to improving their programs.

- Qualified Radiological Control Technicians
  - The depth and breadth of knowledge of radiation protection
  - Technical issues unique to the site/facility
  - Effectiveness of the working relationship between Radiological Control Technicians and their "customers"

- Radiation Protection Program "customers"
  - Knowledge of fundamental radiation protection concepts and good Radiological Worker practices
  - Working relationship with the Radiological Control Technicians
  - Obvious or hidden problems
  - Poor communications
  - Division of work problems
  - Overall, how the Radiological Control Organization is regarded ("policeman" vs. team member)

- DOE Representatives
  - If the Radiological Control Organization staff solicits his/her input on technical decisions affecting Radiation Protection Program performance
  - If the relationship is one of mutual respect or adversarial in nature

- Facility Manager
  - Whether the Facility Manager has made a written commitment and is striving to achieve excellence in the Radiation Protection Program
  - His/her perspective on how the Radiation Protection Program should be improved, and the necessary priorities

8. Observe Radiological Workers/Radiological Control Technicians in the workplace

   - Recommendations for observing work include:
     - Dress as the individuals being observed are dressed.
     - Work the same hours they work.
     - Stand away from the immediate work area, but close enough to watch the work proceed.
     - Resist the urge to get involved in the work.
     - Be professional and courteous, but not familiar.

- Key areas to watch for include:
  - Procedure violations
  - Failure to follow RWP requirements for:
    - Dosimetry
    - Protective clothing
    - Respiratory protection
    - Radiological Control Technician coverage
    - Surveys
    - Special instructions
  - Poor Radiological Worker practices:
    - Reaching across radiological boundaries
    - Scratching body with gloved hand
    - Inadequate frisking
    - Loitering in a high radiation field
  - Lack of organization or formality in the work process
  - Poor housekeeping, disorderly work area
  - Wasted time and effort due to ineffective work planning
  - Communication problems
  - Poor relationships between Radiological Workers and Radiological Control Technicians

C. Post-assessment actions

Show OT 15.21.

At the post-assessment conference, summarize the findings identified during the assessment. This is an opportunity for additional questions about the findings. Any requests for corrective actions, dates, or a need for follow-up assessments can be identified at this time. Thank everyone for cooperation and support during the assessment.

1. Publish assessment findings.

2. Receive site responses, which should include the following:
   - Action items
   - Responsible individuals/groups
   - Action item due dates
3. Accept/reject/modify responses.
4. Develop corrective action tracking list.
5. Publish a periodic action item status report.
6. Maintain a separate file of open action items.

Show OT 15.22.

7. Personally verify the closure of action items.
8. Evaluate the adequacy of actions taken to close open findings:
   - Has root cause been correctly identified and corrected?
   - Are follow-up assessments needed?

D. Follow-up assessments

Show OT 15.23.

1. Qualifying conditions

Obj. 5
Describe two qualifying conditions for a follow-up assessment.

   - Widespread problem
     – Problem occurs at several locations in the same facility or several facilities at the same site.
     – Problem identified by the assessment is only part of a larger, more generic deficiency.
   - Recurring problem: earlier efforts to resolve the problem have been ineffective.

2. Actions

   - Widespread problem
     – Take a longer sample to confirm/refute a widespread problem
     – Look for related problems in the same work unit.

   - Recurring problem
     – Scrutinize root cause analysis.
     – Try a different approach to solving the problem.
     – Solicit outside help. Perhaps others have "lessons learned".

3. Incorporate follow-up assessment information into corrective action tracking system.

V. Marginal radiological performance

When radiological control performance is less than adequate, strengthen line management's commitment to radiological control by notifying the Radiological Control Organization to obtain their support in improving radiological support.

In cases where the work force does not have the required level of sensitivity for radiological work practices, additional management attention is needed to assure the proper outcome. Line management should be held accountable for implementation of the Radiation Protection Program.

Show OT 15.24.

Obj. 5
Describe what actions should be taken when assessments indicate marginal radiological control performance.

Initial actions should include:

- More direct line supervision in the work space
- Curtailment of work schedules
- Addition of extra radiological control personnel
- Conduct of additional training

Take action, then reevaluate conditions. If necessary, repeat and/or revise actions until deficiency is resolved.

Summarize lesson.

Review objectives.

Ask for questions.

DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Case Studies

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Describe causes of radiological incidents.
2. Identify primary cause and contributing causes of radiological incidents.
3. Describe effective corrective actions.

Training Aids:

Overhead Transparencies (OTs): OT 16.1 – OT 16.7 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

References:

Investigation Report KY/E-112*, C-337-A Contamination Incident at the Paducah Gaseous Diffusion Plant,* 1991.

Martin Marietta Energy Systems, *Occurrence Report,* ORO–MMES-PGDPOPERD-1991-1045, 1991.

I. Introduction

II. Case studies guidance

Point to remember: If each root cause is not adequately treated/corrected by a corrective action, recurrence of the event or some variation of it is likely.

Review a reconstruction of events from the available data.

A proper investigation report or occurrence report reconstructs the events as they occurred.

Show OT 16.1.

State objectives.

The radiological incident about which the case study is developed concerned a loss of control of radioactive contamination at the Paducah Gaseous Diffusion Plant in August of 1991. This event was worsened by the fact that some contamination was carried offsite to employees' homes and personal possessions.

As a group, discuss the known facts and whether there is enough information to reconstruct the event.

Determine whether the "performance of the workers" or the "systems in place" led to the event. This discussion will lead to how the systems support the workers and the workers support the systems.

III. Description of occurrence (edited from investigation report)

A. Incident

The layout of the buildings and equipment at this site are included.

Two employees at the Paducah Gaseous Diffusion Plant (PGDP) received skin and clothing contamination from Thorium-234 (^{234}Th) and Protactinium 234m (^{234m}Pa) while disconnecting a used uranium hexafluoride (UF_6) cylinder at the C-337-A building, UF_6 Feed Vaporization Facility, on August 23, 1991.

B. Scenario of events

Starting at shift change, 12 employees, one of them a Health Physics Technician, found contamination on shoes and clothing. The incident was initially identified during routine monitoring of the C-337-A facility by a Health Physics Technician at 0900 (two hours after the shift change). Efforts were initiated by Health Physics to survey the area, identify the source, and control the spread of contamination. Surveys indicated widespread contamination in both radiological and nonradiological areas of C-337 (adjacent to C-337-A) and C-337-A.

At some unspecified time, a critique was conducted by the Assistant Shift Superintendent and all personnel involved in the accident were interviewed.

All personnel who had been in the facility on the day shift were contacted and surveyed. One individual was found to have contaminated shoes and skin contamination on the elbow and was taken to a change house in C-337 for decontamination. Later this employee's personal clothing was also found to be contaminated, and through further investigation it was learned that this contamination occurred in the change house.

A thorough survey was conducted in the change

Discuss underlying reference materials to support a program of radiological questions which would preclude occurrence of such an event.

Obj. 1
Describe causes of radiological incidents.

Obj. 2
Identify primary cause and contributing causes of radiological incidents.

Obj. 3
Describe effective corrective actions.

Show OT 16.2.

house, and it was discovered that, in addition to a few articles in the change house itself, two locks and lockers used by Employee No. 1 (who performed the pigtail changes on the previous shift) were contaminated. This employee returned to work at 1830 on August 23, 1991. Surveys of the locker contents indicated contamination on company-issued clothing worn the previous shift. The employee was also found to have skin contamination of 6500 dpm/100 cm^2 on the arm, 4500 dpm/100 cm^2 on the knee, and 2750 dpm/100 cm^2 on each ankle.

A survey of the employee's coworker's (Employee No. 2) locker revealed contaminated items (both company-issued and personal). Personal surveys conducted when Employee No. 2 returned to work showed the presence of skin contamination of 4500 dpm/100 cm^2 on hair, 5000 dpm/100 cm^2 on neck, and 40,000 and 15,000 dpm/100 cm^2 on wrists. Later (2130 hours on August 23 for Employee No. 2, and 1900 hours on August 24 for Employee No. 1) surveys were conducted at the employees' homes. Monitoring of one employee's home found one T-shirt and one pillowcase slightly contaminated. A pair of shoes at the other employee's home was found slightly contaminated. This employee's (No. 2) coveralls had already been sent to the laundry, since it was not recognized they were contaminated. After laundering, significant contamination was still present (up to levels of 250,000 dpm/100 cm^2 at ankles, and lower levels at other places). A survey of the laundry equipment did not indicate any contamination.

Show OT 16.3.

Show OT 16.4.

Show OT 16.5.

Based on statements from the involved employees, they utilized the required personal protective clothing and equipment for the job at the time. The autoclave area is designated as a Contamination Zone. Anti-contamination clothing designated for cylinder changes at the time of the incident consisted of company-issued coveralls (blues), gloves, and shoe scuffs. Operational procedures require the use of a respirator when disconnecting pigtails. Surveys conducted as part of this

Some area designations have changed since 1991 (e.g., Contamination Zone).

"Anti-contamination clothing" is another term for "protective clothing."

investigation did not show any contamination on the employees' respirators or respirator cartridges.

The actual incident began between the hours of 0130 and 0415 on August 23, 1991, at the PGDP C-337-A Feed Vaporization Facility.

Show OT 16.6.

The operators routinely assigned to C-337-A for the period of 1900 hours on August 22, 1991, through 0700 hours on August 23, 1991, were not available due to the illness of one and an alternate work assignment of the other at another facility (C-360). Two operators who are not routinely assigned to the area were then assigned to cover C-337-A. One operator (No. 2) was qualified for operation of the facility while the other (No. 1) was in training for qualification. (This is in compliance with facility Operational Safety Requirements.) Supervisor interaction was minimal, with only one brief visit around the middle of the shift.

The operations in process at the time of the incident were the routine disconnection and removal of emptied UF_6 feed cylinders and subsequent replacement with full cylinders. This operation consists of disconnecting a short length of connecting pipe between the cylinder and the system piping that leads to the diffusion process equipment. This pipe is called a pigtail; it has threaded connections and gaskets on each end. Since pigtails are routinely reused, each cylinder change requires replacement of gaskets on pigtails to minimize the possibility of UF_6 releases during heating and feeding of the UF_6 into the diffusion process. At times these gaskets can be difficult to remove from the pigtail. A special tool is available to assist in the removal of these gaskets; however, difficulty can still be encountered. The pigtails used that night had been used for several feeding cycles, as is normally the case. The exact number of cycles could not be determined.

Show OT 16.7.

There are levels of ^{234}Th and ^{234m}Pa that occur naturally from the decay of ^{238}U present in the cylinder pigtail, pigtail gaskets, and cylinder valves. Approximately one curie each of those two radioisotopes builds up in a cylinder within a few months. These materials are less volatile than UF_6, so they remain as solids at the autoclave temperature, but some small amounts are entrained in the UF leaving the cylinder and small quantities are deposited in the cylinder valve and pigtail as the UF passes through it. These materials are present as removable surface contamination in these components, as well as being present in quantity in the cylinder heels (the material remaining in the cylinder after feeding). No containment of the ends of the pigtail during the gasket removal process was required by procedure. Additionally, the facility-specific training program does not address the specific contamination hazard the cylinder/pigtail change represents.

The operators changed four cylinders on the shift. The cylinder number, autoclave used, and approximate time of change (from logs and recorder data) are shown below:

Refer participants to the last page of this module.

Cylinder Number	Autoclave Number	Approximate Time
K-438	3 West	0130 08/23/91
K-505	5 West	0320 08/23/91
K-472	1 West	0500 08/23/91*
AC-1090	4 West	0500 08/23/91

*Time is very approximate. Operator statements place the change late in shift.

There was a portable fan temporarily positioned to cool employees just north of the 5 West autoclave control panel, inside the Contamination Zone. The fan had only been in place a few weeks. It was operating during the shift in question. Apparently no one had questioned the use of this fan in the area prior to the event. Circumstantial evidence places one operator exiting from either the 4 West or 5 West autoclave in the path of this fan while trying to remove a pigtail gasket. The area of highest surface contamination was spread along a line from the fan (located by 5 West autoclave), past the 4 West autoclave to the 3 West autoclave control panel in the direction that the fan blows.

Show OT 16.6.

Self-monitoring performed by the employees upon exiting the Contamination Zone where the job was performed was inadequate, in that the employees did not recognize the contamination present on their skin and/or clothing. The employees performed their other duties during the remainder of the shift, thereby spreading this contamination to both radiological and nonradiological areas. This spread of contamination to nonradiological areas through failure to recognize personal contamination at exit monitoring stations caused other personnel to become contaminated when the shift change at 0700 on August 23, 1991, brought new personnel into these areas.

Based on the interview with Employee No. 1, the employee traveled to C-337 around 0400 for a break. Upon exiting the vaporizer Contamination Zone and going to the C-337-A Operation's Monitoring Room, the Bicron frisker was indicating high but not alarming due to high ambient background radiation levels. The employee reset the monitor and remonitored. The employee indicated that the reading was elevated, but was not alarmed this time. The employee stated this was normal since the background in that area is often high.

At approximately 0600 on August 23, 1991, both operators left C-337-A bound for the C-337 change houses and the C-337 Area Control Room for shift turnover. Both operators stated they used Bicron friskers to check for contamination prior to entering the nonradiological (green) pathway in C-337. Training previously received by each operator for each type of frisking equipment was documented. Employee No. 1 noted that the Berthold hand-and-foot monitor previously used was "not operating properly," so the employee used the Bicron frisker. Neither operator noted any contamination. Employee No. 2 monitored hands and feet only, based on subsequent interviews, which indicated that the employee did not know that a whole-body frisk was required when exiting a radiological area. Based on statements from both employees, they showered, changed into personal clothing, completed the shift turnover activities, and exited the building after monitoring hands and feet at the building exit, as required.

Show OT 16.2.

Since some personnel exit monitoring data is regularly recorded, this data was reviewed. The operators passed between the C-337-A Operation's Monitoring Room and the C-337 Area Control Room several times during the shift and should have performed a whole-body frisk for contamination each time. Data for Employee No. 2 was not available, as the employee used a Bicron frisker. (These instruments do not have the added feature of storing monitoring data for later review.) Data for employee No. 1 shows 0414 hours on August 23, 1991, as the first time a monitor station evaluated this operator as contaminated. This station would normally be used when passing from C-337-A to the C-337 nonradiological walkway when going to the maintenance shops and change houses (restrooms, lockers, and showers).

This same employee was also known to be contaminated at the C-337 building exit on two separate monitors (twice on one, once on the other) when leaving after the shift change approximately 0700 on August 23, 1991. The employee stated that the first monitor alarmed, but that the second monitor did not indicate the contamination.

No monitoring data was found for the second employee, since he did not utilize equipment capable of storing this information.

Personal egress monitoring data from the facility was also reviewed, and individuals from prior shifts were contacted and monitored. An operator who was in the C-337-A area extensively from 0700 to 1830 hours on August 22, 1991, had a new pair of company-issued shoes, which were found to be free of contamination. This operator had left the C-337-A facility at 1830 hours on August 22, 1991. Additionally, routine surveys on August 19, 1991, did not indicate a similar contamination problem. Since no significant contamination problems were identified prior to 1900 hours on August 22, 1991, the investigation focused on the activities from 1900 hours on August 22, 1991, to 0700 hours on August 23, 1991.

Urinalysis, as well as *in vivo* internal dosimetry assessments, was performed on these employees and did not indicate any evidence of internal contamination. Personnel whole-body external radiation dosimeters worn by both employees, although externally contaminated, did not indicate that abnormal doses to ionizing radiation were received.

Skin dose calculations showed less than 0.10 rem for Employee No. 2 and 1.50 rem for Employee No. 1, compared to an annual limit of 50 rem.

It was noted that in the occurrence report of Reference 2, there had been 26 similar occurrence reports (in 1991) at the facility.

IV. Compensatory measures

Following the detection of contamination, several actions were taken by facility management in order to determine the source and type of contamination, the personnel and areas which may have been contaminated, and actions which could be taken to minimize additional spread of contamination. The following list of significant actions were accomplished after the event:

1. A critique of the incident was conducted, interviewing all individuals involved.

2. All nonradiological areas were decontaminated, and contamination levels within the radiological areas were reduced.

3. Personal protective equipment requirements in C-337-A were upgraded to require full anti-contamination protective clothing within the Contamination Area.

4. A full-time Health Physics Technician was stationed at C-337-A and required to monitor all personnel and equipment leaving the radiological area.

5. The two operators involved in the incident were sent to the Fernald, Ohio (DOE), facility for *in vivo* (whole-body) monitoring.

6. The fan was removed from the facility.

7. *In vitro* urine bioassay samples were obtained from the individuals involved in the incident, as well as other individuals who were either contaminated on previous shifts or involved in surveying and decontaminating the area.

8. Dosimeters were collected and monitored to assist in determination of radiation dose.

9. A walkdown of all plant boundary control stations was performed by senior management to determine location of substandard boundary control stations.

10. Efforts were initiated to determine other possible sources of Th^{234} and Pa^{234m} at other plant locations.

11. Actions were initiated to reduce the potential for the spread of contamination from the UF_6 cylinder pigtails during disconnection, gasket replacement, and reconnection activities.

12. Surveillance was established by line management of exit monitoring stations.

13. An investigation for an organizational finding was initiated.

14. A news release was issued.

15. A plant announcement was made and a plant bulletin was issued to emphasize the seriousness of the situation and the need for proper monitoring.

16. Complete locker room surveys were performed by Health Physics Technicians.

17. Meetings with union membership were conducted by union leadership to emphasize the importance of monitoring.

18. A letter, jointly signed by PGDP management and union leadership, was issued to all PGDP employees.

19. A DOE visit from Headquarters (HQ) Health and Safety personnel was conducted. They concluded that the breadth and scope of the organization finding investigation was appropriate.

20. The Portsmouth Gaseous Diffusion Plant was notified of the incident for possible application at its site.

21. Operators involved in the incident were not allowed to work in radiological areas until Radiation Worker retraining had been completed.

22. All fact sheets were put into "operator-required reading" files.

23. Development of a training film to review monitoring requirements and techniques was initiated. Upon completion, review of this film will be mandatory for all employees.

Summarize lesson.

Review objectives.

Ask for questions.

Analysis - Contamination Levels on Gaskets and Pigtails

Sample Number	Nuclide Analyzed	Concentration (dpm)
C-337-A Gaskets (2 gaskets combined for one sample)	^{234}Th and ^{234m}Pa	11,000,000 Beta*
	U activity	156,000 Alpha
C-310 Burp Station Gasket (1 gasket)	^{234}Th and ^{234m}Pa	163,000 Beta
	U activity	140,000 Alpha
C-310 Product Withdrawal Gasket (1 gasket)	^{234}Th and ^{234m}Pa	40,000 Beta
	U activity	1,900 Alpha
C-315 Tails Withdrawal Gasket (2 gaskets)	^{234}Th and ^{234m}Pa	117,000 Beta
	U activity	20,600 Alpha
C-360 Sampling and Transfer Facility Gasket (3 gaskets)	^{234}Th and ^{234m}Pa	1,500,000 Beta
	U activity	78,000 Alpha
SP-8757, Pigtails coupling, feed header end of pigtail	^{234}Th and ^{234m}Pa	see Note 1 Beta*
	U activity	see Note 1 Alpha
SP-8758, Pigtail coupling, cylinder end of pigtail	^{234}Th and ^{234m}Pa	see Note 1 Beta
	U activity	see Note 1 Alpha
SP-8759, Material knocked loose from SP-8757	^{234}Th and ^{234m}Pa	2,300,000 Beta
	U activity	27,000 Alpha
SP-8760, Material knocked loose from SP-8758	^{234}Th and ^{234m}Pa	2,300,000 Beta
	U activity	75,000 Alpha

*Each radionuclide contributes 50 percent to this total activity.

Note 1: Beta/gamma levels were too high to be accurately counted on the spectrometer due to detector dead time (saturation).

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Review and Critique of Findings and Improved Writing of Findings

Objectives:

Upon completion of this lesson, the participant will be able to:

1. List the three finding categories and describe how to separate surface issues from underlying substantial issues.
2. List three of the five priority groupings for assessment findings.
3. Identify the three steps needed to write an appropriate finding.
4. List three suggestions for effective presentation of findings and concerns.

Training Aids:

Overhead Transparencies (OTs): OT 17.1 – OT 17.4 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

I. Introduction

Show OT 17.1.

State objectives.

Obj. 1
List the three finding categories and describe how to separate surface issues from underlying substantial issues.

II. Writing assessment findings

A. Organization of findings

There may be considered to be three categories of assessment findings in order of increasing severity:

Show OT 17.2.

- Surface findings (Type I) are usually indicators of underlying issues that may be more significant. Note that a common problem is treating or correcting only the surface issue while ignoring the underlying problem—this results in problem recurrence.

Example - One Radiological Worker is seen leaving Contamination Area without frisking properly.

- Substantial findings (Type II) are typically issues that are underlying and more significant. Note that correcting the underlying problem results in solving the problem.

Example - Lack of monitoring training or adequate monitoring instrumentation.

- Organizational findings (Type III) deal with programmatic or global issues. Note that correcting these is very difficult if they involve system, organizational, or institutional problems.

Example - Culture is such that frisking is not routinely performed, nor protective clothing worn.

Now, remembering that there are three levels of findings, we must analyze the long list of findings compiled during the field exercise and establish what is really important in the "big picture."

First, group like, related, or similar findings into a broader issue.

Then, review the overall list of groupings for priority. The bases are:

1. Imminent danger
    - Life Safety Code
    - Personnel Safety
    - Facility Safety
    - Criticality
    - Confined Space
    - Traps
2. Not imminent, but potential danger
    - Environmental monitoring, e.g., inadequate stack monitors
3. Violations of regulations, laws, orders
4. Areas where adverse public opinion may reside
5. Performance and effectiveness issues
    - Usually a large number of findings fall into this category, which captures effectiveness and quality issues.

Finally, establish what is most important and what should be brought to the attention of the senior DOE and contractor management.

Obj. 2
List three of the five priority groupings for assessment findings.

Show 17.3.

Place the findings on dry erase board, list the groups (concerns) that constitute the basis for a concern or overall finding.

B. Writing of findings

When it has been established what issues will be brought to site management, review techniques for writing about the findings:

Obj. 3
Identify the three steps needed to write a finding properly.

There are cases where a strict format does not work.

There is an established style or method often used in industry for writing findings. It consists of the following three steps:

Show OT 17.4.

1. List the requirement
2. State what was observed (different from requirement)
3. State the concern

III. Presentation of Findings

Obj. 4
List three suggestions for effective presentation of findings and concerns.

After findings are prepared in written form, it is important that they be presented properly. Skills for presenting findings are directly related to the techniques used for writing findings.

Some rules to keep in mind when presenting findings are listed below.

- Identify the assessment team leader and members, and their organizational affiliation.
- Explain the reason for the assessment.

Procedural requirement, recurrent problem area, industry issue, management request.

- NEVER, NEVER read the findings in a close-out. Most senior management can read as well as the presenter.
- Present the most significant findings first.

In case time is limited or diminished.

- Be prepared to present additional information to support the finding. In most cases, there is much more material in the file than is appropriate to be included in the write-up. Be prepared to use that material to support the finding.

- In some cases, this is the time to cover material in the report that was not written for public consumption.

- It may be appropriate to discuss other material such as related findings from previous reports or audits.

- Maintain proper perspective by including both positive and negative findings.

- Start with the positive findings, then make a clear, shift to the negative findings or concerns.

- Explain the concerns/findings enough so that senior management will understand the issue.

- Thank the site contact person and most senior manager(s) for help and hospitality extended during the assessment.

Identify follow-up issues and generic findings.

Indicate the severity, ramification of the finding.

Pause periodically and ask if there are questions.

Summarize lesson

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Compliance-Based Versus Performance-Based Evaluations

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Define compliance-based audits.
2. Define performance-based assessments.
3. Describe the four key elements of the assessment process.
4. Describe the advantage of planning for an assessment.
5. Identify the preferred type of checklist.

Training Aids:

Overhead Transparencies (OTs): OT 18.1 – OT 18.3 (may be supplemented or substituted with updated or site-specific information)

Equipment Needs:

Overhead projector

Screen

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

I. Introduction

Show OT 18.1.

State objectives.

II. Compliance-based versus performance-based evaluations

Show OT 18.2.

A. Compliance-based audits

Obj. 1
Define compliance-based audits.

A compliance-based audit is a comparison of the requirements laws, rules, orders, guidance, policies, procedures, and other documentation with site practices to confirm implementation of the specific requirements. For example, determining whether bioassay samples were collected in accordance with site procedure requirements.

B. Performance-based assessments

Obj. 2
Define performance-based assessments.

Assessment is fundamental to the operation of a satisfactory Radiation Protection Program.

A performance-based assessment is a review of how the actual performance of the task is accomplished and assessing whether the intent of the requirement is being met. For example, determining whether bioassay samples were being analyzed for the appropriate isotopes given the workplace environment.

We should be monitoring and assessing as opposed to auditing, appraising, and inspecting.

III. Assessment process

The assessment process is one of the evaluation methods used to determine the status and effectiveness of an overall management system.

With this perspective, the assessment process should be planned and scheduled to accomplish the following:

- Evaluate the effectiveness of program implementation in order to meet compliance requirements
- Provide input for assessment process improvement.

The assessment process consists of four phases:

Show OT 18.3.

Obj. 3
Describe the four key elements of the assessment process.

1. Planning
2. Performance
3. Reporting
4. Response evaluation, follow-up, and close-out

A. Planning

Planning is the key to a successful assessment. It is possible to go immediately to the field to observe, work with, and find out how things are being done. That is one element and approach to the process, but there is a greater advantage to be made with proper planning and preparation.

Obj. 4
Discuss the advantage of planning for an assessment.

Benefits:

- You are not just observing the field, but comparing how things are done with how the program states they are to be done.
- You will know what to expect, and where and when to look for it.

The most successful assessments start with a checklist. The checklist development is critical to the success of the assessment and serves as a commonly accepted method for documenting what was looked at and what the results were. It also serves as a guide to the person performing the assessment and provides objective evidence that an assessment was performed.

- You will understand justifiable differences for things you see. The site maybe doing some unorthodox things for very good reasons.

In performing the assessment, several types of checklists can be used. The preferred style of a checklist is the question-and-answer variety. With this kind of checklist, the assessor has to write-in an evaluation of the answer to each question and any qualifying remarks. The question-and-answer format is more difficult to review, but provides more information with which to judge the performance level of a system element.

Obj. 5
Identify the preferred type of checklist.

See also Module 15, Planning and Conducting Assessments.

B. Performance

The elements of conducting an effective Radiation Protection Program assessment are:

- Overall plan (annual)
- Establish weekly, daily, breakdown
- Actually write a plan (modify later)
- Preparations-obtain material
- Use protocol for entry, conduct, exit
- Keep contact informed/no surprises

C. Report

Documentation of the findings and observations (note taking) in the field will involve some combination of the following:

- Record book
- 3 x 5 cards
- Actual times, logistics
- What, when, who, why, where, how
- Documents reviewed
- Interviews

Then comes the time to start to put the report together, whether a weekly report or the inspection report of some other type. The following are suggested:

- Distill as information is gathered, while memory fresh
- Start draft report early

D. Post-assessment actions

- Evaluate assessment responses
- Establish corrective actions and due dates
- Track the status of open action items
- Perform follow-up assessments as necessary

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Field Exercise Guidelines

Objectives:

Upon completion of this lesson, the participant will be able to:

1. Demonstrate applied field assessment techniques.
2. Present a finding to the class after return from the field.

Training Aids:

Overhead Transparencies (OTs): OT 19.1 – OT 19.4 (may be supplemented or substituted with updated or site-specific information)

Handout - "Field Exercise Guidelines for Participants"

Equipment Needs:

Overhead projector

Screen

Flip chart

Markers

Masking tape

Student Materials:

Student's Guide

References:

U.S. Department of Energy, DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004.

I. Introduction

Show OT 19.1.

State objectives.

II. Field exercise guidelines

A. Briefing for field exercise

The field instructors have prepared to take their participants to the field. They have visited the facility and areas for review, and have compiled information for their participants to use in preparation for the field exercise.

This afternoon, we are going to start the preparations for going to a facility where we will be assessing radiological operations. This training should enhance our assessment skills.

B. Preparations to go to field

A tendency exists to identify surface issues and seek correction of the many items found while walking through the facility. It is vital that personnel who assess be able to sort the issues noted and categorize them so effective use of resources can be made. In other words, identification of symptoms leads to contractors working on the symptoms and not on the underlying, substantive problems.

Good assessment techniques can be taught and learned through classroom discussions, but nothing brings it all together like the application of techniques under the tutelage of an experienced field instructor. This is your opportunity to apply the material and practice the methods learned during the field exercise portion of the course.

It can be extremely damaging if we (as overseers, facility representatives, auditors, or assessors) violate the high standards of performance and rules that are being assessed.

Show OT 19.2.

It is important to understand that we are constantly being monitored ourselves and that we must set the example.

Personal safety and facility safety are first and foremost.

Please follow all radiation protection rules and regulations.

C. Findings

Each person will make a presentation to the group. The team leaders will introduce the group, tell where you went, and introduce each presenter. Each person should take no more that one and one-half minutes for the presentation of a finding. Some of the "cats and dogs," or other findings and observations, will be covered at the end of the individual findings. The Lead Field Instructor will monitor the overall presentation and comment as appropriate.

We hope to see presentations in this form:

1. List the requirement.
2. State what was observed.
3. State the concern.

Show OT 19.3.

Review the requirement for each person to prepare one finding or concern to be shared with the class
(one-and-one-half minute time limit per finding).

Show OT 19.4.

Refer participants to page 49 of handouts, "Field Exercise Guidelines for Participants." Allow sufficient time for participants to read and ask questions.

Obj. 1
Demonstrate applied field assessment techniques.

Obj. 2
Present a finding to the class after return from the field.

Summarize lesson.

Review objectives.

Ask for questions.

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DEPARTMENT OF ENERGY	**LESSON PLAN**
Course Material	Topic: Course Summary
Objectives: Upon completion of this lesson, the participant will be able to: 1. Demonstrate an understanding of the knowledge required to perform basic assessments of occupational radiation protection programs and activities at DOE nuclear sites and facilities.	
Equipment Needs: Overhead projector Screen	
Student Materials: Final examination - as applicable.	

I. Summary

(Insert individualized summary.)

Review course highlights.

Ask for questions.

As applicable:

Administer examination.

Upon completion of examination by participants, review exam.

Collect all exams.

Regulatory Documents

Objectives:

- **Identify the hierarchy of regulatory documents.**
- **Define the purpose of 10 CFR Part 835.**
- **Define the purpose of the DOE Radiological Control Standard.**

Regulatory Documents
(cont.)

Objectives:

- **Define the terms "shall" and "should" as used in the above documents.**
- **Describe the role of the Defense Nuclear Facilities Safety Board (DNFSB) at DOE sites and facilities.**

DOE Radiological Health and Safety Policy

- Establish and maintain a system of regulatory policy and guidance.
- Ensure appropriate training and the technical competence of the DOE workforce.
- Establish and maintain line management involvement and accountability.

DOE Radiological Health and Safety Policy (cont.)

- Ensure accurate and appropriately made measurements.
- Conduct radiological operations that control the spread of radioactive materials and are ALARA.
- Incorporate measures to minimize contamination.
- Conduct oversight to ensure compliance.

Written Standards

- **10 CFR Part 835**
- ***DOE Radiological Control Standard***

Hierarchy of Requirements

Two parallel hierarchies:

- **Rules and/or regulations**
- ***DOE* Orders**

Rules and Regulations

- Price-Anderson Amendments Act (PAAA) of 1988
- 10 CFR Part 820 of 1993:
  - Civil penalties
  - Criminal penalties
- DOE Nuclear Safety Requirements

10 CFR Part 835

- Purpose: Codification of radiation protection requirements
- Prescriptive language
- Emphasis on ALARA
- Radiation Protection Program requirements
- Federal law
- Criminal and civil penalties for violations

Radiation Protection Program

- Required by 10 CFR Part 835
- Noncompliance may lead to PAAA enforcement

Guidance Documents (10 CFR Part 835)

Two types:

- **Implementation guides**
- **Technical positions**

10 CFR 835 vs. 10 CFR 20

10 CFR Part 835:

- **DOE sites and facilities**
- **Unique activities**

10 CFR Part 20:

- **NRC**

DOE Radiological Control Standard

- **Originally promulgated as the Radiological Control Manual with DOE Notice 5480.6 (July 1992)**
- **<u>Purpose:</u> provides guidance for comprehensive radiological control program - not a regulation**
- **Notice which made the Radiological Control Manual a requirement was cancelled by N441.1 (Sept 1995):**
  - **May still be be contractual requirement**
  - **Updated on July 1999 by DOE STD-1098-99 Radiological Control**

10 CFR 835 vs. DOE Radiological Control Standard

10 CFR Part 835:

- **EH-10 enforces**
- **"Shall" statements (mandatory requirements)**
- **Program Offices audit**

DOE Radiological Control Standard:

- **Program Offices audit contractual agreements**
- **Mostly "should" statements (recognizes site- or facility-specific attributes)**

Conflicts

10 CFR 835 requirements take precedence over DOE Radiological Control Standard

Unlikely the two will conflict, one may have a requirement that is not in other

DOE Standards

- Some DOE Standards are requirements for certain sites: for example, DOELAP
- Others provide guidance
- As part of assessment, need to review site requirements documents

Defense Nuclear Facilities Safety Board

- **Five-member board:**
  - **Reviews and evaluates standards**
  - **Investigates any event or practice at DOE nuclear facilities that the Board determines has (or may) adversely affect public health and safety**
  - **May establish reporting requirements for the Secretary of Energy**

DNFSB Recommendations

91-6:

- **Radiological protection performance**

92-7:

- **Enhance radiological qualification**

98-1:

- **Resolution of audit findings**

99-1:

- **Safe storage of fissionable material**

10 CFR Part 835, Background and Focus

Objectives:

- **Describe the contents of 10 CFR Part 835.**
- **Identify the site requirements of 10 CFR Part 835.**

10 CFR Part 835

- A — General Provisions
- B — Management and Administrative Requirements
- C — Standards for Internal and External Exposure
- D — Reserved
- E — Monitoring of Individuals and Areas
- F — Entry Control Program
- G — Posting and Labeling

10 CFR Part 835 (cont.)

H — Records
I — Reports to Individuals
J — Radiation Safety Training
K — Design and Control
L — Radioactive Contamination Control
M — Sealed Radioactive Source Control
N — Emergency Exposure Situations

Exclusions from 10 CFR Part 835

- Activities regulated by the NRC
- Activities under authority of the Director, Naval Nuclear Propulsion Program
- Specified activities conducted under the Nuclear Explosives and Weapons Surety Program
- Radioactive material transportation
- DOE activities in certain foreign countries
- Background radiation
- Radioactive material on or within material, equipment and real property which is approved for release when the radiological conditions of the material, equipment and real property have been documented to comply with the criteria for release set forth in a DOE authorized limit which has been approved by a Secretarial Officer in consultation with the Chief Health, Safety and Security Officer.

Exclusions from 10 CFR Part 835 (Cont.)

Occupational doses received as a result of excluded activities and radioactive material transportation, as listed above, shall be considered when determining compliance with the occupational dose limits (835.202 and 835.207), and with the limits for the embryo/fetus (835.206).

Included in the RPP

- Formal plans and measures for applying ALARA to occupational exposures
- Existing and anticipated operational tasks
- Each requirement in Part 835
- Plans, schedules, and other compliance measures

Standards for Internal and External Exposure

Addresses limits for:

- **General employees (occupational)**
- **Embryos/fetus**
- **Occupationally exposed minors**
- **Members of public in controlled area**
- **Planned special exposures**
- **Nonuniform exposures of the skin**
- **Concentrations of radioactive material in air**

Summary of Dose Limits

Exposed Individual		Annual Limit
General Employee:	Whole Body (internal and external)	5.0 rem
"	Lens of Eye	15.0 rem
"	Extremity (below elbow and knees) and skin	50.0 rem

Summary of Dose Limits
(cont.)

Exposed Individual		Annual Limit
General Employee:	Any Organ or Tissue (other than lens of eye)	50.0 rem
Declared Pregnant Worker:	Embryo/Fetus (gestation period)	0.5 rem
Occupationally exposed minors: (also have limit of 10% of other General Employee limits)		0.1 rem
Members of the Public in Controlled Areas:		0.1 rem

Planned Special Exposures

- Advance approval of DOE
- Informed employee consent

DACs

DACs are listed in appendices A and C of 10 CFR 835.

For intakes, they are the airborne concentration that equals the annual limit on intake (ALI) divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m^3).

Monitoring of Individuals and Areas

- Demonstrate compliance with Part 835
- Document radiological conditions
- Detect changes in conditions
- Detect the gradual buildup of radioactive material
- Verify effectiveness of engineering and process controls
- Identify and control potential radiation sources and/or radioactive material

Instrumentation

- Periodically maintained and calibrated
- Reviewed for appropriateness:
  - Types, levels, and energies of radiation
  - Environmental conditions
- Routinely tested for operability

Individual Monitoring – External

Dosimetry provided to and used by:

- **Radiological Workers**
- **Declared Pregnant Workers**
- **Occupationally exposed minors and members of the public in controlled area**
- **Persons entering High or Very High Radiation Areas**

Individual Monitoring – Internal

Conducted for:

- **Radiological Workers**
- **Declared Pregnant Workers**
- **Occupationally exposed minors and members of the public in a controlled area**

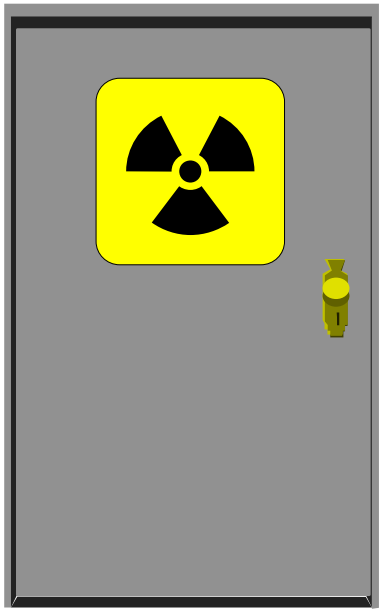
Receipt of Packages of Packages Containing Radioactive Material

Applicable to certain types of packages:

- **Requires monitoring**
- **Specifies time limit for monitoring; within 8 hours after start of next working day**

Entry Control Program

- Radiological Areas
- High Radiation Areas
- Very High Radiation Areas



Methods to Ensure Control

- Signs and barricades
- Control devices on entrances
- Alarms
- Locked entrances
- Administrative controls

Radiological Area Egress

- No control(s) shall be installed at any radiological area exit that would prevent rapid evacuation of personnel under emergency conditions.

High Radiation Areas

- Where an individual could exceed a deep dose equivalent of 0.1 rem in one hour, measured 30 cm from the source or from any surface that the radiation penetrates
- If individual could receive a dose > 1.0 rem in an hour require one or more of the following:
  - Control devices
  - Alarms
  - Surveillance to prevent entry
  - Locks

Very High Radiation Areas

- **Dose in excess of 500 rad in one hour at 1 meter from source or from any surface that the radiation penetrates**

Very High Radiation Areas (Cont.)

- In addition to the requirements for a High Radiation Area, additional measures shall be implemented to ensure individuals are not able to gain unauthorized access to Very High Radiation Areas.

- "No control(s) shall be established in a High or Very High Radiation Area that would prevent rapid evacuation of personnel."

Signs

- Yellow background
- Black or magenta radiation symbol
- Clear and conspicuous signs

Records Requirements Include:

- Demonstrate compliance with 10 CFR 835
- Individual monitoring
- Sealed source inventory and control
- Results of surveys:
  - Release of material and equipment
  - Radiation and radioactive material in the workplace
- Maintenance and calibration of instruments
- Internal audits
- Radiation safety training

Reports to Individuals Include:

- Annual report of dose
- Employment termination record of exposure

Radiation Safety Training

- Based on:
  - Area access
  - Receiving occupational dose
  - Assignment as Radiological Worker
- Requirements:
  - Examination for certain level (e.g., Radiological Worker Training)
  - Training intervals of twenty four months or less
  - Specifies topics
  - Provision for allowing use of escorts

Design and Control

- **Facility design and modifications:**
  - **Optimization methods shall be used**
  - **Maintain dose rates below 0.5 mrem/hour**
  - **Avoid release of airborne radioactivity**
  - **Facilitate operations, maintenance, decontamination, and decommissioning**

Workplace Controls

- **Physical design features and administrative controls shall provide:**
  - **Occupational dose to general employees not exceed the limits**
  - **ALARA process is utilized**

Radioactive Contamination Control

- To controlled areas (Part 835)
- To uncontrolled areas (DOE O 5400.5)
- Monitor contamination level
- Provisions to release to controlled area items with fixed contamination
- Requires personnel monitoring
- Requires protective clothing

Sealed Radioactive Source Control

- **Sealed radioactive sources shall be used, handled and stored in a manner commensurate with the hazard.**

Emergency Exposure Situations

Addresses:

- **Employees who have exceeded dose limits as a result of an authorized emergency exposure**
- **Nuclear accident dosimetry**

Nuclear Accident Dosimetry

- Required for installations possessing potential critical mass
- Method to conduct initial screening
- Method and equipment to analyze biological materials
- A system of fixed nuclear accident dosimeters
- Personal nuclear accident dosimeters

Overview of the *DOE Radiological Control Standard*

Objectives:

- **Describe the managerial responsibilities in the *DOE Radiological Control Standard*.**
- **Describe the contents of the *DOE Radiological Control Standard*.**

Excellence in Radiological Control (Chapter 1)

- *DOE Radiological Control Standard*
- Leadership in Radiological Control
- Improving Radiological Control Performance
- Contractor Radiological Control Organization
- DOE Management

Leadership in Radiological Control

- Commitment of senior management
- ALARA accountability
- Conduct of radiological operations

Improving Radiological Performance

- Critiques used as a management tool
- Root cause identification
- Over 20 radiological performance indicators:
  - Tools to focus priorities on radiological control performance

Contractor Radiological Control Organization

- Requirements for the contractor
- Qualifications of the Radiological Control Manager

Radiological Standards (Chapter 2)

- Administrative Control Levels and Dose Limits
- Contamination Control and Control Levels
- Posting

Conduct of Radiological Work (Chapter 3)

- Planning Radiological Work
- Work Preparation
- Entry and Exit Requirements
- Radiological Work Controls

Conduct of Radiological Work (Chapter 3) (cont.)

- Evaluation of Performance
- Special Applications
- Radiological Design Criteria
  - Design of New Facilities
  - Modification of Existing Facilities

Radioactive Materials (Chapter 4)

- Identification, Storage, and Control
- Release and Transportation
- Source Controls
- Waste Management
  - Solids
  - Liquids
- Airborne Management

Radiological Health Support Operations (Chapter 5)

- External Dosimetry
- Internal Dosimetry
- Respiratory Protection Program
- Handling Radiologically Contaminated Personnel
- Radiological Monitoring and Surveys
- Instrumentation and Calibration

Training and Qualification (Chapter 6)

- General Employee Radiological Training
- Radiological Worker Training
- Radiological Control Technician/Supervisor Qualification
- Other Radiological Training
- Training for Special Applications

Radiological Records (Chapter 7)

Requirements for:

- **Employee Records**
- **Visitor records**
- **Radiological Control Procedures**
- **Radiological Surveys**
- **Instrumentation and Calibration Records**
- **Radiological Reporting**

Elements of a Radiological Control Program

Objectives:

- **Identify factors that influence the scope and magnitude of a Radiological Control Program at any nuclear facility.**
- **Identify typical elements of a Radiological Control Program.**

Radiological Control Program

- Requirements
- Responsibilities
- Programs/procedures
- Assessments

Radiological Control Program Elements

- Organization and administration
- Personnel training and qualifications
- Quality assurance
- ALARA
- Radiological work control
- Posting and labeling

Radiological Control Program Elements (cont.)

- Radioactive material control
- Radiation-generating devices
- Entry control
- Contamination control
- Instrumentation/alarms
- Monitoring

Radiological Control Program Elements (cont.)

- Dosimetry
- Respiratory protection
- Facility-specific features
- Radioactive waste management
- Emergency response
- Records
- Assessments/performance indicators

Technical Safety Requirements

Objectives:

- **Describe the purpose of DOE Order 5480.22 and its relationship to 10 CFR 830.205.**
- **Describe the purpose of Technical Safety Requirements (TSRs) in regard to facility operations/activities.**
- **Identify the source(s) of information required to develop reasonable and appropriate TSRs.**

Technical Safety Requirements (cont.)

Objectives:

- **Describe the responsibilities for the development and use of TSRs.**
- **List the criteria for identifying problems in meeting TSRs.**
- **List areas in TSRs which could be reviewed as part of a radiological assessment.**

Technical Safety Requirements

- Definition
- TSRs consist of:
  - Safety limits
  - Operating limits
  - Surveillance requirements
  - Administrative controls
  - Use and application instructions
  - Bases for above items

Basis

Summary statements of the reasons for the operating limits and associated surveillance requirements. It shows how the numerical value, condition, or the surveillance fulfills the purpose from the safety documentation.

TSRs

- Contract between operating contractor and DOE management
- Minimize potential risk
- Controlled document
- Reduce likelihood and potential impact of events

Facility-Specific Safety Analysis

Considers all credible accidents including:

- **Most significant possible releases**
- **Criticality scenarios**
- **Expected accidental releases during life of facility**

Accident Analysis

Provides:

- **Values for defining operational limits**
- **Parameters and operating conditions that should be limited**

Requirements Expected to Be Developed

- Operating limits
- Technical and administrative conditions
- Availability of safety equipment and systems
- Critical functions of instrumentation and controls

Analyses

- **In order to serve as the basis for the TSRs, studies must systematically evaluate:**
  - **All potential off-normal conditions that could occur during the life of the facility**
  - **What could be considered design basis accidents**

Responsibilities for TSRs

- **Preparation** → **Contractor**
- **Review** → **DOE Field Office**
- **Approval** → **CSO**

Violations of a TSR

Four circumstances:

- **Exceeding Safety Limit**
- **Failure to take necessary actions within time allotted**
- **Failure to perform surveillance within required time**
- **Failure to comply with Administrative Control requirement**

Reporting Requirements

- Categorization
  - Operational Emergency
  - Significance Category 1 - 4
- Notification
- Follow-up notification
- Occurrence Report preparation
- Noncompliance Tracking System

Area monitors

- Criticality monitors
- Area Radiation Monitors
- Air Monitors (i.e., real time air monitors, fixed head air samplers)

Radiological Aspects of Uranium

Objectives:

- **Identify the radiological properties of uranium.**
- **Describe the toxicological properties and behavior of uranium.**
- **Identify appropriate instrumentation, measurement techniques, and special radiological survey methods for uranium.**

Radiological Aspects of Uranium (cont.)

Objectives:

- **Describe personnel protection requirements, external dose control techniques, and internal dose control techniques.**
- **Describe special controls and considerations required for uranium operations.**

Radiological Properties

Uranium can:

- **Occur naturally**
- **Be man-made**
- **Become enriched for reactor fuel or weapons**
- **Be depleted**

Radioisotopes

- Alpha and beta emitters
- Emit neutrons
- Fissile material

Detection and Measurement

- Health physics program ensures detection
- Exposure rate surveys using photon-sensitive instruments
- Beta detectors (decay products)
- Neutron surveys
- Continuous air monitors

Survey Techniques

- **Monitoring practices:**
  - **Contamination surveys of the workplace**
  - **Release surveys**
  - **External exposure surveys**
  - **Airborne contamination surveys**
  - **Routine surveillance by a RCT**
- **Regularly scheduled monitoring (all work areas)**

Workplace Characterization

- **Airborne contamination surveys:**
  - **Prompt detection**
  - **Personnel dose assessment**
  - **Monitoring of trends**
  - **Special studies**

Personnel Protection

- Personnel air sampling
- Protective clothing
- Respiratory protection

External Dose Control

- Beta radiation
- Gamma radiation:
  - Time
  - Distance
  - Shielding
- Neutron radiation

Internal Dose Control

Hazard must be controlled by:

- **Appropriate facility and equipment design**
- **Contamination control procedures**
- **Protective clothing**
- **Control verified by:**
  - **Bioassay program**

Special Controls

- Criticality safety:
  - Alarm systems
  - Nuclear accident dosimetry
  - Fire prevention
- Hydrofluoric acid
- Separation/concentration of decay products

Radiological Aspects of Tritium

Objectives:

- **Describe the radiological properties of tritium.**
- **Identify personnel protection requirements and dose control techniques.**
- **Identify the biological effects of internally deposited tritium.**

Radiological Aspects of Tritium (cont.)

Objectives:

- **Describe appropriate instrumentation, measurement techniques, and special radiological survey methods for tritium.**
- **Identify special controls and considerations required for the use of tritium.**

Radiological Aspects of Tritium

- **Primary sources:**
  - **Environmental**
  - **By-product of power reactors**
  - **DOE production**

Chemical Forms

- Elemental tritium
- Tritiated water
- Organically bound tritium (OBT)
- Stable metal tritides (SMT)

Radiological Properties of Tritium

- **Radiological properties:**
  - **Beta particle emitter**
  - **Weak beta particle energy (18 keV max)**
  - **12.3 yr half-life**
  - **High specific activity (9619 Ci/g)**

Dose Pathways

- Inhalation
- Ingestion
- Skin absorption

General Sources of Release

- Gaseous releases (ventilation exhaust systems)
- Liquid wastes
- Solid wastes

Dose Controls

- Airborne controls
- Contamination controls
- Personnel protection equipment

Modes of Entry

- Inhalation
- Ingestion
- Absorption

Containment

- Primary
- Secondary
- Tertiary

Airborne Controls

- Differential room pressure zones
- Dilution ventilation
- Room-air detritiation systems
- Local exhaust ventilation

Measurement Techniques

- Air monitoring
- Differential monitoring
- Discrete sampling
- Process monitoring
- Surface monitoring
- Liquid monitoring

Special Controls (Bioassay)

- Chronic exposure:
  - Periodic urinalysis
- Acute exposure:
  - Wait one to two hours.
  - Void bladder.
  - Collect sample as soon as possible.
  - Collect daily.

Special Controls (cont.)

- Dose assessment for SMTs and OBT may need to be based on air monitoring
- Tritium effluent recovery system:
  - Reduces tritium available for release
  - Tritium gas converted to tritiated water
  - Inventory control and accountability:
  - Tritium = nuclear material

Radiological Aspects of Plutonium

Objectives:

- **Identify the radiological properties of plutonium.**
- **Identify the biological effects of plutonium.**
- **Identify special controls and considerations required for plutonium operations.**

Radiological Aspects of Plutonium (cont.)

Objectives:

- **Describe appropriate instruments, measurement techniques, and special radiological survey methods for plutonium.**
- **Describe personnel protection requirements and dose control techniques for plutonium.**

Radiological Properties of Plutonium

- 15 isotopes, all radioactive
- Pu-238 (heat source)
- Pu-239 (reactor fuel, weapons)
- Pu-240 (reactor fuel, weapons)
- Alpha-emitters:
  - Some associated gamma radiation

Biological Effects of Plutonium

- Exposure pathways:
  - Inhalation
  - Ingestion
- Retention in body
- Removal (chelating agents)
- Long-term concerns:
  - Lung cancer
  - Leukemia

Survey Techniques

- Health physics program for detection of all types of radiation
- Alpha-sensitive instruments
- Continuous air monitors
- Neutron surveys
- Exposure rate surveys

Survey Techniques (cont.)

Monitoring practices:

- **Regularly scheduled contamination surveys**
- **Release surveys**
- **External exposure rate surveys**
- **Airborne radioactivity surveys**
- **Routine surveillance by Radiological Control Technician**

Monitoring Instruments

- Meet site specific requirements
- Effluent monitors
- Criticality alarms

Sources of External Dose

- High-energy gamma photons
- Low-energy photons:
  - Extremity dose
  - From large amounts of Pu-238, Pu-241, Am-241
- Neutrons

External Dose Control

- Time
- Distance
- Shielding
- Other work practices:
  - Good housekeeping
  - Specially designed tools and equipment

Internal Dose Control

- Confinement systems:
  - Primary
  - Secondary
  - Tertiary
- Confinement devices:
  - Fume hoods
  - Glove boxes
  - Ventilation

Personnel Protection

- Training
- Air sampling
- Protective clothing
- Respiratory protection equipment

Special Controls

- Inventory and accountability
- Criticality safety:
  - Alarm systems
  - Nuclear accident dosimetry

Radiological Work Permits

Objectives:

- **Identify types of job hazards that are <u>not</u> addressed by Radiological Work Permits (RWPs).**
- **Describe the two basic types of RWPs.**
- **Determine the types of jobs that may and may not be worked under the controls imposed by RWPs.**

Radiological Work Permits (cont.)

Objectives:

- **Identify typical time limits for the two basic types of RWPs.**
- **List essential elements of an effective RWP.**
- **List RWP program elements which may be included in a radiological assessment.**

RWP Process

- Requester submits RWP request form.
- Radiological Control Supervisor accepts form, assures completion of surveys of work area.
- Trained personnel perform surveys.
- RWP controls established.
- RWP form completed and posted.

RWP
Process (cont.)

- Radiological Control and work group review RWP:
  - Pre-job briefings
  - ALARA reviews
- Radiological Control terminates RWP when job is finished or RWP expires.
- Radiological Control maintains survey and RWP documentation.

Types of RWPS

- **Job-specific RWP:**
  - **Potential for significant radiation dose, airborne radioactivity, or spread of contamination**
  - **"Hands on" work with potential health physics concerns**
- **General RWP:**
  - **"Hands on" and other work with less potential for health physics concerns**

RWP Time Limits

- **Job-specific RWP:**
  - **Duration of job**
  - **Usually ≤ 30 days**
- **General RWP:**
  - **Standing use (tours, rounds)**
  - **Usually ≤ 1 year**
  - **Often renewed on calendar year basis**

Elements of an RWP

- Description of work (detailed)
- Radiological conditions
- Dosimetry requirements
- Pre-job briefing requirements
- Radiological Control Technician coverage requirements
- Training requirements

Elements of an RWP (cont.)

- Protective clothing requirements
- Respiratory protection requirements
- Stay time requirements
- Conditions limiting work or voiding RWP
- ALARA measures
- Contamination monitoring requirements
- Work document number

Elements of an RWP (cont.)

- Unique RWP number
- Permit issue and expiration date
- Signatures:
  - Read and understand RWP
  - Agree to follow controls

RWP Elements for Radiological Assessment

- RWPs appropriately required for activities and areas
- Completeness of information on RWPs
- Adequacy of radiological surveys to support RWP
- Worker adherence to RWP requirements

RWP Elements for Radiological Assessment (cont.)

- RWP appropriately reviewed and approved
- Adequacy of worker monitoring (TLDs, bioassay, air monitoring RCT coverage) specified on RWP
- ALARA considerations included in RWP
- RWP program implemented in accordance with written procedures

Contamination Containment and Temporary Control Measures

Objectives:

- **Describe what temporary engineered radiological controls can be used to reduce or eliminate contamination spread.**
- **Describe why engineered and administrative controls are needed.**

Engineered Controls

- Glove boxes
- Glove bags
- Portable filtration units
- Containment tents
- Portable shielding

Administrative Controls

- Access restrictions
- Work practices

Use of Respiratory Protection

- Airborne Radioactivity Areas
- Breach of contaminated systems
- High removable contamination
- Work may generate airborne radioactivity

Special Conditions

- **Use of respiratory protection contraindicated:**
  - **Physical limitations**
  - **Increased dose from respirator use**
  - **Written authorization required**
    - **Prior to incurring internal dose**
    - **Specific justification of dose acceptance**

Radiological Work Site Mockup Demonstration

Objectives:

- **Identify poor radiological work practices, in and around a mock radiological work site.**
- **Inspect a typical contamination containment (glove bag).**
- **Develop field assessment notes to support findings (hands-on exercise).**

Radiation-Generating Devices

Objectives:

- **Identify radiation-generating devices.**
- **Describe the basic components of an x-ray machine.**
- **Identify the most common use of x-rays.**
- **Identify the potential hazards associated with x-rays.**

Radiation-Generating Devices (cont.)

Objectives:

- **Identify the most common use of sealed gamma ray sources and the potential hazards.**
- **Identify the most common use of beta and neutron sources and the potential hazards.**

Radiation-Generating Devices (cont.)

To meet the intent of the 10 CFR 835 use:

- **DOE G 441.1- 5**
- **ANSI N43.3**
- **ANSI N43.2**
- **10 CFR Part 34**

Radiation-Generating Devices (cont.)

Include:

- **Devices producing ionizing radiation**
- **Sealed sources emitting ionizing radiation**
- **Small particle accelerators**
- **Electron-generating devices**

X-Ray Machine Design

Basic components include:

- **A source of electrons**
- **An electrical potential difference to accelerate the electrons**
- **An anode or target to strike**
- **An evacuated tube for all the above components**

X-ray Energy Spectrum

- Characteristic x-rays
  - Discrete energies
- Bremsstrahlung photons
  - Produced with range of energies

X-ray Machines

Radiography:

- **Medical applications:**
  - **Standardized appearance and installation**
- **Industrial applications:**
  - **Fixed installation**
  - **Mobile units**
  - **Enclosed cabinet system**

Analytical X-ray Machines

- Fluorescence analysis
- X-ray diffraction

Sealed Gamma Ray Sources

Uses:

- **Radiography**
- **Thickness gauges**
- **Level gauges**
- **Density gauges**

Other Sealed Sources

- Beta particles (thickness gauges)
- Neutrons:
  - Moisture gauges
  - Radiography of dense materials

Radiation-Generating Device Installations

ANSI Categories:

- **Exempt shielded**
- **Shielded**
- **Unattended**
- **Open**

Radiological Aspects of Accelerators

Overhead 13.1

Objectives:

- **Identify the general characteristics of accelerators.**
- **Identify the types of particles accelerated.**
- **Identify the two basic types of accelerators.**
- **Identify uses for accelerators.**
- **Define prompt radiation.**
- **Identify prompt radiation sources.**

Radiological Aspects of Accelerators (cont.)

Overhead 13.2

Objectives:

- **Define radioactivation.**
- **Explain how contaminated material differs from activated material with regard to radiological concerns.**
- **Identify activation sources.**

Radiological Aspects of Accelerators (cont.)

Overhead 13.3

Objectives:

- **Identify engineered and administrative controls at accelerator facilities.**
- **Identify the special radiological concern and recommended instrument for each type of accelerator radiation survey.**

Accelerated Particles

- Electrons
- Protons
- Nuclei of various elements

Types of Accelerators

- Linear accelerators:
  - Van de Graaff
  - Cockcrott-Waltons
- Circular-path accelerators:
  - Cyclotrons
  - Betatrons
  - Synchrotrons
- Colliders

Uses for Accelerators

- Basic research
- Production of radioisotopes
- Generation of bremsstrahlung for radiography
- Induction of fusion
- Pumping for lasers
- Detoxification of hazardous waste
- Production of synchrotron radiation

Radiological Concerns

- **Prompt radiation:**
  - **Primary beam**
  - **Secondary beam**
  - **Skyshine**
  - **Electromagnetic radiation**
  - **Neutrons**
  - **Muons**

Radiological Concerns
(cont.)

- Residual radioactivity:
  - Contaminated materials
  - Activated materials
- Ancillary sources

Controls

- **Engineered controls**
- **Administrative controls**

Engineered Controls

- **Passive:**
  - **Barriers**
  - **Shielding**
- **Active:**
  - **Status lights**
  - **Alarms**
  - **Interlocks**
  - **Scram buttons**

Administrative Controls

- Signs/postings
- Search and secure procedures
- Controlled access procedures
- Configuration control procedures
- Radiological Work Permits (RWPs)

Monitoring

- May be complicated (unique conditions)
- Prompt radiation fields
- Environmental
- Personnel

Assessment Techniques

Objectives:

- **Describe the difference between structured and unstructured assessments.**
- **Describe the difference between vertical and horizontal reviews.**
- **List the documents needed in order to perform a radiological assessment.**

Assessment Techniques
(cont.)

Overhead 14.2

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Objectives:

- Define the term assessment.
- Describe how to evaluate a contractor assessment program using DOE's Technical Safety Appraisal approach.
- Describe the desired characteristics of performance goals.
- List five performance indicators used in assessing Radiation Protection Program effectiveness.

Assessment Types

- Unstructured
- Structured techniques:
  - Vertical review
  - Horizontal review

Vertical versus Horizontal Reviews

- **Vertical:**
  - **Narrow scope**
  - **Detailed assessment**
- **Horizontal:**
  - **Broad scope**
  - **Less detailed assessment**

Documents Needed for Assessment

- 10 CFR Part 835
- Site Radiation Protection Program
- DOE-STD-1098-98 Radiological Control
- Other federal regulations
- Applicable DOE orders
- State regulations
- DOE Implementation Guides

Documents Needed for an Assessment (cont.)

- Site DOE contract
- Site commitments
- Site reports (deficiency, occurrence)
- Site-Specific RadCon Manual
- Approved exemptions
- Peer/industry group standards/recommendations

Assessing Radiological Performance

- **Assessments include:**
  - **Internal audits**
  - **Inspections**
  - **Reviews**
  - **Investigations**
  - **Self-assessments**

Assessment Approach

- **Assessments:**
  - **Management**
  - **Operational**
  - **Quality assurance**
- **Functional areas:**
  - **Performance objectives**
  - **Criteria for each performance objective**

Radiation Protection Deficiencies

- Managers should regard them as opportunities.
- Work practices should be continually scrutinized.
- Number of deficiencies does not measure overall quality.

Critiques

- Formal process to obtain pertinent facts
- Follow radiological incident
- Quickly establish facts in chronological order
- Focus on "lessons learned," not on blame
- Complement the Occurrence Reporting and Processing of DOE Order 232.1A

Radiation Protection Program Performance

Goals should be:

- **Established, approved, and maintained by contractor senior site executive**
- **Measurable**
- **Achievable**
- **Auditable**
- **Challenging**
- **Meaningful in promoting improvement**

Radiation Protection Program Performance (cont.)

- Developed by those performing work
- Reviewed at least annually
- Revised as appropriate

Performance Indicators

- **Evaluate Radiation Protection Program performance.**
- **“What gets measured, gets done.”**

Planning and Conducting Assessments

Objectives:

- **List 10 of the 19 elements of a Radiation Protection Program.**
- **Identify five deficiencies in a Radiation Protection Program that point to the need for an assessment.**
- **Describe the preparations needed to conduct a Radiation Protection Program assessment.**

Planning and Conducting Assessments (cont.)

Objectives:

- **Describe how to conduct a Radiation Protection Program assessment.**
- **Describe two qualifying conditions for a follow-up assessment.**
- **Describe what actions should be taken when assessments indicate marginal radiological control performance.**

Elements of a Radiation Protection Program

- Organization and administration
- Personnel training and qualification
- Quality assurance
- ALARA
- Radiological work control
- Posting and labeling
- Radioactive material control

Elements of a Radiation Protection Program (cont.)

- Radiation-generating devices
- Entry control
- Contamination control
- Instrumentation and alarms
- Monitoring
- Dosimetry
- Respiratory protection

Elements of a Radiation Protection Program (cont.)

- Facility-specific features
- Radioactive waste management
- Emergency response
- Records
- Assessments/performance indicators

Indicators: Assessment Is Needed

- Exceeding administrative dose levels or regulatory limits
- Loss of radioactive material control
- Unmonitored/excessive release to environment
- Excessive number of skin contamination incidents
- Uptakes of radioactive material
- Excessive number of radiological incidents

Indicators: Assessment Is Needed (cont.)

- Inadequate training
- Ineffective work control systems
- Incomplete or inaccurate:
  - Radiological surveys
  - Records

Assessment Preparation

- Review operating history
- Examine previous assessment reports
- Collect input from person(s) assessed
- Determine applicability of industry issues
- Review policies and procedures
- Assemble regulations and guidance documents
- Prepare an assessment plan

Operating History

- Occurrence reports
- Radiological deficiency reports
- Violations/citations
- Facility design changes

Previous Assessments

- DNFSB Recommendations
- Self-assessments
- Corporate quality assurance
- External audit group

Input from Person(s) to be Assessed

- Management
- Radiological Control Manager
- Radiological Control Organization's "customers"

Industry Issues

- Emerging technical issues
- Application of best industry standards

Policies and Procedures

- Operating procedures
- Radiological control policies

Regulations and Guidance Documents

- Federal
- State
- Site
- Industry/peer group

Assessment Plan

- Identify elements to assess.
- Generate specific questions.
- Develop record sheet.
- Allocate time (backup plan).
- Leave unscheduled time.

Types of Assessments

- Announced
- Unannounced

Assessment Methods

- Document reviews
- Personnel interviews
- Field observations

Recommended Approach

- Review upper-tier procedures
- Conduct short site tour
- Interview key persons
- Conduct follow-up actions

Key Interviews

- Radiological Control Manager
- Radiological Control Supervisors
- Radiological Control Technical Leads
- Radiological Control Technicians

Key Interviews (cont.)

- Radiological Control Organization's "customers"
- DOE Representatives
- Facility Manager

Post-Assessment Actions

- Publish findings
- Receive responses
- Accept/reject/modify responses
- Develop action tracking list
- Publish status report

Post-Assessment Actions (cont.)

- Maintain file of open action items.
- Verify closure of action items.
- Evaluate adequacy of actions taken:
  - Root cause identified?
  - Follow-up assessments needed?

Follow-up Assessments

Qualifying conditions:

- **Widespread problem**
- **Recurring problem**

Marginal Radiological Performance

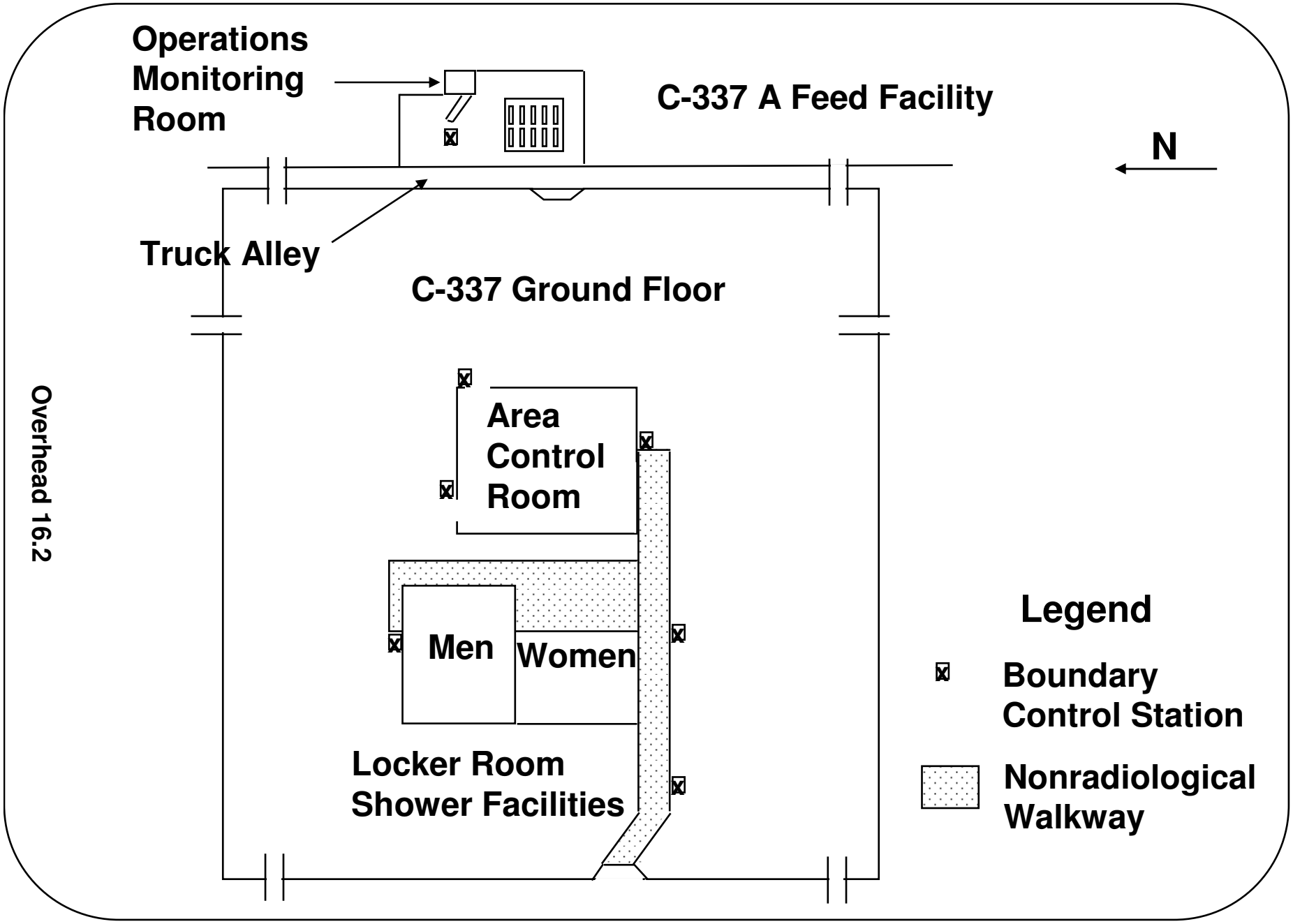
Initial actions should include:

- More direct line supervision in the work space
- Curtailment of work schedules
- Addition of extra radiological control personnel
- Conduct of additional training

Case Studies

Objectives:

- **Describe causes of radiological incidents.**
- **Identify primary cause and contributing causes of radiological incidents.**
- **Describe effective corrective actions.**



Overhead 16.2

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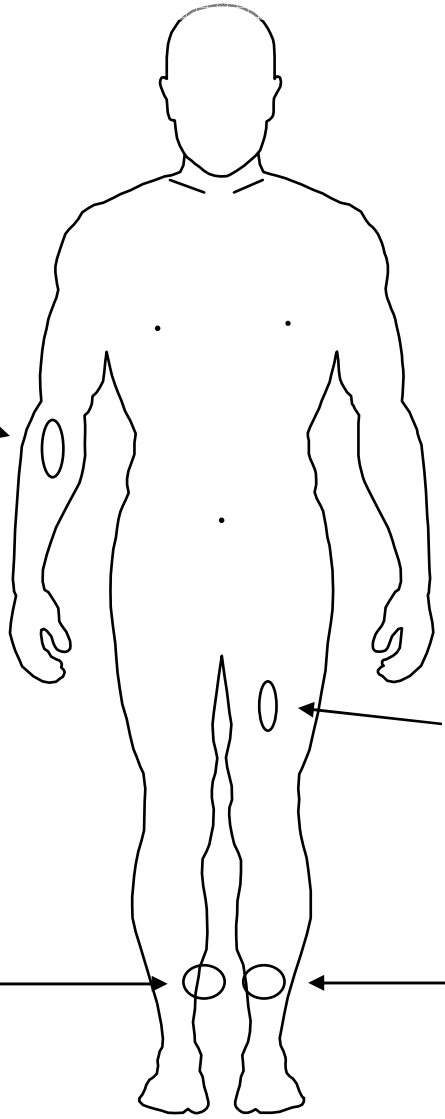
OT 16.2

Pre and Post Decontamination Skin Contamination
(dpm per probe area; beta/gamma)



Employee No. 1

6,500 Pre

< 1,000 Post

4,500 Pre

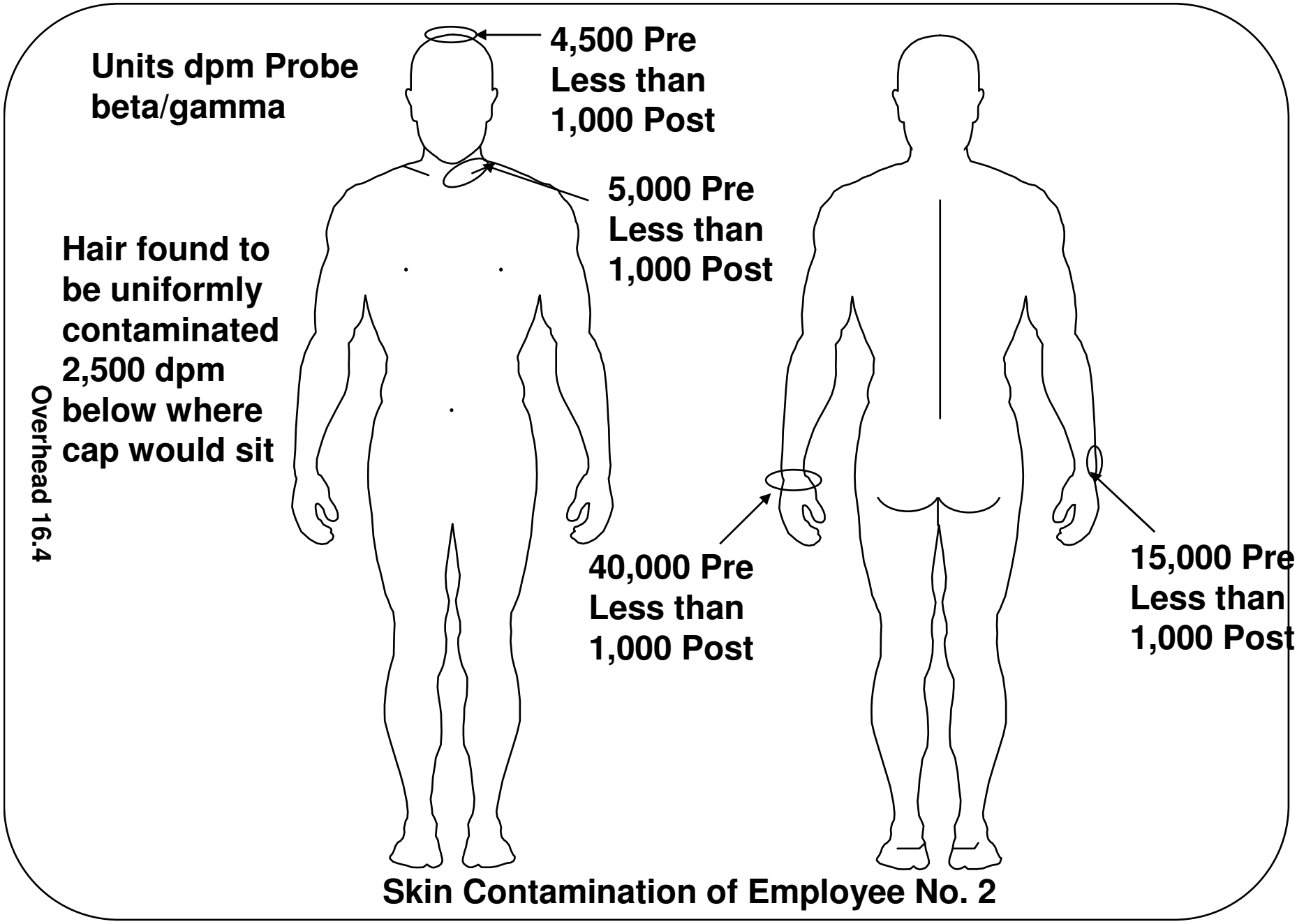
< 1,000 Post

2,750 Pre

<1,000 Post

2,750 Pre

<1,000 Post



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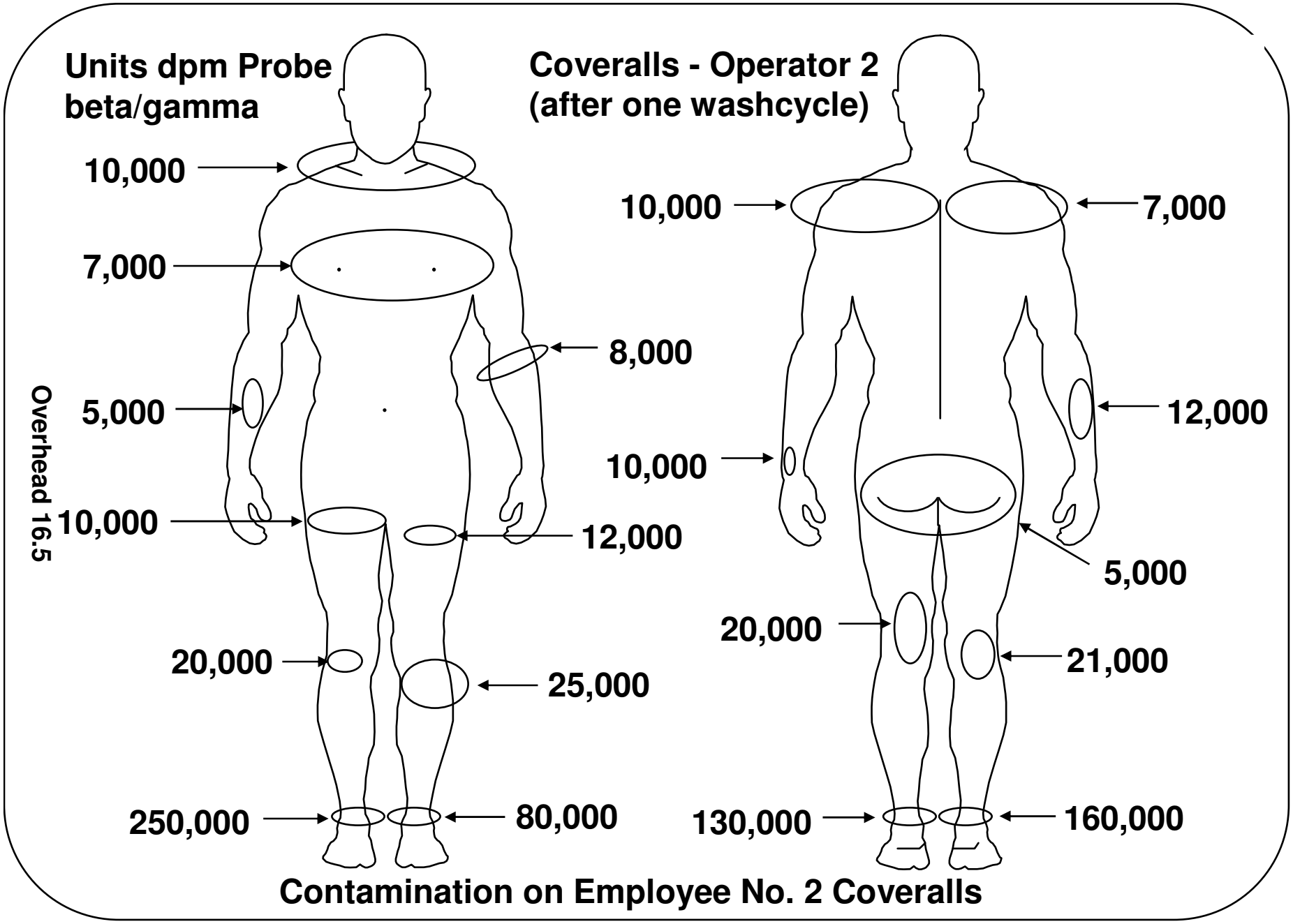
OT 16.4



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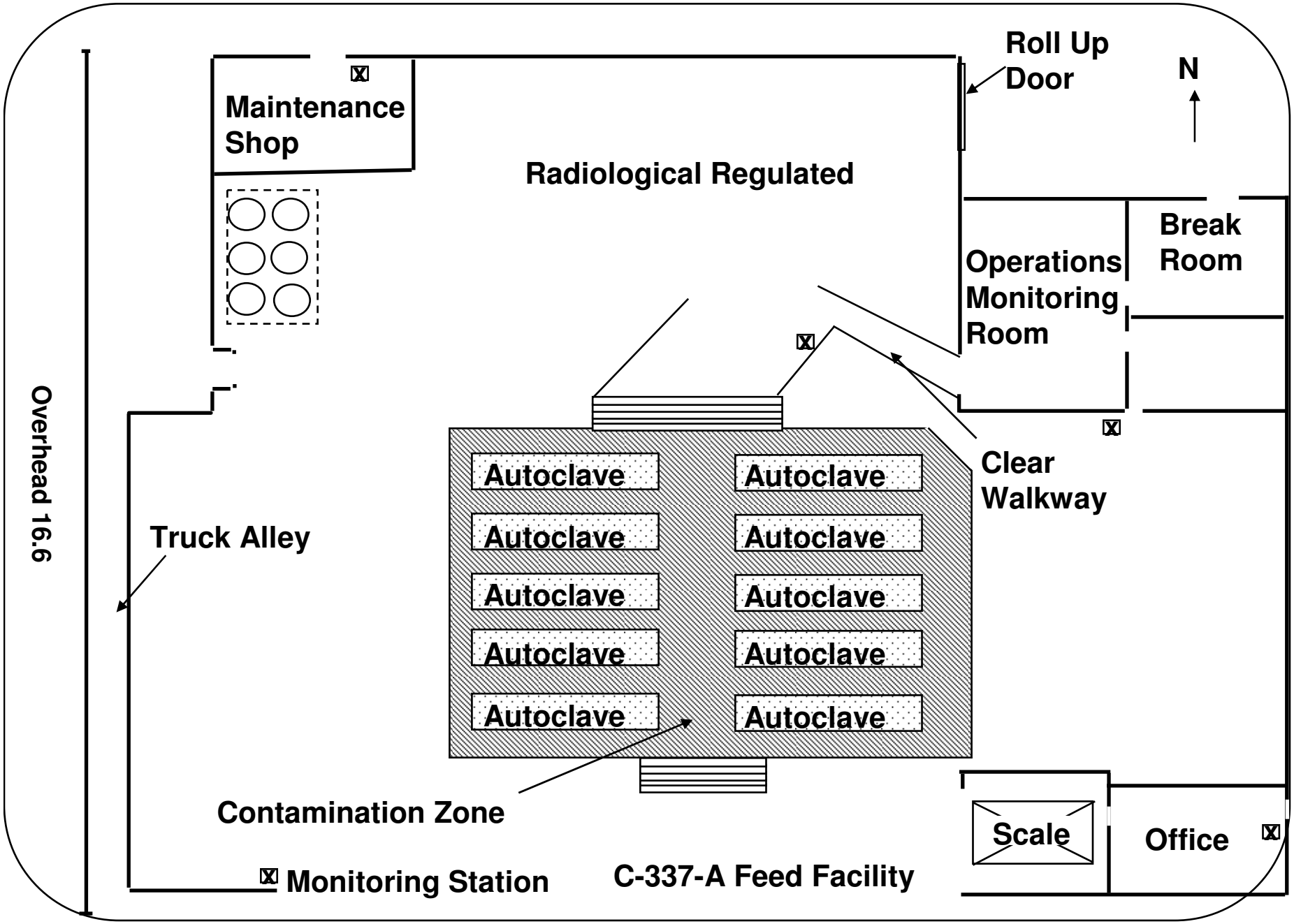
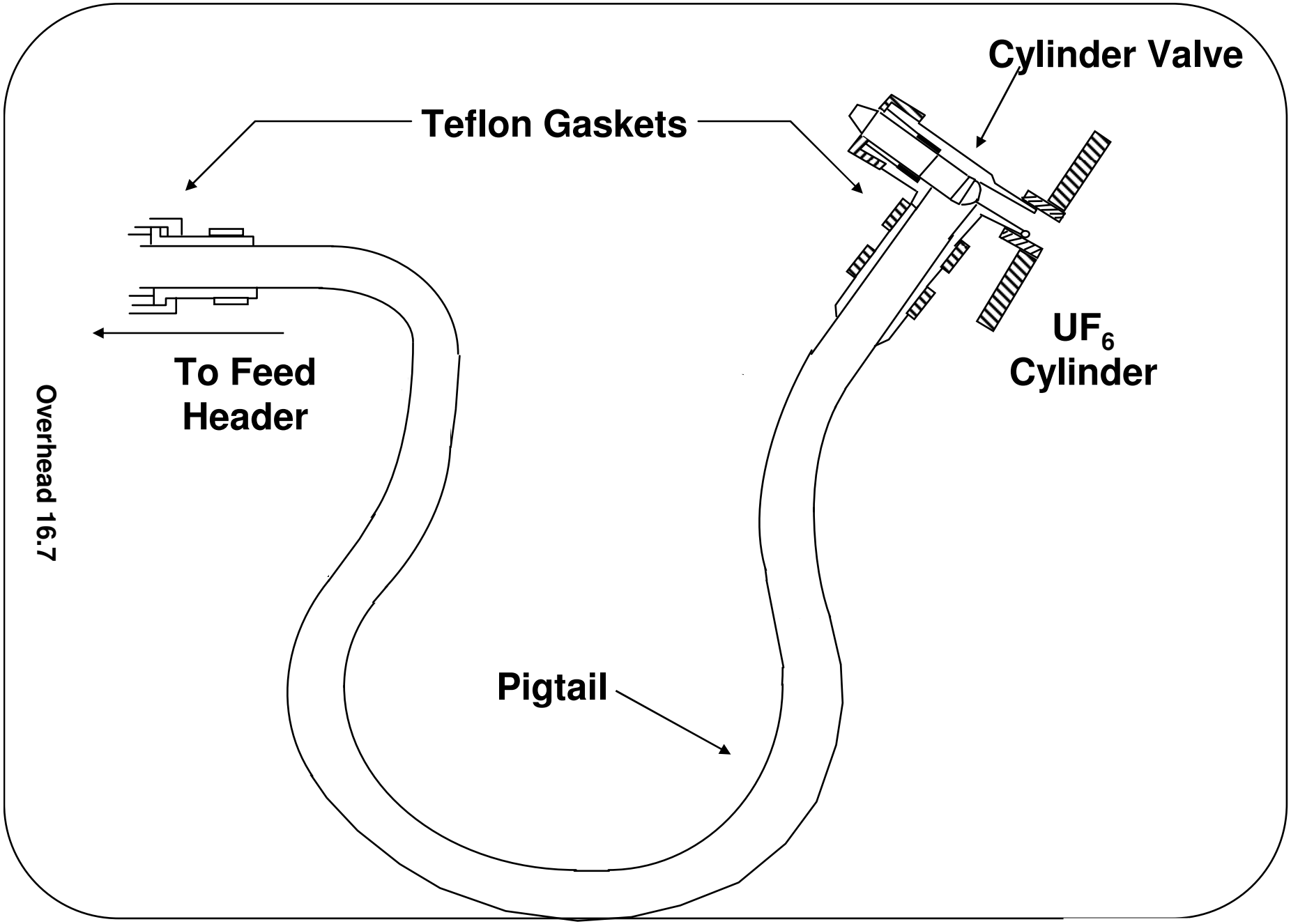
OT 16.5


Roll Up Door
N
Maintenance Shop
Radiological Regulated
Break Room
Operations Monitoring Room
Overhead 16.6
DOE-HDBK-1141-2008
Clear Walkway
Truck Alley
Autoclave
Autoclave
Autoclave
Autoclave
Autoclave
Autoclave
Autoclave
Autoclave
Autoclave
Autoclave
Contamination Zone
Scale
Office
Monitoring Station
C-337-A Feed Facility
OT 16.6



Overhead 16.7

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OT 16.7

Review and Critique of Findings and Improved Writing of Findings

Overhead 17.1

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Objectives:

- List the three finding categories and describe how to separate surface issues from underlying substantial issues.
- List three of the five priority groupings for assessment findings.
- Identify the three steps needed to write an appropriate finding.
- List three suggestions for effective presentation of findings and concerns.

Finding Categories

- Surface:
  - Minor issues
  - Easy to correct
- Substantial:
  - More significant issues
  - Ease in correcting varies
- Organizational:
  - Programmatic issues
  - Difficult to correct

Priority Groupings

In decreasing order of priority:

- **Imminent danger**
- **Not imminent, but potential danger**
- **Violations of regulations, laws, and orders**
- **Adverse public opinion**
- **Performance and effectiveness issues**

Writing Findings

- List requirement
- State observation
- State concern

Compliance-Based Versus Performance-Based Evaluations

Objectives:

- **Define compliance-based audits.**
- **Define performance-based assessments.**
- **Describe the four key elements of the assessment process.**
- **Describe the advantage of planning for an assessment.**
- **Identify the preferred type of checklist.**

Bases

- Compliance-based audits
- Performance-based assessments

Assessment Process

- Planning
- Performance
- Reporting
- Post-assessment actions:
  - Response evaluation
  - Followup
  - Closeout

Field Exercise Guidelines

Objectives:

- **Demonstrate applied field assessment techniques.**
- **Present a finding to the class after return from the field.**

Assessor Conduct

- Set a good example
- Remember safety:
  - Personal
  - Facility
  - Radiological

After Return from the Field

- Write up 1 finding (prescribed format):
  - Observe 1½-2 minute time limit
  - Coordinate with group members
- Present to class tomorrow morning
- Site personnel should be invited to exit briefing

Presentation Findings

- List the requirement
- State what was observed
- State the concern

Part 4 of 5

Radiological Assessor Training
DOE-HDBK-1141-2008

Student's Guide

Office of Health, Safety and Security
U.S. Department of Energy

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Radiological Assessor Training
DOE-HDBK-1141-2008
Student's Guide

Table of Contents

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I. Introduction

II. DOE radiological health and safety

A. Policy (some key points in summary)

- Establish and maintain a system of regulatory policy and guidance.
- Ensure appropriate training is developed and delivered and the technical competence of the DOE workforce.
- Establish and maintain, from the lowest to the highest levels, line management involvement and accountability for Departmental radiological performance.
- Ensure radiological measurements, analyses, worker monitoring results, and estimates of public exposures are accurate and appropriately made.
- Conduct radiological operations in a manner that controls the spread of radioactive materials and reduces exposure to the work force and the general public and utilizes a process that seeks exposure level as low as reasonably achievable (ALARA).
- Incorporate dose reduction, contamination reduction, and waste minimization features into the design of new facilities and significant modifications to existing facilities in the earliest planning stages.
- Conduct oversight to ensure Departmental requirements are being complied with and appropriate radiological work practices are being implemented.

B. History

DOE has provided numerous written standards for on-site radiological protection, the most recent regulation being 10 CFR Part 835, *Occupational Radiation Protection*, Amended June 2007. This regulation was preceded by:

- DOE Notice 5480.6 of June 17, 1992, *Radiological Control*, which specified that the *DOE Radiological Control Manual* (DOE/EH-0256T) would supersede DOE Order 5480.11.

- DOE Order 5480.11, *Radiation Protection for Occupational Workers* (effective December, 1988). The purpose was to establish radiation protection standards and program requirements for DOE and DOE contractors for the protection of workers from ionizing radiation.

The establishment of DOE radiological protection standards did not start with these documents. A chronology of dose limits of DOE and its predecessor agencies, the Atomic Energy Commission (1946-1975) and the Energy Research and Development Administration (1975-1977), demonstrate a lowering of whole body dose limits over the last 50 years.

In the establishment of these dose limits, DOE has followed recommendations of national and international radiological protection groups, notably the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP).

C. Hierarchy of requirements

Currently within DOE there are two parallel hierarchies of requirements:

- Rules and/or regulations (these terms are used interchangeably in this training)
- DOE Orders

III. Rules and regulations

In response to the enforcement authority in the Price-Anderson Amendments Act (PAAA) of 1988, DOE is converting its contractual requirement in orders to enforceable rules to enhance contractor accountability for safety.

A. DOE enforcement of rules under PAAA

10 CFR Part 820 (effective on September 16, 1993, Amended June 2007) sets forth the procedures to implement the provisions of the PAAA. Part 820 requires contractors to comply with DOE Nuclear Safety Requirements.

PAAA demands a “large stick” to enhance contractor accountability for safety. Rules provide authority for the assessment of civil and criminal penalties and thus provide the large stick.

B. Penalties under Part 820

1. Civil penalties

   DOE may assess civil penalties against any person subject to Part 820, for violations of:

   - Codified rules in the CFR
   - Compliance orders
   - Any program or plan required by a rule or compliance order

   Note: Certain nonprofit educational institutions and other listed institutions are exempt from assessment of civil penalties.

2. Criminal penalties

   If a person subject to the Atomic Energy Act of 1954, as amended, or Nuclear Safety Requirements, has by action or omission knowingly and willfully violated, caused to be violated, attempted to violate, or conspired to violate any section of the Atomic Energy Act of 1954, as amended, or applicable DOE Nuclear Safety Requirements, the person shall be subject to criminal sanctions.

3. The “carrot and stick” approach

   DOE may provide monetary incentives in its management and operating (M&O) contracts for actions consistent with or exceeding requirements, and to penalize actions and activities that were not in compliance with requirements.

   Noncompliance with the Radiation Protection Program can subject a contractor to PAAA enforcement. There are provisions to mitigate penalties for self identifying and reporting violations.

C. DOE Nuclear Safety Requirements

DOE Nuclear Safety Requirements are the set of enforceable rules, regulations, or orders relating to nuclear safety that have been adopted by DOE (or by another agency if DOE specifically identifies it).

Compliance orders are issued by the Secretary. They identify a situation that violates, potentially violates, or otherwise is inconsistent with the:

- Atomic Energy Act of 1954, as amended
- Nuclear statutes
- Nuclear Safety Requirements

Compliance orders:

- Mandate a remedy or other action
- States the reason for the remedy or other action

D. 10 CFR Part 835

On December 14, 1993, DOE published a final rule in the *Federal Register* (58 FR 65458) Title 10 Code of Federal Regulations Part 835, *Occupational Radiation Protection* (10 CFR 835). On November 4, 1998 an amendment to 10 CFR 835 was published in the *Federal Register* (63 FR 59663).

The purpose of 10 CFR 835 is the codification of radiological protection requirements. It contains "shall" statements, which are legally binding. It also contains:

- Prescriptive language

- Added emphasis on ALARA
- Requirements for a Radiation Protection Program (RPP)
- Federal law
- Criminal and civil penalties for violations

E. Radiation Protection Program (10 CFR Part 835)

Each site, under Part 835, must submit a written Radiation Protection Program (RPP).

The RPP requires careful consideration because noncompliance may subject a contractor to PAAA enforcement

F. Guidance documents for 10 CFR Part 835

Two types of regulatory guidance documents have been developed:

- Guidance for implementing the provisions of 10 CFR Part 835.
- Guidance providing technical positions.

The above are available through the DOE HS-11 website at:

Insert appropriate URL

Unlike the requirements specifically set forth in 10 CFR Part 835, the provisions in guidance documents are not mandatory. They are intended solely to describe the rationale for, and the objectives of, regulatory requirements and/or to identify acceptable methods for implementing regulatory requirements.

Failure to follow a guidance document does not in itself indicate noncompliance with a specific requirement of the rule. A finding of noncompliance is found for a failure to satisfy the regulatory requirement.

Following a guidance document in the prescribed manner will ordinarily create a presumption of compliance with a related regulatory requirement.

1. Technical guidance

   Technical guidance describes and disseminates technical methods and techniques for fulfilling implementation and, in turn, the requirements in 10 CFR Part 835. Examples of these guidance are DOE Technical Standards and DOE Radiological Control Technical Positions (RCTPs).

2. Implementation guides (IGs)

   Implementation guidance is intended to identify and make available to DOE contractors basic program elements and acceptable methods for implementing specific provisions of the final rule. Thirteen implementation guides have been developed for 10 CFR Part 835.

G. Relationship between 10 CFR Part 835 and 10 CFR Part 20

10 CFR Part 20 is the occupational radiological regulation issued by the Nuclear Regulatory Commission (NRC).

The question of consistency among federal agencies in their occupational radiological protection regulations became a major point of discussion during the rule making process.

While agreeing with the goal of consistency, DOE believes that it must promulgate its own regulations because of the unique nature and diversity of radiological activities within the DOE complex. The final rule allows DOE to establish more rigorous requirements in areas of particular concern. Overall 10 CFR Part 835 has many similarities as 10 CFR Part 20.

IV. DOE STD *Radiological Control* and Orders

A. *Radiological Control*

In January 1992, a memorandum was sent to the heads of DOE elements involved in managing radiological programs. In the memorandum, the Secretary directed a series of initiatives to enhance the conduct of radiological operations within the Department of Energy. Also in this memo, the Assistant Secretary of Environment, Safety and Health was directed to develop a comprehensive and definitive radiological control manual. The *DOE Radiological Control Manual* was developed to meet that directive and was approved by the Secretary and promulgated with DOE Notice 5480.6, *Radiological Control*, in July 1992.

After the issuance of 10 CFR 835 as a final rule in December 1993, DOE Notice N441.1, *Radiological Protection for DOE Activities*, was issued on 9-30-95. This cancelled the notice which made the Radiological Control Manual a requirements document. However, the notice stated that "cancelled orders that are incorporated by reference in a contract shall remain in effect until the contract is modified to delete the reference.

N441.1 also retained some of the radiation protection requirements from the Radiological Control Manual that were not included in 10 CFR 835.

In July, 1999, the Radiological Control Manual was replaced by the standard, DOE-STD-1098-99, *Radiological Contro*l. Many DOE sites contractually must still adhere to the provisions of either the Radiological Control Manual or the Radiological Control Standard. Subsequent to the 1998 amendment to 10 CFR 835, the effective date of N441.1 has passed.

The DOE Radiological Control Standard is not regulatory in nature. It is a guidance document that describes DOE's policy and expectations for an excellent radiological control program**.**

1. Implementation

   If a site fully implements a provision of the DOE Radiological Control Standard, the user will have most likely complied with any related statutory, regulatory, or contractual requirements. Users are cautioned that they must review the source document (10 CFR 835) to ensure compliance.

2. Enforceability

   When incorporated into contracts, the provisions of the DOE Radiological Control Standard are binding requirements.

   If portions of the Site-Specific Radiological Control Standard are incorporated in the RPP under Part 835 and approved by DOE, they are also binding.

B. The Site-Specific Radiological Control Standard

- The DOE Radiological Control Standard states that a Site-Specific Radiological Control Standard should be written and followed.

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C. Relationship between 10 CFR Part 835 and the DOE Radiological Control Standard

1. Compliance

   - The Office of Enforcement (HS - 40) will enforce 10 CFR Part 835. It can assess fines and penalties.

   - The Program Offices will audit for both compliance with 10 CFR 835 and contractual agreements including the DOE Radiological Control Standard, Orders, etc. Results of these audits can affect the contractor's award fee.

2. What if there are conflicts?

   10 CFR Part 835 takes precedence over requirements of the DOE Radiological Control Standard and orders. It is unlikely that there will be a conflicting requirement between the two documents, although one document may have a requirement that is not addressed in the other.

It is planned that all requirements for nuclear safety will be incorporated into rules.

3. "Shall" and "should" statements

   - 10 CFR Part 835 contains "shall" statements. "Shall" statements in Part 835 are legally binding.

     Processes for exemption relief from Part 835 are set forth in Subpart E to Part 820. If relief is requested from provisions of Part 835, the exemption must be considered and granted, if appropriate, by the Chief Health, Safety and Security Officer (HS - 1).

   - The use of "should" in the DOE Radiological Control Standard recognizes that there may be site- or facility-specific attributes that warrant special treatment. It also recognizes that literal compliance with the elements and requirements of the provision may not achieve the desired level of radiological control performance.

D. DOE Standards

DOE has developed several technical standards for occupational radiation protection. Depending on the site specific application, some standards are required to be followed. For example, sites which need to monitor individual external exposures to ionizing radiation need to follow the DOE Laboratory Accreditation Program (DOELAP) standards. Other standards may be incorporated by reference in the site RPP.

Other standards provide technical guidance on specific applications, but adherence to the standard may not be required.

Prior to conducting an assessment, the site requirements documents must be reviewed to determine applicable requirements.

V. Defense Nuclear Facilities Safety Board

A. Establishment

The Atomic Energy Act of 1954 was amended by adding Chapter 21, Defense Nuclear Facilities Safety Board (DNFSB). This amendment established an independent board in the executive branch to provide oversight of some DOE operations at DOE facilities and sites.

B. Members

The DNFSB consists of five members appointed by the President with consent of the Senate.

The Board shall:

- Review and evaluate standards
- Investigate any event or practice at a DOE defense nuclear facility that the Board determines has adversely affected or may adversely affect public health and safety.

The Board may:

- Establish reporting requirements for the Secretary of Energy

By evaluating how well DOE meets its objectives, the DNFSB helps DOE achieve and maintain excellence in radiological protection.

C. Secretary of Energy

The Secretary of Energy shall fully cooperate with the Board.

D. DNFSB Recommendations

DNFSB provides DOE with recommendations for improving safety at DOE defense nuclear facilities. Examples include:

DNFSB Recommendation 91-6 dealt with radiological protection concerns throughout the DOE defense nuclear facilities complex, and identified several actions to be taken by the Department to improve radiological protection performance.

DNFSB Recommendation 92-7 dealt with training and qualification at DOE sites and facilities.

DNFSB Recommendation 98-1 dealt with resolution of internal audit findings.

DNFSB Recommendation 99-1 dealt with safe storage of fissionable materials.

Implementation of DOE and site commitments made in response to DNFSB recommendations are areas to review during an assessment.

I. Introduction

This module provides an overview of many of the provisions of 10 CFR 835. For completeness, individuals should always reference back to 10 CFR 835 for the complete text.

II. Outline of 10 CFR Part 835

Part 835 is the codification of radiological protection requirements. Part 835 contains 14 subparts and five appendices. The outline consists of the following subparts:

A — General Provisions
B — Management and Administrative Requirements
C — Standards for Internal and External Exposure
D — Reserved
E — Monitoring of Individuals and Areas
F — Entry Control Program
G — Posting and Labeling
H — Records
I — Reports to Individuals
J — Radiation Safety Training
K — Design and Control
L — Radioactive Contamination Control
M — Sealed Radioactive Source Control
N — Emergency Exposure Situations

Under 10 CFR Part 835, each site must submit a Radiation Protection Program (RPP).

Part 835 helps to ensure that DOE facilities are operated in a manner such that occupational radiological exposure to workers is maintained within acceptable limits and as low as is reasonably achievable (ALARA).

A. Subpart A - General Provisions

Subpart A contains the scope of the rule. The rule in this part establishes radiological protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from the conduct of DOE activities.

It also includes activities excluded from the provisions of the rule. Activities that are excluded include the following (summarized):

- Activities regulated through a license by the Nuclear Regulatory Commission (NRC) or a state under an agreement with the NRC.
- Activities conducted under the authority of the Director, Naval Nuclear Propulsion Program.
- Specified activities conducted under the Nuclear Explosives and Weapons Surety Program.
- Radioactive material transportation.
- DOE activities in other countries with acceptable radiation protection program.
- Background radiation.

Occupational doses received as a result of excluded activities and radioactive material transportation, as listed above, shall be considered when determining compliance with the occupational dose limits (835.202 and 835.207), and with the limits for the embryo/fetus (835.206).

Subpart A also addresses:

- Definitions
- Radiological units (Curie, rad, roentgen, rem, and multiples)

B. Subpart B - Management and Administrative Requirements

The RPP shall:

- Include formal plans and measures for applying the ALARA process to occupational exposures.
- Specify the existing and/or anticipated operational task.
- Address, but not be limited to, each requirement in Part 835.
- Include plans, schedules, and other measures for achieving compliance.

DOE may direct or make modifications to an RPP. An initial RPP or update shall be considered approved 180 days after its submission unless rejected by DOE at an earlier date.

Compliance with 835.402(d) for radiobioassay program accreditation shall be achieved no later than January 1, 2002.

Internal Audits (10 CFR 835.102)

Internal audits of the radiation protection program, including examination of program content and implementation, shall be conducted through a process that ensures that all functional elements are reviewed no less frequently than every 36 months. This training material and DOE G 441.1, *Management and Administration of Radiation Protection Programs Guide*, provide guidance on DOE's expectations.

Education, Training and Skills (10 CFR 835.103)

Individuals responsible for developing and implementing measures necessary for ensuring compliance with the requirements of this part shall have the appropriate education, training, and skills to discharge these responsibilities. DOE STD-1107-97 *Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities,* provides guidance on DOE's expectations.

Written Procedures (10 CFR 835.104)

Written procedures are required, as necessary, to ensure compliance with 835, commensurate with radiological hazards and education, training and skills of exposed individuals.

C. Subpart C - Standards for Internal and External Exposure

This subpart addresses limits for:

- General employees (occupational)
- Embryos/fetus of declared pregnant worker (i.e., A woman who has voluntarily declared to her employer, in writing, her pregnancy for the purpose of being subject to the occupational dose limits to the embryo/fetus. This declaration may be revoked, in writing, at any time by the declared pregnant worker.)
- Occupationally exposed minors
- General public in a controlled area

It also addresses:

- Planned special exposures
- Nonuniform exposures of the skin

- Concentrations of radioactive material in air

1. Summary of dose limits

10 CFR Part 835 employs the rem unit for several different physical quantities. For information about these quantities refer participants to page 1 of handouts, "Dosimetric Quantities in 10 CFR Part 835."

Exposed Individual	Annual Limit
General Employee: Whole Body (internal and external) (TED)	5.0 rem
General Employee: Lens of Eye	15.0 rem
General Employee: Extremity (below elbow and knees) and skin	50.0 rem
General Employee: Any Organ or Tissue (other than lens of eye) (DED + CED)	50.0 rem
Declared Pregnant Worker: Embryo/Fetus (gestation period)	0.5 rem
Occupationally Exposed Minors (under age 18): (TED)	0.1 rem *
Members of the Public in Controlled Areas: (TED)	0.1 rem

- And 10% of other general employee limits.

2. Planned special exposures (PSEs)

It is acknowledged that unusual conditions can arise in which higher-than-normal doses can be justified. In these well-planned, well-controlled, and highly infrequent and unusual conditions operating management would be permitted to allow specified individual doses exceeding the occupational limit, such as 5 rem per year.

The term "unusual conditions" is made clear by specifying that alternatives which would preclude exposures higher than the prescribed dose limits must be either unavailable or impractical.

10 CFR 835.204 specifies requirements for annual and lifetime dose from PSEs. It also specifies requirements for determining previous individual exposures prior to allowing a PSE.

Every PSE must be approved in advance by DOE and requires the informed consent of the employee involved.

3. Concentration of radioactive material in air

   Appendices A and C contain the derived air concentration (DAC) values used in the control of occupational exposure to airborne radioactive material.

   DACs are listed in appendices A and C of 10 CFR 835. For intakes (appendix A), they are the airborne concentration that equals the annual limit on intake (ALI) divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m^3).

   The ALI is the smaller value of intake of a given radionuclide in a year by a standardized man that would result in a CEDE of 5 rems or a CDE of 50 rems to any individual organ or tissue.

Appendix C contains DACs for controlling external dose from being immersed in a cloud of airborne radioactive material.

Estimation of internal dose shall be based on bioassay data rather than air concentration values unless bioassay data are:

- Unavailable (e.g., radon or very short lived radioisotopes)
- Less accurate than internal dose estimates based on representative air concentration values
- Inadequate

E. Subpart D - Reserved

E. Subpart E - Monitoring of Individuals and Areas

This subpart addresses:

- General requirements
- Instrumentation
- Individual monitoring - external
- Individual monitoring - internal
- Air monitoring
- Receipt of packages containing radioactive material

1. General requirements (10 CFR 835.401)

   Monitoring of individuals and areas shall be performed to:

   - Demonstrate compliance with Part 835.
   - Document radiological conditions.
   - Detect changes in the radiological conditions.
   - Detect the gradual buildup of radioactive material.
   - Verify the effectiveness of engineering and process controls in containing radioactive material and reducing radiation exposure.
   - Identify and control potential sources of individual exposure to radiation and/or radioactive material.

2. Instrumentation

   Instruments and equipment used for monitoring and contamination control shall be:

   - Periodically maintained and calibrated on an established frequency.
   - Appropriate for the type(s), levels, and energies of the radiation(s) encountered.
   - Appropriate for existing environmental conditions.
   - Routinely tested for operability.

3. Individual monitoring - external (10 CFR 835.402)

   For the purpose of monitoring individual exposure to external radiation, personnel dosimetry shall be provided to and used by:

   - Radiological Workers likely to receive:
     – An effective dose equivalent to the whole body of 0.1 rem (100 mrem) or more in a year
     – A shallow dose equivalent to the skin or to any extremity of 5 rem or more in a year
     – A lens of the eye dose equivalent of 1.5 rem or more in a year
   - Declared Pregnant Workers who are likely to receive from external sources a dose equivalent to the embryo/fetus in excess of 10 percent of the applicable limit.

- Members of the public in a controlled area and occupationally exposed minors likely to receive, in one year, from external sources, a dose in excess of 50 percent of the applicable limits.

- Individuals entering a High or Very High Radiation Area.

DOE Laboratory Accreditation for Personnel Dosimetry is required for external dose monitoring programs implemented to demonstrate compliance with 10 CFR 835.

4. Individual monitoring - internal (10 CFR 835.402)

   Internal dose evaluation programs (including routine bioassay programs) shall be conducted for:

   - Radiological Workers who, under typical conditions, are likely to receive 0.1 rem or more committed effective dose equivalent from all occupational radionuclide intakes in a year.

   - Declared Pregnant Workers likely to receive an intake or intakes resulting in a dose equivalent to the embryo/fetus in excess of 10 percent of the limit.

   - Members of the public in a controlled area and occupationally exposed minors who are likely to receive a committed effective dose equivalent in excess of 50 percent of the limit from all intakes in a year.

DOE Laboratory Accreditation for Radiobioassay is required for internal dose monitoring programs implemented to demonstrate compliance with 10 CFR 835.

5. Air monitoring (10 CFR 835.403)

   Measurements of radioactivity concentrations in the ambient air of the workplace shall be performed as follows:

   - Air sampling shall be performed in occupied areas where an individual is likely to receive an exposure of 40 DAC-hrs or more in a year (i.e. an annual intake of 2 percent or more of the specific ALI value) for the mixture of isotopes.

   - Samples shall be taken as necessary to characterize the levels or concentration of airborne radioactive material when respirators are worn for radiation protection purposes.

   - Real-time air monitoring shall be performed when there is a need to alert potentially exposed individuals to unexpected increases in airborne radioactivity levels such that immediate action is necessary in order to minimize or stop inhalation exposures.

6. Receipt of Packages Containing Radioactive Material (10 CFR 835.405)

   Establishes requirements to monitor certain types of packages and sets a time limit of not later than 8 hours after the beginning of the working day following receipt of the package.

F. Subpart F - Entry Control Program (10 CFR 835.501)

Subpart F addresses entry into:

- Radiological Areas
- High Radiation Areas
- Very High Radiation Areas

1. Radiological Areas

   The degree of control shall be commensurate with existing and potential radiological hazards within the area.

   One or more of the following methods shall be used to ensure control:

   - Signs and barricades
   - Control devices on entrances
   - Conspicuous visual and/or audible alarms
   - Locked entrance ways
   - Administrative controls

   "No control(s) shall be installed at any radiological area exit that would prevent rapid evacuation of personnel under emergency conditions."

2. High Radiation Areas

   A High Radiation Area is an area where radiation levels exist such that an individual could exceed a deep dose equivalent to the whole body of 0.1 rem in any one hour at 30 centimeters from the

source or from any surface that the radiation penetrates.

If an individual receive a deep dose equivalent exceeding 1.0 rem in an hour (at 30 cm), a High Radiation Area shall have one or more of the following:

- A control device that prevents entry to the area when high radiation levels exist or that, upon entry, causes the radiation level to be reduced below that level that defines a High Radiation Area.

- A device that functions automatically to prevent use or operation of the radiation source or field while individuals are in the area.

- A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the High Radiation Area and the supervisor of the activity are made aware of the entry.

- Entryways that are locked. During periods when access to the area is required, positive control over each entry is maintained.

- Continuous direct or electronic surveillance that is capable of preventing unauthorized entry.

- A control device generating audible and visual alarm signals to alert personnel in the area before use or operation of the radiation source and in sufficient time to permit evacuation of the are or activation of a secondary control device that will prevent use or operation of the source.

3. Very High Radiation Areas

   A Very High Radiation Area is an area in which an individual could receive a dose in excess of 500 rad in one hour at 1 meter from the radiation source or from any surface that the radiation penetrates.

   In addition to the requirements for a High Radiation Area, additional measures shall be implemented to ensure individuals are not able to gain unauthorized access to Very High Radiation Areas.

   "No control(s) shall be established in a High or Very High Radiation Area that would prevent rapid evacuation of personnel."

G. Subpart G - Posting and Labeling

Subpart G addresses the general requirements for signs:

- Yellow background
- Black or magenta radiation symbol
- Clear and conspicuous signs

In addition, Subpart G addresses specific posting requirements for:

- Controlled Areas
- Radiation Areas
- High Radiation Areas
- Very High Radiation Areas
- Airborne Radioactivity Areas
- Contamination Areas
- High Contamination Areas
- Radioactive Material Areas

This subpart also addresses exceptions to posting and labeling.

H. Subpart H - Records

Subpart H addresses requirements for records documenting compliance with Part 835 and with the Radiation Protection Program.

Records that are specifically required include those necessary to demonstrate compliance with the ALARA provisions of the rule.

10 CFR 835 also requires that certain records be maintained, including records of:

- Individual monitoring
- Sealed source inventory and control
- Results of surveys for the release of material and equipment
- Results of specified monitoring for radiation and radioactive material
- Maintenance and calibration of radiation monitoring instruments
- Internal audits

Each individual's training as a general employee and as a Radiological Worker must be recorded. Where appropriate, demonstration and documentation of proficiency is required.

Refer to 10 CFR 835 Subpart H for a complete listing of required records.

DOE G 441.1-1B, *Occupational Radiation Protection Record-Keeping and Reporting Guide*, provides additional guidance on record-keeping requirements, including reference to DOE O 231.1A, Change 1, *Environment, Safety and Health Reporting*, and DOE M 231.1-1A, Change 2, *Environment, Safety and Health Reporting Manual*. This order and manual specify radiation protection reporting requirements that may be applicable to the site or facility being assessed.

I. Subpart I - Reports to Individuals (10 CFR 835.801)

Subpart I addresses reports to individuals and their accessibility to reports, including:

On an annual basis, each DOE or DOE contractor-operated site or facility must provide each individual monitored for occupational exposure a radiation dose report of his/her occupational exposure at that site or facility.

Upon the request from an individual terminating employment, records of exposure shall be provided to that individual as soon as the data are available, but not later than 90 days after termination. A written estimate of the radiation dose received by that employee based on available information shall be provided at the time of termination, if requested.

J. Subpart J - Radiation Safety Training

This subpart addresses radiation safety training. The tailored approach to training requirements are based on:

- Unescorted access to or receiving occupational dose in controlled areas (e.g., General Employees)
- Unescorted access to radiological areas or unescorted assignment as Radiological Workers

Requirements of Part 835 include:

- Verification by examination for certain training (e.g., Radiological Worker Training)
- Intervals of training not to exceed twenty four months
- List of topics which must be included in training
- Provisions for limited use of escorts in lieu of training

DOE G 441.1-1B, *Radiation Protection Program Guide*, provides additional guidance on DOE's expectations on radiation safety training.

K. Subpart K - Design and Control

Subpart K addresses added emphasis on facility and equipment design and administrative controls to maintain radiological exposures ALARA.

1. Facility design and modifications (10 CFR 835.1001)

   During the design of new facilities or modification of old facilities, the following objectives shall be adopted:

   - Optimal methods shall be used to assure ALARA
   - Maintain exposure levels below an average of 0.5 mrem/hr
   - Avoid release of radioactivity to the workplace atmosphere
   - The design or modification of a facility and the selection of materials shall include features that facilitate operations, maintenance, decontamination, and decommissioning

2. Workplace controls (10 CFR 835.1003)

   During routine operations, the combination of physical design features and administrative control shall provide that:

   - The anticipated occupational dose to general employees shall not exceed the limits
   - The ALARA process is utilized for personnel exposures to ionizing radiation

L. Subpart L - Radioactive Contamination Control

1. Control of material and equipment

   This section addresses the requirements for release of materials and equipment from radiological areas to controlled areas. Releases to uncontrolled areas are addressed in DOE O 5400.5. Some of the provisions:

   - Specifies conditions for material and equipment in contamination areas (CAs), high contamination areas (HCAs), and airborne radioactivity areas (ARAs) to be released to a controlled area
   - Addresses movement of material and equipment with removable surface contamination, on-site from one radiological area for immediate placement in another radiological area
   - Specifies conditions for material and equipment with fixed contamination to be released for use in controlled areas outside of radiological areas

Control of Areas (10 CFR 835.1102) addresses

- Prevention of inadvertent transfer or removal of contamination to locations outside radiological areas under normal conditions
- Where contamination levels exceed values in Appendix D, the area is controlled commensurate with hazards
- Areas with fixed contamination exceeding radioactivity values may be located outside radiological areas, provided certain controls, conditions, or provisions are met
- Personnel monitoring for contamination upon exiting CAs, HCAs, or ARAs
- Use of protective clothing in CAs and HCAs

M. Subpart M - Sealed Radioactive Source Control

Sealed radioactive sources shall be used, handled and stored in a manner commensurate with the hazard.

Specifies values (Appendix E) for sources which must be inventoried and leak tested at intervals not to exceed six months.

N. Subpart N - Emergency Exposure Situations

This subpart addresses:

- Employees who have exceeded dose limits as result of authorized emergency exposure
- Nuclear accident dosimetry

Individuals whose occupational exposures have exceeded any limits as a result of an authorized emergency exposure may be permitted to return to work provided that certain conditions are met.

Nuclear accident dosimetry

Nuclear accident dosimetry involves installations possessing sufficient quantities of fissile material to constitute a critical mass, and shall include;

- Method to conduct initial screening of personnel involved
- Method and equipment for analysis of biological materials
- A system of fixed nuclear accident dosimeter units
- Personal nuclear accident dosimeters

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I. Introduction

II. *DOE Radiological Control Standard*

The DOE Radiological Control Standard is written for line management. It is designed to assist line managers in fulfilling their duties and responsibilities for implementing an occupational radiation protection program.

It is also designed to assist site/facility workers in having the information they need to be responsible for their own radiological exposures and to help ensure that the controls are in place to eliminate any releases, unplanned exposures or uptake, and to apply ALARA principles. The emphasis is on teamwork and support from line management.

The Radiological Control Standard may be considered as an occupational radiation protection good practices document. Individual sites may have contractual commitments to implement sections of the standard.

III. Chapter 1, Excellence in Radiological Control

This chapter defines the roles of DOE and the contractors in achieving the goal of radiological control excellence. It consists of the following five sections:

- *DOE Radiological Control Standard*
- Leadership in Radiological Control
- Improving Radiological Control Performance
- Contractor Radiological Control Organization
- DOE Management

A. *DOE Radiological Control Standard*

The contractor is responsible for implementing an occupational radiation protection program. To assist this effort, they may develop a Site Radiological Control Standard Implementation Plan. The Site-Specific Radiological Control Standard, which is developed from the Implementation Plan, does not require DOE approval.

B. Leadership in Radiological Control

Commitment of senior management to radiological control is defined in this section of the Standard.

The responsibilities and accountability of each individual for ALARA and radiological excellence is emphasized.

Worker responsibilities and the concepts of conduct of radiological operations are clearly defined.

C. Improving Radiological Control Performance

The use of critiques as a management tool, rather than as a method to “fix blame” or “shoot the messenger,” and the importance of real root cause identification are emphasized. Over 20 radiological performance indicators are identified that are tools designed to assist managers in focusing their priorities and attention on radiological control performance.

D. Contractor Radiological Control Organization

This section discusses the contractor’s radiological control organization and the qualifications of the Radiological Control Manager.

E. DOE Management

This section discusses the roles and responsibilities of DOE management for providing guidance and performance evaluation of radiological control programs.

IV. Chapter 2, Radiological Standards

This chapter deals with administrative control dose limits, contamination control and control levels, and posting.

A. Administrative Control Levels (ACLs) and Dose Limits

Lifetime control levels and dose limits for Radiological Workers, members of the public, embryos/fetuses, and special control levels are discussed in this section.

For most facilities an ACL of 500 millirem or less will be challenging for Radiological Workers. Individual occupational doses, in rem, should be kept below the individual's age in years.

B. Contamination Control and Control Levels

In this section, personnel contamination control, removable and fixed contamination control levels, and airborne radioactivity control levels are given.

C. Posting

Posting requirements are presented in this section and include several non-regulatory areas including: Radiological Buffer Areas, Underground Radioactive Material Areas, and Soil Contamination Areas.

V. Chapter 3, Conduct of Radiological Work

The planning of radiological work, work preparation (e.g., Radiological Work Permits), and the requirements for the entry to and exit from the various types of controlled areas are contained in this chapter. Also covered are: radiological work performance, the aspects of radiological work in different operations with radiation-generating equipment, and construction and restoration projects.

A. Planning Radiological Work

This section emphasizes that the conduct of radiological work is a line responsibility. Worker responsibility, along with systematic planning, provides the necessary information for safe radiological work. Of fundamental importance is the requirement to plan work with an emphasis on ALARA principles.

B. Work Preparation

In this section, the Radiological Work Permit (RWP) is discussed. This chapter states that the RWP is the key to any particular radiological operation, and preplanning is essential.

C. Entry and Exit Requirements

The minimum requirements for entry into and exit from defined radiological areas and other non-regulatory areas are discussed in this section.

D. Radiological Work Controls

This section discusses radiological work as a team effort involving the Radiological Workers, their supervisors, and Radiological Control personnel. The DOE Radiological Control Standard discusses stop-radiological work authority for Radiological Control Technicians (RCTs), their supervisors, line supervision, and workers through their supervisors because of:

- Inadequate radiological controls
- Radiological controls not being implemented
- A radiological control hold point not being satisfied

DOE O 440.1B*, Worker Protection Program for DOE (Including the National Nuclear Safety Administration) Federal Employees*, May, 2007, specifies that individuals have the authority to stop work due to hazardous conditions.

This stop work authority is not limited to just radiological hazards. Workers may "stop work when they discover employee exposures to imminent danger conditions or other serious hazards." Contractors are required to have procedures addressing stop work authority.

E. Evaluation of Performance

Evaluation of performance, critiques, post job reviews, and lessons learned are discussed in this section.

F. Special Applications

This section examines the special aspects for the control of radiological work when working with the following:

- Plutonium
- Uranium
- Tritium
- Accelerators
- Radiation Generating Devices

G. Radiological Design Criteria

This section addresses design objectives for design of new facilities and modification of existing facilities.

VI. Chapter 4, Radioactive Materials

The requirements for labeling, storage, control, release, and transportation of radioactive materials, and the control of radioactive sources, are discussed in this chapter. This chapter also deals with the management of solid and liquid radioactive wastes, and airborne radioactivity. Support activities such as personnel protective clothing and equipment, laundry, decontamination and vacuum cleaners, and portable air-handling equipment are also discussed.

VII. Chapter 5, Radiological Health Support Operations

This chapter discusses the requirements for external dosimetry, internal dosimetry, a respiratory protection program, the handling of contaminated personnel, radiological monitoring and surveys, and instrumentation and calibration.

VIII. Chapter 6, Training and Qualification

The requirements that ensure personnel have the training and qualifications needed to safely work in and around radiological areas and to maintain their own doses and those of others (ALARA) are discussed in this chapter.

A. General Radiological Training

Within these sections, training and qualification standards are discussed for:

- General Employees
- Radiological Workers I and II
- Radiological Control Technicians and Supervisors

B. Other Radiological Training

This section addresses training and qualification for:

- Managers/supervisors
- ALARA training for:
  - Engineers
  - Schedulers
  - Procedure writers
- Radiological control personnel
  - Dosimetry technicians
  - Instrument technicians
  - Medical personnel
  - Records clerk
  - Whole body counter technicians
  - Laboratory personnel
- Radiographers

- Radiation-generating device operators
- Emergency response personnel

C. Training for Special Applications

This section addresses training for the following facilities:

- Plutonium
- Uranium
- Tritium
- Accelerators

IV. Chapter 7, Radiological Records

The requirements for employee and visitor records, radiological control procedures (policies, procedures, Radiological Work Permits (RWPs), ALARA, and quality assurance records), radiological surveys, instrumentation and calibration records, records management, and radiological reporting are presented in this section.

I. Introduction

II. Radiological Control Program

A. Overall program

The Radiological Control Program consists of the commitments, policies, and procedures that are administered by a site or facility to meet the EH Health and Safety Policy.

The Radiation Protection Program required by 10 CFR Part 835 is an element of the overall Radiological Control Program.

The Radiological Control Program should address the following:

- Requirements
- Responsibilities
- Programs/procedures
- Assessments

B. Size of the program

Radiological Control Programs vary in size.

There are several factors that may affect the magnitude of a Radiological Control Program. The specific mission, types and quantities of radioactive material, and the radiation-generating devices that will be used at the site are just a few.

III. Elements of a radiological control program

A. Requirements

B. Responsibilities

C. Programs/procedures

D. Assessments

IV. List of Radiological Control Program Elements

- Organization and administration
- Personnel training and qualification
- Quality assurance
- ALARA
- Radiological Work Control
  - Procedures
  - Radiological Work Permits
- Posting and labeling
- Radioactive material control
  - Source control
  - Release of materials
  - Receipt and transportation
- Radiation-generating devices
  - Sealed source
  - X-ray machines
- Entry control
- Contamination control
- Instrumentation/alarms
- Monitoring
  - Workplace
  - Effluent
  - Environmental

- Dosimetry
  - External
  - Internal
    - Program management (e.g., staffing, technical basis, procedures, quality assurance)
    - Individual monitoring (e.g., air monitoring, contamination monitoring, bioassay)
    - Internal dose evaluation

- Respiratory protection

- Facility specific features
  - Uranium
  - Plutonium
  - Tritium
  - Accelerators

- Radioactive waste management

- Emergency response

- Records

- Assessments/performance indicators

I. Introduction

II. Purpose of DOE Order 5480.22

The intended purpose of DOE Order 5480.22, *Technical Safety Requirements*, is "to clearly state the requirements to have Technical Safety Requirements (TSRs) prepared for DOE nuclear facilities and to delineate the criteria, content, scope, format, approval process, and reporting requirements of these documents and revisions thereof."

On October 10, 2000 an Interim final rule was published in the Federal Register for 10 CFR 830, "Nuclear Safety Management". The Interim Final Rule was effective December 11, 2000, and codifies requirements for TSRs in 10 CFR 830.205. The new rule requires contractors to develop and submit TSRs to DOE for approval by April 10, 2003. In the interim, contractors are required to meet existing safety bases, including TSRs.

TSRs are a critical element in the overall DOE safety program.

A. Definitions (Paragraph 6)

- Technical Safety Requirements are those requirements that define the conditions, safe boundaries, and the management or administrative controls necessary to ensure the safe operation of nuclear facilities and to reduce the potential risk to the public and facility workers from uncontrolled releases of radioactive materials or from radiation exposure due to inadvertent criticality. Technical Safety Requirements consist of safety limits, operating limits, surveillance requirements, administrative controls, use and application instructions, and the bases thereof.

- A controlled document is content maintained uniformly among the copies by an Administrative Control System (paragraph 6, Item e).

Basis: Summary statements of the reasons for the operating limits and associated surveillance requirements. It shows how the numerical value, condition, or the surveillance fulfills the purpose from the safety documentation.

B. Policy (Paragraph 7)

It is the policy of the Department that nuclear facilities operate Cognizant Secretarial Officer (CSO)-approved Technical Safety Requirements, which prescribe the bounds for safe operation of these facilities in order to protect the health and safety of the public and reduce risk to workers.

The TSRs constitute a contract between the operating contractor and DOE management of the methods that will be utilized or constraints to be applied to minimize the potential risk of operating the proposed facility or conducting the proposed activity.

NOTE: TSRs apply to actions by specific facility personnel and their commitments to responsible DOE managers.

The Technical Safety Requirements document is to be a controlled document.

TSRs are <u>not</u> based upon maintaining worker doses below some acceptable level following an uncontrolled release of hazardous material or inadvertent criticality; rather, the risk to workers is reduced through controls that reduce the <u>likelihood</u> and <u>potential</u> <u>impact</u> of such events.

C. Source for bases (justification) of TSRs

In the development of limits, set-points, staffing requirements, and other parameters for input into the individual TSRs, the facility/operation-specific Documented Safety Analysis , particularly the accident analyses contained therein, is normally the primary basis.

The limitations that are included in the TSRs should be derived from the facility-specific safety analysis, which considers all credible accidents. This includes the most significant possible releases of radioactive and hazardous materials, criticality scenarios, and the accidental releases expected during the life of the facility.

Careful and thorough examination of these accident analyses will provide values for defining the operational limits necessary to ensure that facility operations do not occur outside the bounds assumed in the analyses. Such an examination will also identify parameters and operating conditions that should be limited in order to reduce, provide warning of, and mitigate the uncontrolled releases of hazardous materials and to prevent inadvertent criticality.

Examples of requirements expected to be developed include:

- Operating limits for principal process parameters
- Technical and administrative conditions that must be met
- Availability of safety equipment and systems
- Critical functions of instrumentation and controls

Operations within the boundaries of the resulting requirements will provide reasonable assurance that the nuclear facility will not:

- Threaten the health and safety of the public
- Pose an undue risk to workers from the uncontrolled releases of radioactive or other hazardous materials and inadvertent criticality

For facilities that do not have an approved DSA, the technical input into the TSRs must be derived from existing documents/analyses that specifically demonstrate the limiting conditions that the facility is expected to experience during normal operations and potential accident conditions.

In order to serve as the basis for the TSRs, these studies must systematically evaluate:

- All potential off-normal conditions that could occur during the life of the facility
- What could be considered design basis accidents

D. Responsibilities for TSRs

- Prepare → Contractor
- Review → DOE Field Office
- Approve → CSO

E. Identification of violations

Violations of a TSR occur as the result of four circumstances:

- Exceeding a Safety Limit (SL)
- Failing to take the necessary actions within the required time limit following:
  - Exceeding a Limit Control Setting (LCS)
  - Failing to meet Limiting Conditions for Operations (LCO)
  - Failing to successfully meet a Surveillance Requirement (SR)
- Failing to perform a surveillance within the required time limit
- Failing to comply with an Administrative Control (AC) requirement

As stated previously, compliance with TSRs is required by 10 CFR 820.205, violations may be enforceable under PAAA.

F. Reporting Requirements (DOE Order 231.1A Change 1) Occurrence Reporting and Processing of Operations Information

- Categorization
  - Operational Emergency
  - Significance Category (1 – 4)
- Notification
- Follow-up notification
- Occurrence Report preparation

TSR ACs may impose additional facility- or operations-specific reporting requirements, which must also be carefully and fully followed.

Violations of TSRs may need to be reported as part of the Noncompliance Tracking System (NTS). For guidance on NTS reports, refer to Operation Procedure *Identifying, Reporting, and Tracking Nuclear Safety Noncompliances*, June 1998, prepared by the DOE Office of Enforcement (HS-40).

G. Ancillary guidance

The TSR document shall be kept current at all times so that it reflects the facility as it exists and is analyzed in the SAR. The TSR must be approved prior to changes in the facility or facility practices.

TSRs should be written in a clear and concise manner, in language that is understandable by those in the facility operating organization. The TSR should not contain excessive details that belong more appropriately in the SAR.

The scope and content of TSRs are to be limited to only the most critical nuclear safety areas. This serves to make TSR Documents more useful for controlling facility safety.

H. Radiological Assessment of TSR Compliance

TSRs typically specify requirements for several areas that may be reviewed as part of a radiological assessment. These areas include:

Area monitors:
- Criticality monitors
- Area Radiation Monitors
- Air Monitors (i.e., real time air monitors, fixed head air samplers)

Surveillance requirements for area monitors

HEPA ventilation systems and their surveillances

Shift Staffing
- Facility staff qualification, training and retraining

Audits and reviews

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I. Introduction

The guidance in DOE-STD-1136-2004, *Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities, 2004,* should be reviewed in detail prior to conducting an assessment of uranium facilities. The following is a brief overview of the radiological aspects of uranium.

II. Radiological aspects of uranium

A. Radiological properties of uranium

Fifteen radioisotopes exist, but the three of most concern to the uranium industry are:

Uranium-238:
99.7% abundant in natural uranium;
half-life = 4.5 billion yrs,
specific activity = 3.3 E-7 Ci/g

Uranium-235:
0.72% abundant;
half-life = 710 million yrs,
specific activity = 2.1 E-6 Ci/g

Uranium-234:
0.006% abundant;
half-life = 247 thousand yrs,
specific activity = 6.2 E-3 Ci/g

Enriched uranium has a higher content of Uranium-235 than found in nature. Typical enrichment values are:

- 2%-3% Uranium-235: power reactor grade fuel
- >90% Uranium-235: weapons grade material

Specialized reactor fuel may have enrichments other than those listed above.

The uranium byproduct of enrichment is reduced in Uranium-235 content and is called depleted uranium. Its typical composition is as follows:

- 99.75% Uranium-238
- 0.20% Uranium-235
- 0.0007% Uranium-234

As a result of the differences in specific activities, Uranium-234 may account for a significant fraction, or even the majority, of the radioactivity for enriched uranium.

For example, for 3% enriched uranium (i.e., 3% Uranium-235), the Uranium-234 (with an abundance of 0.03%) would have approximately 6 times the activity as Uranium-238 and approximately 30 times the activity as Uranium-235.

Uranium-238 and Uranium-234 are part of the uranium decay series, while Uranium-235 is part of the actinium series. Therefore, following chemical separation, decay products will continue to grow in. The most significant of these are Thorium-234 and Protactinium-234m from the uranium series and Thorium-231 from the actinium series.

Other small amounts of radioactive material may be present as the result of reprocessing uranium. These include Neptunium, Plutonium, Technetium-99, and other radioisotopes of uranium, including Uranium-232 and Uranium-236.

B. Radioisotopes

The primary radioisotopes of uranium are all long-lived alpha-emitters. The specific activity (Ci/g) of uranium increases as enrichment increases; therefore, enriched uranium is a more serious radiation hazard.

In most uranium facilities, the inhalation hazard from alpha particles released in the respiratory tract is the predominant radiological hazard associated with the alpha emitting uranium isotopes. In addition, uranium decay products are primarily beta-emitters. For external exposure, the major concern is the high energy beta particle from Protactinium-234m (2.29 MeV). As a result of beta radiation, the typical contact dose with a block of uranium is approximately 200 mrad/hr.

Trace contaminants such as Technetium-99 and Uranium-232 may result in additional external radiation dose when present.

As a result of the alpha-neutron reaction, casks of enriched uranium hexafluoride may also emit neutrons. Typical dose rates are on the order of a few mrem/hr.

C. Criticality

Uranium-235 and Uranium-233 are both fissile materials; therefore, facilities handling enriched uranium and/or Uranium-233 have the potential for criticality accidents, generating large amounts of neutron and gamma radiation.

D. Toxicological properties of uranium

Uranium is a heavy metal poison and is toxic in much the same way lead or mercury is. For soluble compounds of low enrichments (< 5% Uranium-235), the toxic properties of uranium override the radiological hazards. The kidney is the primary organ of concern.

For insoluble compounds of any enrichment or all compounds of highly enriched uranium, the radiological hazards are limiting.

III. Detection, measurement, and survey techniques

A. Monitoring program

A radiation protection monitoring program in a uranium facility must ensure the detection of typical ionizing radiations over wide energy ranges.

To detect alpha radiation from the uranium isotopes, exposure rate surveys using photon-sensitive portable and fixed alpha detectors such, as zinc sulfide or gas proportional counters, should be used.

Appropriate beta detection instrumentation should be available to measure decay products such as Protactinium-234m. If Technetium-99 is suspected, special low-energy beta particle detection equipment should be available.

If large quantities of uranium hexafluoride are present, appropriate neutron survey instruments should be available to measure the neutron radiation.

If the facility contains enriched uranium and/or Uranium-233, appropriate criticality safety alarm systems shall be in place and appropriate neutron and gamma survey instruments available.

Continuous air monitors (CAMs), sample extraction lines that go to CAMs, and continuous radiation dose monitors should be placed outside glove boxes and fume hoods.

B. Survey Techniques

Monitoring practices include, but are not limited to, the following:

- Contamination surveys of the workplace
- Release surveys
- External exposure surveys
- Airborne contamination surveys
- Routine surveillance by a Radiological Control Technician

All work areas must be monitored for contamination levels on a regularly scheduled basis. The frequency of such surveys will depend on the potential for dispensability of the radioactive material. During these routine surveys, all work enclosures, work surfaces, floors, and equipment within the workplace should be surveyed.

C. Workplace characterization

At the time a program is established, measurements of external dose should be made at all locations where it occurs to delineate the levels involved (workplace characterization). Additional measurements should be made at the same frequency as the contamination surveys to identify the buildup of uranium in HEPA filters and glove boxes.

Airborne contamination surveys should be performed for:

- Prompt detection of airborne contamination for worker protection
- Personnel dose assessment
- Monitoring of trends within the workplace
- Special studies

IV. Personnel protection requirements

Workers in uranium facilities need to be appropriately trained on the hazards. DOE has developed DOE-HDBK-1113-98*, Radiological Safety Training for Uranium Facilities*, 1998. This handbook provides DOE's guidance on expectations for training of uranium workers.

A. Personnel air sampling

The use of personnel air sampling programs should be considered in monitoring individual Radiological Workers.

B. Protective clothing

As a minimum, personnel who perform operations in controlled areas should wear

coveralls, gloves, and shoe covers. No personal outer clothing should be permitted under coveralls. For inspections or visits, lab coats, gloves, and shoe covers may be permissible.

Protective clothing should be removed at the step-off pad, and personnel monitoring for contamination shall be performed. If this is not practical, strict control of the movement of personnel shall be maintained from the step-off pad to a location where protective clothing can be removed. Personnel wearing protective clothing shall not be allowed to mingle with individuals wearing personal street clothing. Protective clothing shall not be allowed in uncontrolled areas such as offices, lunchrooms, or control rooms.

C. Respiratory protection

Respiratory protection should be readily available. Respiratory protective equipment should be used for all bag-out operations, bag and glove changes, and any situation involving a potential or actual breach of confinement.

V. External dose control

A. Beta radiation

Beta radiation is usually the dominant external radiation hazard in work with unshielded forms of uranium. The primary concern is Protactinium-234m, though other radionuclides may be present. Particular care should be taken in operations such as melting and casting, where decay products could be separated and concentrated. Appropriate measurements should be made of the material and appropriate extremity dosimetry worn by workers handling the material.

B. Gamma radiation

Gamma radiation is normally not the controlling factor at uranium facilities. However, significant gamma fields can exist in areas where large quantities of uranium are stored. Appropriate actions including time, distance, and shielding considerations should be taken to maintain radiation doses ALARA.

C. Neutron radiation

Neutron radiation from enriched uranium fluoride compounds should also be considered in determining potential external radiation hazards.

VI. Internal dose control

Intakes

In most uranium facilities, the primary radiological hazard is the potential for internal intakes of uranium. This hazard must be controlled by appropriate facility and equipment design, contamination control procedures, and protective clothing.

Inhalation is the primary route of concern. Uranium transported from the lungs is deposited in the bone (22%), kidney (12%), or other tissues (12%), or excreted (54%), according to International Commission on Radiological Protection (ICRP) Publication 30.

Control must be verified by a bioassay program. Urinalysis is the most common technique, but fecal analysis and *in vivo* monitoring may also be appropriate.

DOE-STD-1121-98, *Internal Dosimetry, Reaffirmed May 2003,* provides technical guidance on internal dosimetry programs, including evaluation of occupational internal doses from exposure to radon and thoron. This standard should be reviewed prior to conducting assessments of internal dosimetry programs.

VII. Special controls and considerations at uranium operations

A. Criticality alarm systems (gamma or neutron) shall be provided in each area where an accidental criticality is possible. Site requirements documents relating to criticality alarms should be reviewed prior to the assessment, if applicable. These requirements may include: ANSI/ANS 8.1, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*; ANSI/ANS 8.3 *Criticality Accident Alarm* Systems; ANSI/ANS 8.7, *Nuclear Criticality Safety in the Storage of Fissile Materials*; ANSI/ANS 8.15, *Nuclear Criticality Control of Special Actinide Elements*; and ANSI/ANS 8.19, ANS *Administrative Procedures for Nuclear Criticality*.

B. All DOE facilities that possess sufficient quantities and kinds of fissile material to constitute a potentially critical mass shall provide nuclear accident dosimetry (fixed and personal). The number of dosimeters needed and their placement will depend on the nature of the operation, structural design of the facility, and accessibility of areas to personnel. An analysis of the dosimeters and their placement should be conducted and documented.

C. Uranium metal in finely divided form is pyrophoric; therefore, any grinding or milling operations must be carefully conducted to avoid fires.

   Uranium hexafluoride is commonly found in many uranium operations. This material is a solid at room temperatures but volatilizes readily at elevated temperatures. As a gas, it is extremely hazardous, forming hydrofluoric acid when it comes in contact with water. Operations involving uranium hexafluoride must be conducted very carefully to prevent release of the gas.

D. External radiation hazards from uranium are primarily associated with decay products; therefore, operations in which the decay products can separate and concentrate must be monitored carefully. For example, crucibles used to melt depleted uranium and casks used to ship uranium hexafluoride are sometimes more radioactive after they are emptied than when they are full. The reason is that the decay products are left in the emptying process and are no longer self-shielded by the uranium.

I. Introduction

II. Radiological aspects of tritium

A. There are three primary sources of tritium. These are:

1. Environmental sources - Reactions between cosmic rays and the upper atmosphere

$^{14}N + {}^{1}n \rightarrow {}^{3}H + {}^{12}C$

$^{2}H + {}^{2}H \rightarrow {}^{3}H + {}^{1}H$

2. By-product of power reactors

- Ternary fission - A fission event resulting in fission fragments, one of which is tritium. Occurrence typically has a 0.1% yield.

B-10 (n, 2 alpha) ^{3}H

Li-7 (n, n alpha) ^{3}H

3. DOE production of tritium (Hanford, Savannah River reactors) is by the following reaction:

$^{6}Li + {}^{1}n \rightarrow {}^{3}H + \text{alpha}$

B. Chemical and radiological properties of tritium

1. Chemical forms

- Elemental tritium (tritium gas, HT, DT, T_2)
- Tritiated water (tritium oxide, HTO, DTO, T_2O)
- Special tritium compounds (STCs): created by intentional combination of tritium with the desired materials or by inadvertent contamination of a material that has been subjected to the presence of tritium for a period of time.

  These are classified in a number of ways, depending on their host material (metal or organic), rate of tritium release (stable or unstable), and physical form (particulate or non-particulate). They include:

  - Organically bound tritium (OBT); the main types of OBT encountered in the DOE complex are solvents, oils, and solid particulates (e.g., plastics, nylon, and organic dust forms).
  - Particulates; stable or insoluble forms are referred to as stable tritiated particulates (STPs).

2. Radiological properties

   - $^{3}H \rightarrow {}^{3}He$ + beta minus and anti-neutrino
   - E_{max} = 18.6 keV, E_{avg} = 5.69 keV
   - Half-life = 12.32 years
   - Specific activity = 9619 Ci/gram
   - ALI_{water} = 3000 MBq = 8 E4 μCi (inhalation and ingestion)
   - DAC_{water} = 0.8 MBq/m^3 = 2 E-5 μCi/cm^3
   - $DAC_{elemental}$ = 2 E4 MBq/m^3 = 0.5 μCi/cm^3
   - f_1 = 1
   - Committed equivalent dose per unit intake = 1.73 E-11 Sv/Bq = 6.4 E-2 mrem/μCi
   - $DAC_{elemental}/DAC_{water}$ = 25,000

In addition, DOE has issued guidance on radiological protection for special tritiated compounds in Radiological Control Technical Position, RCTP 99 - 02, *Acceptable Approach for Developing Air Concentration Values for Controlling Exposures to Tritiated Particulate Aerosols and Organically-Bound Tritium*. DOE has also issued RCTP 06-01, *Acceptable Approaches for Developing Sealed Radioactive Sources and Posting and Labeling Requirements for Special Tritium Compounds* (*STCs*).

DOE has also developed a technical standard, *Radiological Control Programs for Special Tritium Compounds*, DOE-HDBK-1184-2004, Change Notice 1 May 2006.

C. Potential exposure pathways of tritium

Dose pathways and biological effects

- Inhalation
  - Elemental tritium (tritium gas) - Limiting condition is exposure to the lung
  - Approximately 0.005% of HT inhaled is converted to HTO prior to exhalation
  - Nearly 100% of inhaled HTO is incorporated into body fluids/tissues.

- Ingestion
  - Tritiated water
    - Assumed to be instantaneous
    - Biological half-life is normally ten days, but may be reduced by a factor or two-three with increased fluid intake

- Skin absorption of HTO through intact skin ≈50% of that inhaled.

For different modes of entry of STCs:

- STPs behave with the characteristics of the particle to which they are attached.

- Soluble OBT distributes throughout the body causing a whole body dose. Insoluble OBT can be taken into the body by inhalation when in particulate form. Airborne droplets of insoluble components of oils may be treated as stable particulates.

D. General sources of tritium releases

1. Gaseous releases - ventilation exhaust systems

2. Liquid wastes

   - Aqueous

   - Organic (e.g., oils)

3. Solid wastes

   - Contaminated wastes

   - Treatment residues

E. Exposure controls for tritium

The personnel protection requirements for tritium include:

- Airborne contamination controls

- Surface contamination controls

  1. Airborne controls

     - Differential room pressure zones

     - Dilution ventilation

     - Room-air detritiation systems

     - Local exhaust ventilation

2. Contamination controls

    - Good housekeeping
    - Good work practices

3. Personnel protective equipment

    - Air supplied respirators
    - Protective clothing

F. Metabolism of tritium

The tritium beta lacks sufficient energy to penetrate the dead cell layer in skin. Therefore, it is of little consequence as an external hazard. The beta particles can produce Bremsstrahlung radiation when they interact with matter, although the tritium Bremsstrahlung is extremely low energy. It is remotely possible that the Bremsstrahlung exposure could become significant around materials with very high specific activities and little or no shielding.

Tritium can deliver a radiation dose if it gets inside the body. Modes of entry include:

- Inhalation
- Ingestion
- Absorption

1. Inhalation

    Tritium gas (HT) is only slightly incorporated into the body when inhaled. Approximately 0.005% of HT inhaled is converted to tritiated water prior to being exhaled. Depending upon the rate at which HT converts to HTO *in vivo,* it is possible that some dissolved HT may be excreted in urine.

Tritiated water (HTO) is much more radiologically hazardous than tritium gas. Inhaled HTO enters the body through the lung fluids with 100% efficiency, and mixes rapidly with body water. Nearly 100% of tritiated water (HTO) inhaled is incorporated into body fluids and tissues.

2. Ingestion

   Ingested HTO is assumed to be completely and instantaneously absorbed from the gastrointestinal tract and mixes rapidly with the body fluids so that following ingestion, the concentration in sweat, sputum, urine, blood, perspiration and expired water vapor is the same.

3. Absorption

   There is negligible skin absorption for tritium gas. Some HT can be absorbed through the skin from contact with surface contamination. This uptake is probably in the form of HTO, resulting from the oxidation of HT. Some tritium may be retained in the skin in the form of organics, presumably resulting from exchange reactions with HT on or in the skin.

   HTO can be readily absorbed through the skin. It will be uniformly distributed in all biological fluids within one to two hours.

   Most exposures are to HTO, which rapidly enters the body water via absorption through the lungs and/or skin. A small amount of HT can dissolve in lung fluids, convert to HTO, and enter the body fluids. Exposures to HTO are approximately 10,000 to 25,000 times more hazardous than exposure to HT. HTO has an effective half-life in the body in the range of 4 to 18 days, with a mean effective half-life of about 9 or 10 days.

Most tritium leaves the body either in urine or through evaporation from the lungs and skin. The dose commitment from an uptake of one curie of HTO is approximately 63 rem.

For the above 3 discussed modes of entry: STPs and insoluble components of tritiated oils behave with the characteristics of the particle to which they are attached.

For dose calculations for STPs, ICRP Publication 66 uses absorption types; slow, medium, and fast (S, M, F). These are used in place of the lung retention classes (day, week, and year; D, W, Y) used in ICRP Publication 30. Depending on the absorption type of the compound, the dose per intake will be different than HTO.

For example: The air concentration value (which could be used in assessing dose per intake) for Type S STP is 10 times more restrictive than HTO, while the air concentration value for Type F STP is 5 times less restrictive than HTO.

Soluble OBTs act somewhat similar to HTO, however a larger percentage of nuclear transformations occur in the stomach. The dose per intake is approximately twice that of HTO.

Skin absorption is also a valid intake pathway for tritiated oil components and solvent OBT.

G. Methods of tritium containment

1. Primary - Process equipment and piping

2. Secondary

   - Glove boxes

   - Temporary vented enclosures

3. Tertiary - Room and associated ventilation systems

    - Effluent recovery systems
    - Emergency containment systems

H. Airborne tritium controls

1. Differential room pressure zones - The air ventilation system plays a key role in controlling the spread of contamination. In addition to providing the necessary humidity and temperature control for a building, differential pressure zones should be established within a building to ensure that the air flows from areas with lower hazardous contamination potential to areas with more hazardous contamination potential.

2. Dilution ventilation - Dilution ventilation is the once-through flow technique of exchanging outside air for inside air for comfort and basic contamination control.

3. Room-air detritiation systems - Such a system uses tritium monitors located in the room exhaust to activate (close) fast acting dampers. The dampers then route the exhaust through a special oxidation/drying system and return the air to the room.

3. Local exhaust ventilation - The primary advantage of local exhaust ventilation techniques is the removal of airborne tritium, regardless of its evolution rate or chemical or physical form. In addition, these techniques use relatively low flow rates compared to normal ventilation requirements.

I. Measurement techniques for tritium

1. Air monitoring - Fixed and portable ionization chambers most widely used.

2. Differential monitoring - Separate monitoring of HT and HTO components through the use of bubblers in conjunction with desiccants or catalysts.

3. Discrete sampling - Samples collected with a bubbler or “cold finger” type sampler, then later analyzed by liquid scintillation counting techniques.

4. Process monitoring

   - Stack, room, hood, glove box

   - Mass spectroscopy, gas chromatography, calorimetry

5. Surface monitoring

   - Difficult to measure directly due to low-energy emission

   - May have some success with thin window GM (pancake style probe), thin window sodium iodine, or gas flow proportional counters

   - Smears taken for loose contamination, and measured by dissolution and analysis by liquid scintillation counting techniques

6. Liquid Monitoring - Liquid scintillation counting techniques

J. Bioassay program for tritium workers

An adequate bioassay program for tritium workers would test for chronic and acute exposure.

1. Chronic exposure - Periodic urinanalysis for tritium (daily to biweekly identified in Tritium Good Practices Manual)

2. Acute exposure

   - Wait one to two hours.
   - Void bladder.
   - Collect sample as soon as possible thereafter.
   - Continue to collect daily to determine individual half-life.

Dose from exposure to STCs may need to be assessed based on air monitoring results, see RCTP 99-02.

DOE-STD-1121-99, *Internal Dosimetry*, 1999, provides guidance on internal dosimetry programs including monitoring and assessing dose from tritium.

K. Tritium effluent recovery systems

1. Purpose - Reduce tritium available for release

2. Method - Tritium gas converted to HTO and ultimately a stable waste form

L. Inventory control and accountability for tritium

1. Nuclear materials, including tritium, need to be controlled and have material accountability.

2. Appendix D to the Tritium Good Practices Manual discusses inventory control and defines it to consist of:

   - Measurements
   - Measurement controls
   - Determination of holdup in systems
   - Development of predictors
   - Establishment of accounting practices

I. Introduction

The guidance in DOE-STD-1128-98, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities, Change Notice 2 December 2006* should be reviewed in detail prior to conducting an assessment of plutonium facilities. The following is a brief overview of the radiological aspects of plutonium.

II. Background

Plutonium was first synthesized in the winter of 1940-41 by a team of scientists at the University of California. Its potential use in weapons was quickly identified, and much of the effort of the Manhattan Project was in the production of sizable quantities of plutonium. Other uses for plutonium include use as:

- Reactor fuel
- Heat sources in thermoelectric generators to power satellites
- Components in portable neutron sources

Plutonium is a silvery-white metal that readily oxidizes to a dull gray color. It can be found in a variety of physical and chemical forms. Several of the chemical forms (including the pure metal) are pyrophoric, so care must be exercised in handling the material. Because of the pyrophoric nature of plutonium and its alloys, the preferred form for storing, shipping, and handling is as plutonium oxide.

III. Radiological properties of plutonium

A. Isotopes

There are 15 isotopes of plutonium, all radioactive, beginning with Plutonium-232 and ending with Plutonium-246. The radioisotopes of primary interest are Plutonium-238, Plutonium-239, and Plutonium-240, all of which are primarily alpha-emitters.

1. Plutonium-238 (half-life = 87.7 yrs) is most commonly used as a heat source in thermoelectric generators. Because of its heat production, care must be taken in handling gram or larger quantities, as it could melt plastic or ignite other materials.

2. Plutonium-239 (half-life = 24,000 yrs) is the primary component of plutonium reactor fuel (>85%) and weapons grade plutonium (>90%), with Plutonium-240 (half-life = 6,560 yrs) constituting most of the remainder in both cases.

3. Plutonium radioisotopes emit relatively few high-energy gamma rays, so kilogram quantities can often be processed without serious gamma dose problems. However, small amounts of some radioisotopes or decay products can increase external dose. For example, Plutonium-241 decays by beta emission to Americium-241, which emits a 60-keV gamma ray. This can be a significant source of dose to hands in glove boxes. Large amounts of Americium-241 can produce high dose-rates due to higher energy gamma rays.

4. Neutron dose rates from spontaneous fission and from alpha-neutron reactions with light elements may be significant (e.g., 1 kg of $Pu\text{-}F_4$ (Pu-238) would have a contact neutron dose equivalent rate of 4800 rem/hr).

B. Biological effects of internally deposited plutonium

The primary hazards from the most common chemical form of plutonium (PuO_2) are inhalation and ingestion. This chemical form is relatively insoluble. Therefore, uptake through the gastrointestinal (GI) system following an ingestion is small.

Inhaled plutonium can remain in the lungs for a considerable time before being removed through the lymph system.

Plutonium is difficult to remove from the body. The primary method is through the administration of chelating agents as soon after the intake as possible. Trained medical personnel are needed to administer chelating agents.

The plutonium that enters the systemic system is mostly translocated to the liver and the bone (as is discussed in the following section). Accordingly, development of cancer in these organs and in the lungs are of particular interest in evaluating long-term effects from intakes of plutonium.

C. Survey techniques

A radiation protection program in a plutonium facility shall ensure the detection of all types of radiation (i.e., alpha, beta, gamma, x-ray, and neutron) over large energy ranges. Alpha-sensitive instruments are necessary for most contamination control surveys.

Continuous air monitors (CAMs), sample extraction lines that go to CAMs, and continuous radiation dose monitors should be placed outside the glove boxes and hoods.

Neutron surveys become important when processing tens of grams of Plutonium-238 or hundreds of grams of mixed isotopes of plutonium, particularly compounds (i.e., PuO_2, PuF_4). The neutron survey is important in instances where photon shields, such as leaded glass, are used. Such shields normally stop all of the charged particles, most of the low-energy photons, and essentially none of the neutrons. Under these circumstances, neutron radiation is likely to be the major contributor to whole body dose.

Exposure rate surveys are normally conducted with photon-sensitive instruments with known

energy responses for photons with energies ≥ 10 keV.

Monitoring practices include, but are not limited to, the following:

- Contamination surveys of the workplace
- Release surveys
- External exposure rate surveys
- Airborne radioactivity surveys (both real time (CAMs) and historical (fixed air head))
- Routine surveillance by a Radiological Control Technician

All workplaces shall be monitored for contamination levels on a regularly scheduled basis. The frequency of such surveys will depend on the potential for dispensability of the radioactive material. As a minimum, all gloves, work surfaces, floors, and equipment within the workplace should be surveyed.

Airborne radioactivity surveys should be performed for:

- Prompt detection of airborne contaminants for worker protection
- Personnel dose assessment
- Monitoring of trends within the workplace
- Special studies

Intakes

In most plutonium facilities, the primary radiological hazard is the potential for internal intakes of plutonium. This hazard must be controlled by appropriate facility and equipment

design, contamination control procedures, and protective clothing/equipment.

Plutonium transferred from the initial entry site is assumed to be translocated to the liver (45%) and the bone (45). Retention half-life in the liver is 20 yrs and in the bone is 50 yrs, according to International Commission on Radiological Protection (ICRP) Publication 30.

Control must be verified by a bioassay program. Urinalysis is the most common technique, but fecal analysis and *in vivo* monitoring may also be appropriate.

U.S. Department of Energy, DOE-STD-1121-98, *Internal Dosimetry*, Reaffirmation May 2003. provides technical guidance on internal dosimetry programs, including enhanced workplace monitoring for instances where there is a technology shortfall, such as for plutonium. This standard should be reviewed prior to conducting assessments of internal dosimetry programs.

The standard also discusses appropriate evaluation of bioassay results.

D. Monitoring instruments

DOE-STD-1128-98, Change Notice 2 December 2006 has additional guidance on monitoring instrumentation.

Facilities that deal with unencapsulated plutonium should have continuously operating effluent monitors to determine whether or not plutonium is being released to the environment.

Criticality alarm systems (gamma or neutron) should be provided in each area where an accidental criticality is possible.

E. Sources of external dose

External dose control for plutonium is primarily concerned with photon dose rates from handling plutonium in a glove box and from the neutron dose rate from some mixtures of plutonium.

While significant high-energy penetrating photons are not commonly associated with plutonium, low-energy photons (x- and gamma-rays) can create significant dose rate problems to extremities. This is particularly a concern when large amounts of Plutonium-238, Plutonium-241, or Americium-241 (from the decay of Plutonium-241) are present.

Neutrons can also represent a potentially significant dose due to spontaneous fission (alpha, neutron) reactions or neutron induced fission. The neutron dose is largely determined by the radioisotope and other materials near the source.

F. Control of external dose

External dose control is accomplished with traditional dose reduction techniques:

- Time (minimize)
- Distance (maximize)
- Shielding (use as needed)

Other work practices, including good housekeeping and specialized tool and equipment design, can reduce external dose, as well.

G. Techniques for internal dose control

The confinement system is a series of physical barriers that, together with a ventilation system, minimizes the potential for release of radioactive material into work areas and the environment under normal and abnormal conditions, thereby minimizing internal dose.

Generally, three confinement systems are used to achieve the confinement system objectives at plutonium handling facilities. They consist of the following:

- Primary confinement is provided by piping, tanks, glove boxes, encapsulating material, and the like, and any off-gas system that controls effluent from within the primary confinement. It provides confinement of the area immediately surrounding the hazardous material.

- Secondary confinement is provided by the walls, floor, roof, and associated ventilation exhaust systems of the cell or enclosure surrounding the process material or equipment. Except in the case of glove box operations, the area inside this barrier is usually unoccupied; it provides protection for operating personnel.

- Tertiary confinement is provided by the walls, floor, roof, and associated ventilation exhaust system of the facility. It provides a final barrier against release of hazardous material to the environment.

Different devices may be used to confine and control radioactive material. The selection of the appropriate device will depend on the quantity of material, its form, and the operations to be performed.

Fume hoods may be used for some operations with plutonium, depending on the quantity and dispersability of the material. In general, plutonium fume hood operations shall be limited to wet chemistry processes and less than 100 mg of plutonium.

Higher levels of plutonium are generally handled in glove boxes. Care should be taken in the design of the glove box to ensure confinement of the material and any fire.

Ventilation may also be employed to confine plutonium, although it usually is used in conjunction with other measures.

H. Personnel protection

Workers in plutonium facilities need to be appropriately trained on the hazards. DOE has developed *Radiological Safety Training for Plutonium Facilities*, DOE-HDBK-1145-2001. This document provides DOE's guidance on expectations for training of plutonium workers.

The use of personal air sampling programs should be considered to monitor individual workers for exposure to airborne plutonium. Section 4.4.4 of DOE-STD-1121-98, Reaffirmed May 2003,*Internal Dosimetry*, discusses use of breathing zone or personal air monitoring when there is a technology shortfall (i.e., the derived investigation level is less than the minimum detectable activity). Technology shortfalls are common for routine plutonium bioassay programs.

In addition, DOE has issued guidance on use of air monitoring results when there is a technology shortfall in Radiological Control Technical Position (RCTP) 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*.

In part, RCTP 2001-01 states that, when there is a technology shortfall for bioassay and air monitoring results indicate exposures greater than 100 millirem in a year are likely, one should assess dose based on the air monitoring results.

As a minimum, personnel who perform operations in controlled areas should wear coveralls and shoe covers. For inspections or visits, lab coats and shoe covers may be permissible. When contaminated wet areas are to be entered, water-repellent (plastic or rubber) clothing shall be worn. No personal outer clothing should be permitted under coveralls.

Hands should be protected by a minimum of two barriers; for example, at least one pair of surgeon's gloves and one pair of rubber gloves should be worn.

Protective clothing should be removed at the step-off pad, and personnel monitoring for contamination shall be performed.

Respiratory protection equipment shall be readily available. Respiratory protection equipment should be used for all bag-out operations, bag and glove changes, and any situation involving a potential or actual breach of confinement. Protection, in the form of air-purifying or atmosphere-supplying respirators, shall be used whenever concentrations of radionuclides in the air are likely to exceed the applicable DACs.

I. Inventory control and accountability requirements

Real-time or near real-time accountability systems should be incorporated if possible.

J. Criticality safety considerations

Criticality alarm systems (gamma or neutron) shall be provided in each area where an accidental criticality is possible.

Criticality safety requirements may include: ANSI/ANS 8.3-1986*, Criticality Accident Alarm Systems*; ANSI/ANS 8.1-1983, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*; and ANSI/ANS 8.19-1984, *ANS Administrative Procedures for Nuclear Criticality.*

It is important to review site requirements documents prior to conducting the assessment.

All DOE facilities that possess sufficient quantities and kinds of fissile material to potentially constitute a critical mass shall provide nuclear accident dosimetry.

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I. Introduction

10 CFR Part 835.501(d) requires written authorizations to control entry and perform work in radiological areas, commensurate with the radiological hazards. DOE-STD-1098-99, *Radiological Control*, July 1999, Chapter 3, Part 2, provides guidance on DOE's expectations for such written authorizations.

These written authorizations may take a variety of forms tailored to the work processes involved. Often, the form will be that of a Radiological Work Permit (RWP), discussed in detail below.

II. Radiological Work Permits (RWPs)

A. Purpose

The RWP is designed to document the radiological conditions and associated controls in a work area. The RWP should be integrated with other work authorizations that address safety and health issues, such as those for industrial safety and hygiene, welding, and confined space entry.

Articles 311 and 312 of DOE-STD-1098-99 provide guidance on preparing work control procedures consistent with the principles of Integrated Safety Management. This includes use of multidiciplinary teams to prepare work control procedures for tasks involving significant types of hazards and referring to DOE Order 440.1B, *Worker Protection Program for DOE (Including National Nuclear Security Administration) Federal Employees*.

B. Typical RWP process

1. Requester submits an RWP request form.

2. Radiological Control Supervisor accepts

form, collects additional job information as necessary, and assures that completion of appropriate radiological surveys to be performed in the work area.

3. Radiological Control Technicians, or other appropriately trained and authorized personnel, perform surveys, analyze samples, and report results.

4. RWP controls are established based on the results of the surveys.

5. Radiological Control personnel, in consultation with relevant technical staff, complete, distribute and implement the RWP.

6. Radiological Workers and Radiological Control personnel review completed RWP, prior to start of job, during pre-job briefs, and/or ALARA reviews.

5. Radiological Worker/Supervisor advises Radiological Control personnel when job is complete (so RWP can be terminated).

8. Radiological Control personnel maintain surveys and RWP documentation.

C. Types of RWPs

There are two basic types of Radiological Work Permits:

- Job-specific RWP

- General RWP

The job-specific permit is used for jobs which present a greater potential for significant radiation dose, airborne radioactivity, or spread of contamination, and which involve “hands on” work.

Examples of jobs that would likely require job-specific RWPs include those where work is:

- Performed with detailed, specific, written work procedures, approved in advance by Radiological Control personnel

- "Hands-on" work performed infrequently on radiological systems (e.g., valve replacement in process buildings)

- Performed in areas in which the radiological conditions have no history of remaining stable

The general RWP typically is used for jobs with less potential for health physics concerns and for routine, repetitive jobs that do not involve "hands on" work.

Examples of jobs that may be worked under a general RWP include:

- Routine tours, inspections, inventories, valve lineups, equipment tagouts, surveys, and equipment operation.

- Work routinely performed on nonradiological systems (e.g., fire protection systems in shut-down process buildings).

- Routine operations involving radioactive material for which the radiological conditions have a history of remaining stable.

Keep in mind that there may be a need for other (nonradiological) permits or authorizations to safely perform these jobs. For example permits may be needed to address nonradiological hazards, such as: electrical, confined space, asbestos, hazardous materials, respiratory protection, fire, heavy equipment and scaffolding.

D. Time limits

The job-specific RWP usually remains in effect only for the duration of the job (typically less than 30 days).

The general RWP typically is approved for a period of time of one year or less.

E. Elements of an RWP include:

- Description of work (detailed)
- Radiological conditions (contamination, airborne, radiation levels) in the work area
- Dosimetry (TLD badge, self-reading dosimetry, special dosimetry) requirements
- Requirements for a pre-job briefing, if necessary
- Radiological Control Technician coverage (start of job, continuous, intermittent)
- Training requirements to work in the area
- Protective clothing requirements
- Respiratory protection equipment requirements
- Stay time requirements
- Radiological conditions that may limit work or void the RWP
- Special dose reduction (ALARA) or contamination reducing measures to be considered
- Special personnel contamination monitoring requirements

- Work document number (if used)
- Unique RWP identification number
- Date of permit issue and expiration date
- Signatures of Radiological Worker and supervisor (attesting to their understanding of RWP requirements and agreement to follow) and Radiological Control staff

F. RWP Elements for Radiological Assessment

The following are RWP program elements which may be reviewed as part of a radiological assessment:

- RWPs appropriately required for activities and areas
- Completeness of information on RWPs
- Adequacy of radiological surveys to support RWP
- Worker adherence to RWP requirements
- RWP appropriately reviewed and approved
- Adequacy of worker monitoring (TLDs, bioassay, air monitoring RCT coverage) specified on RWP
- ALARA considerations included in RWP
- RWP program implemented in accordance with written procedures

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I. Introduction

10 CFR Part 835, *Occupational Radiation Protection*, Amended June 2007, specifies contamination control requirements in Subpart L. Chapters 3 and 4 of DOE-STD-1098-99, *Radiological Control*, Reaffirmed December 2004 also provide guidance on meeting the requirements and additional information for implementing an effective contamination control program. All of these documents should be reviewed prior to conducting an assessment.

II. Contamination containment and temporary control measures

Minimization of internal dose

The minimization and control of internal dose should be conducted in accordance with the following hierarchy of controls:

1. Engineered controls, including containment of radioactive material at the source wherever applicable, should be the primary method of minimizing airborne radioactivity and internal dose to workers.

   Engineered controls are devices such as glove boxes, glove bags, portable filtration units, and containment tents. They should be used to prevent worker inhalation of radionuclides.

The use of these devices reduces the spread of contamination, cleanup time, and decontamination costs. These measures help maintain doses ALARA. In addition, they can reduce the need for respirators and the impact on work in nearby areas.

Engineered controls should be used in accordance with technical instructions, proper training, and effective administrative controls

Site-specific manuals should contain generic instructions on the design, controls, training, and use of engineered controls.

2. Administrative controls, including access restrictions and the use of specific work practices designed to minimize airborne contamination, should be used as the secondary method to minimize worker internal dose.

3. Only when engineered and administrative controls have been applied and the potential for airborne radioactivity still exists, should personnel protective equipment, including use of respiratory protection, be considered.

   Chapter 3 of DOE-STD-1098-99 discusses:
   Access controls for Contamination Areas
   Controlling the spread of contamination
   Monitoring for contamination.

   Appendix 3 C*, Contamination Control Practices*, includes recommended selection of protective clothing, and a recommended sequence for donning and doffing.

   Use of respiratory protection should be considered under the following conditions:

   - Entry into posted Airborne Radioactivity Areas
   - During breach of contaminated systems or components
   - Work in areas or on equipment with removable contamination levels greater than 100 times the values in Table 2-2 of DOE-STD-1098-99
   - During work on contaminated or activated surfaces with the potential to generate airborne radioactivity

   The selection of respiratory protection equipment should include consideration of worker safety, comfort, and efficiency. The use of positive pressure respiratory protection devices is recommended wherever practicable to alleviate fatigue and increase comfort.

Respirators can provide adequate protection for workers in an airborne radioactivity environment, but engineered controls may be more practical. By using engineered controls instead of respirators, the worker is not subjected to the stresses created by wearing a respirator. It is more difficult to breath and communicate when wearing a respirator. Vision is impaired, and the respirator is not comfortable. Productivity can therefore be improved by using engineered features instead of respirators.

To minimize intakes of radioactive material by personnel, smoking, eating, or chewing shall not be permitted in Contamination, High Contamination, Airborne Radioactivity Areas, or Radiological Buffer Areas established for contamination control purposes.

Contamination should be contained at its source. The principle is to prevent contamination spread from occurring. The most effective methods based on sound ALARA principles should be used. All controls should be documented and clearly controlled by RWPs.

Respirators may be appropriate for simple, straightforward jobs.

In specific situations the use of respiratory protection may be contraindicated due to physical limitations or the potential for significantly increased external dose.

In such situations, written authorization should be obtained from the line organization manager and the Radiological Control Manager prior to incurring internal dose. Specific justification of the need to accept the dose, including a description of measures taken to mitigate the intake of airborne radioactivity, should be documented as part of the radiological work documentation.

The use of personal air sampling programs should be considered to monitor individual workers for exposure to airborne radioactive material, especially when the use of respiratory protection is contraindicated. This is particularly important when there is a bioassay program technology shortfall (i.e., the derived investigation level is less than the minimum detectable activity). Section 4.4.4 of DOE-STD-1121-98, *Internal Dosimetry*, discusses use of breathing zone or personal air monitoring.

In addition, DOE has issued guidance on use of air monitoring results when there is a technology shortfall in Radiological Control Technical Position (RCTP) 2001-01, *Questions and Answers Concerning Acceptable Approaches to Implementing Bioassay Program Requirements*.

In part, RCTP 2001-01 states that, when there is a technology shortfall for bioassay and air monitoring results indicate exposures greater than 100 millirem in a year are likely, one should assess dose based on the air monitoring results.

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Radiological Work Site Mockup Demonstration Checklist for Module 11

The exercise is a mock-up demonstration that is performed by the instructors to give the participants an opportunity to assess and identify poor radiological work practices.

You will be instructed to identify and make notes of the poor radiological practices during the demonstration. Observe the demonstration and watch for poor radiological work practices. Write down poor work practices in your student's guide for discussion after demonstration. After the demonstration:

- Identify poor radiological practices
- Make recommendations for improvement

Notes

I. Introduction

10 CFR Part 835, *Occupational Radiation Protection*, includes provisions for exposure to ionizing radiation from DOE activities. Included in the 10 CFR 835 definition of a radiological worker is "operation of radiation producing devices". 10 CFR 835 also specifies requirements for sealed radioactive sources.

II. *DOE* Guidance

Article 365 of DOE-STD-1098-99, *Radiological Control*, provides additional guidance, including the use of ANSI N43.3, ANSI N43.2, and 10 CFR Part 34 for meeting its requirements covering RGDs.

DOE HDBK-1109-97*, Radiological Safety Training for Radiation-Producing (X-Ray) Devices*, Reaffirmed January 2007, provides guidance on DOE's expectations for radiation safety training for individuals using RGDs.

III. X-ray machines

A. Components

X-ray devices have been in existence for about 100 years. Although there are many different designs of x-ray machines, they all have the same basic components. These include a source of electrons, an electrical potential difference to accelerate the electrons, and an anode, or target for the accelerated electrons to strike.

Usually, the source of electrons in an x-ray machine is a thin wire filament from which electrons are emitted when it is heated by a large electrical current. Controlling the current through the filament, then, becomes a way to control the number of electrons available for acceleration.

The electrical potential difference between the cathode (filament) and the anode (or target) is the force that accelerates the electrons. The larger the potential difference, the more kinetic energy the electrons will acquire. The potential difference is measured in units of kilovolts (kV). The energy of the electrons is measured in units of kilo electron volts (keV), with one electron volt being the amount of energy required to move one electron through a potential difference of one volt.

The accelerated electrons then strike the anode (or target). The target may consist of various materials, depending on the purpose and design of the x-ray tube. X-ray production is most efficient in high atomic number targets, like tungsten.

When electrons strike and excite target atoms, the kinetic energy of the electrons is deposited in the target as heat. When electrons ionize target atoms, characteristic x-rays will be emitted as electrons from outer shells fill vacancies created by ejected electrons.

B. X-ray energy spectrum

The energy of the x-ray photons coming out of the x-ray machine is of interest to the users of the machine. The typical energy spectrum from an x-ray machine consists of the characteristic x-rays from the target, which have discrete energies, and the bremsstrahlung photons which have a whole range of energies, the maximum energy depending on the potential difference across the tube. For a typical x-ray machine, the bremsstrahlung photons far outnumber the characteristic x-rays.

C. Design features

The cathode and anode of the x-ray tube are enclosed in an evacuated glass tube or envelope. The vacuum is necessary to ensure that the accelerated electrons will interact in the target, and not with gas molecules.

The x-rays are produced in all directions in the target. However, only x-rays directed toward the exit port, or window, will comprise the useful beam.

Several devices are used to control the size of the useful x-ray beam. A lead diaphragm is a sheet of lead with a hole in it. It is placed near the exit port, and restricts the size of the useful beam by absorbing x-rays that don't pass through the hole. The size of the beam is not adjustable with this type of device unless another diaphragm with a different-size opening is used.

For some operations, the size of the useful beam must be adjusted by the operator. An adjustable collimator is essentially a set of movable lead sheets. Two sheets restrict the width of the beam, and two sheets restrict the length of the beam. The operator can then adjust the size of the beam to any desired combination of length and width.

Often, the lowest energy x-rays are not desired in the beam. The low energy x-rays can be filtered out by placing absorbing material (called filters) in the path of the beam. Aluminum or copper is commonly used, depending on the energy of the machine. The addition of filters increases the average energy of the beam, since the lower energy x-rays are removed from the beam when they are absorbed by the filters.

D. Common uses and hazards

X-ray machines are most commonly used for radiography, or the examination or inspection of the structure of materials by non-destructive means.

X-ray machines used in medicine are fairly standardized in appearance, and in the way they are installed. That is not true of x-ray machines used for industrial applications. X-ray machines may be fixed installations, mobile units, or completely enclosed cabinet systems. The cabinet x-ray systems are commonly used for security applications (e.g., baggage inspection units).

The major hazard from x-ray machines is the external dose hazard to machine operators and other people in the vicinity. No one should ever be exposed to the primary (or useful) beam. Exposure to leakage radiation (from the housing) and scatter radiation should be reduced by appropriate controls.

IV. Analytical x-ray machines

A. Fluorescence analysis

Characteristic x-rays that result from ionization of atoms can be used to identify atoms, since the characteristic x-rays will have energies that are unique to that element. This forms the basis for x-ray fluorescence spectroscopy. A sample to be analyzed is irradiated by a beam of high-intensity x-rays. The x-rays ionize atoms in the sample, which emit characteristic x-rays when the electron shell vacancies created by ionization are filled.

The characteristic x-rays can be analyzed by determining their energy, or by determining their wavelength. Either way, the result leads to information about the elemental composition of the sample.

These instruments are usually completely enclosed. Access doors are provided for changing samples, and the doors are equipped with interlocks to prevent access to the x-ray beam.

The hazard is primarily an external dose hazard to scattered radiation from the components and the sample, and is typically fairly low.

B. X-ray diffraction

When x-rays are scattered by a crystalline solid, they are scattered from the different atoms, but only in certain directions. This technique is used for crystal structure research.

The primary beam and the diffracted beams are very small and well collimated. In some types of diffraction equipment, the sample cannot be enclosed in a structure. The primary beam is controlled by a shutter that opens and closes. The major hazard associated with diffraction units is intense, localized exposure from the

primary beam to the hands or eyes that can occur during sample changing or beam alignment procedures with the shutter inadvertently open. The primary beam is very small, but may have an intensity of up to 40,000 R/min. At this exposure rate, even short exposures of the hands and fingers could result in severe injury, and potential loss of fingers.

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V. Other radiation-generating devices

Other radiation-generating devices (RGDs) that may be encountered are small particle accelerators (<10 MeV) used for radiography, ion implantation, or the production of incidental photons or particles (neutron generators).

Some RGDs produce radiation incidental to their primary purpose. Examples of devices that produce radiation incidentally are electron beam welders, electron microscopes, and pulse generators.

VI. Categorizing RGD installations

The ANSI standards referenced earlier categorize RGD installations into the following categories for radiation safety purposes.

A. Exempt shielded installations

The RGD and all objects exposed to the source of radiation shall be within a permanent enclosure that, under all circumstances of use, possesses sufficient inherent shielding and prevents inadvertent entry to any part of the body. The exposure at any accessible region 5 cm from the outside surface of the enclosure shall not exceed 0.5 mrem in any one hour.

B. Shielded installation

The RGD and all objects exposed to the source are within a permanent enclosure from which persons are excluded during the irradiation. Some of the requirements for shielded installations include mandatory interlocks, audible and visual warning devices, a "crash" button, and posting of warning signs.

Skyshine is the term used to describe radiation emerging more or less vertically from a shielded enclosure, which then scatters from air molecules to produce radiation at some distance from the source.

C. Unattended installation

The RGD is installed in a single-purpose shielded enclosure, and the design shall ensure that individuals are not exposed to doses exceeding 100 mrem in a year.

D. Open installation

Open installations must be conspicuously posted, and have a conspicuously defined perimeter. The perimeter must delimit the area in which the exposure can exceed 5 mrem in any one hour. The operational staff shall provide constant surveillance. Other requirements include use of survey meters, personnel dosimetry, and temporary shielding.

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I. Introduction

10 CFR Part 835, *Occupational Radiation Protection*, includes provisions for exposure to ionizing radiation from DOE activities, which includes exposures from accelerator operations.

II. *DOE* Guidance

Article 364 of DOE-STD-1098-99, *Radiological Control*, provides similar guidance, and includes guidance to use the *Health Physics Manual of Good Practices for Accelerator Facilities*, SLAC-327, in meeting occupational radiation protection requirements for accelerators.

DOE HDBK-1108-97*, Radiological Safety Training for Accelerator Facilities*, provides guidance on DOE's expectations for radiation safety training for individuals using accelerators.

III. General characteristics of accelerators

Accelerators are devices that increase the speed and thus the energy of charged particles.

A. Accelerator energy

Accelerators are normally rated by the maximum energy to which the particles are accelerated.

The energy imparted to the charged particles is determined by the potential difference measured in volts (V) in the electrical field. At all but the smallest accelerators, the acceleration is accomplished by directing the charged particles repeatedly through regions containing radiofrequency electromagnetic fields.
One electron volt (eV) is the energy gained by an electron accelerated through an electric potential of 1 volt.

An electron accelerated across a gap by means of a 10,000 volt, or 10 kilovolt (kV), potential difference is said to have gained 10 kilo electron volts (10 keV) of energy after crossing the gap.

Other energy units commonly encountered at accelerators are: MeV (1 million, or 10^6 electron volts), GeV (1 billion, or 10^9 electron volts), and TeV (1 trillion, or 10^{12} electron volts). These units of energy are commonly used not only for electrons, but for all charged particles.

B. Types of particles accelerated

Particles accelerated include:

- Electrons
- Protons
- Nuclei of various elements

C. Types of accelerators

The accelerated charged particle may move in either a linear (straight line) or in a circular (curved) path as the result of moving perpendicular to a magnetic field; these are the two basic types of accelerators.

1. Linear accelerators

Straight-line accelerators suffer from the disadvantage that the finite length of flight path limits the particle energies that can be achieved.

Linear accelerators include:

- Van de Graaffs
- Cockcrott-Waltons

2. Circular-path accelerators

   In circular-path accelerators, magnets guide the particle along a spiral path, allowing a single electric field to apply many cycles of acceleration.

   Circular-path accelerators include:

   - Cyclotrons
   - Betatrons
   - Synchrotrons

   Until the 1980's, all accelerators used for both physics research and in practical applications, such as in medicine and in materials science operated in a so-called "fixed target" mode. In this mode the accelerated energetic particles are delivered to a target made of some material at rest in the laboratory.

   Since that time, research facilities have been constructed in which counter-circulating accelerated beams of particles collide with each other, rather than with targets at rest in the laboratory. The use of accelerated particles in this "colliding beam" mode has been done to take advantage of the fact that the total energy of the colliding particles, including both their kinetic energies and the energy included in their masses at rest, becomes available in the collision process. This condition is not true for fixed target collisions.

   Such colliders are not nearly as numerous as other types of accelerators, but represent important research facilities in which basic physics research is conducted.

D. Purpose and uses

   Accelerators were originally designed to study the

structure of matter. Accelerators today are used not only for basic research purposes, but for many other applications as well. Examples include:

- Production of radioisotopes
- Generation of bremsstrahlung for radiography
- Induction of fusion
- Pumping for lasers
- Detoxification of hazardous waste
- Production of synchrotron radiation

E. Facility size/complexity

Small accelerators/facilities usually mean simpler controls, less staff to coordinate, smaller areas to monitor, and fewer points of access to control. However, small accelerators (lower energy) can produce very intense levels of radiation.

As the size and complexity of the installation increases, so does the importance of clear and concise communication channels and a detailed formality of operations.

IV. Radiological concerns

A. Prompt radiation

Prompt radiation results from the accelerator beam or the interaction of the beam with matter only while the accelerator is operating. Prompt radiation components include:

1. Primary beam

The primary beam consists of accelerated charged particles prior to any interactions that may decrease the beam's energy or intensity.

It is the most intense form of radiation present at an accelerator facility and is made inaccessible to personnel through engineered and administrative controls.

2. Secondary beam

   The secondary beam is produced by interaction of the primary beam with matter such as targets or beamline components. The secondary beam may consist of:

   - Electromagnetic radiation
   - Neutrons
   - Charged particles

3. Skyshine

   Skyshine is the term used to describe radiation emerging more or less vertically from a shielded enclosure, which then scatters from air molecules to produce radiation at some distance from the source.

4. Electromagnetic radiation (photons)

   Prompt photons may include those produced by:

   - Bremsstrahlung: Photons emitted through the deceleration of charged particles in the beam
   - Electromagnetic cascades: Multiple photons emitted through initial high-energy interactions
   - Synchrotron radiation: Photons emitted as charged particles are accelerated in a curved path (a dramatically more significant effect for electrons than it is for protons having the same kinetic energy)

- Thermal neutron capture: Photons can be emitted as a result of nuclear reactions in which materials present in the accelerator enclosure absorb thermalized neutrons produced by the accelerated beams.

5. Neutrons

   Neutrons can be produced through nuclear interactions of the primary and secondary beams with matter. They can also be produced by interaction of high energy photons with matter (photonuclear reaction).

   Neutron radiation is a concern within any area where the beam can interact with physical objects.

6. Muons

   Muons are particles that are physically similar to electrons, but are about 200 times heavier.

   Energies in excess of 212 MeV are required to produce muons by means of pair production at electron accelerators. At proton and ion accelerators, muons cannot readily be produced at energies below about 140 MeV since charged pions or kaons, which decay into muons, must first be produced. Due to the short ranges of low energy muons in matter, they are not normally of concern for accelerators of less than 500 MeV kinetic energy.

   Muons travel mainly in the direction of the beam that produced them, with very little deviation from the beam path. They are a concern directly downstream of targets and beam dumps.

B. Residual radioactivity (radioactivation)

   Radioactivation is the process by which materials become radioactive. It is commonly referred to

as “induced radioactivity” or simply “activation.” Generally energies above 10 MeV are needed to activate materials.

Activated materials will continue to emit radiation after shutoff of the beam. The length of time depends on the half-life and quantity of the activated element.

1. Contaminated materials versus activated materials

   Contaminated materials are considered to be items with removable surface contamination. Activated materials are considered to be volume contamination, meaning the radioactive materials are dispersed throughout the items.

   Activated materials normally do not present a potential loose contamination hazard except during activities such as:

   - Grinding
   - Burning
   - Machining
   - Handling filters of coolant water

   Activated materials are normally controlled based on the residual external radiation dose rate.

2. Activated materials

   Materials that may become radioactive include:

   - Any material within the accelerator enclosure

- Beamline components
- Air
- Liquids

Accelerators used to produce radioisotopes present special problems because of the variety of target materials used, and because the parameters of machine and target are deliberately optimized to produce radioactive materials.

- Beamline components

  Items that intercept a portion of the beam are most likely to be activated. Among those items which have the highest probability for activation are:
  – Targets
  – Beam dumps or stops
  – Collimators and scrapers
  – Septa and other magnets
  – Cavities and beamline

- Air

  Air and other gases in the accelerator enclosure may be activated. Typically, the activation products are short-lived gaseous radionuclides of the elements in the air. Examples are Oxygen-15 from Oxygen-16.

  The two major concerns of air activation products are:
  – Worker (delays entry)
  – Environmental (releases from enclosures)

- Liquids

Tritium is frequently produced in water used to cool the target and/or experimental equipment. As this water supply is usually a closed system, the concentration of the tritium in the water will slowly increase.

Other activated liquids may include:
– Oil in vacuum pumps
– Cryogenic fluids

C. Ancillary sources

Accelerators employ devices to either impart energy to particles, or redirect them during the acceleration process. The following devices may emit ionizing radiation while they are operating.

1. Klystrons

Klystrons provide power to accelerate charged particles. They emit x-rays during operation.

2. Radiofrequency (RF) cavities

These devices accelerate charged particles using electromagnetic fields. Trace gases within the RF cavity cause photons to be emitted by the accelerated particles.

3. Electrostatic separators/septa

These devices split a particle beam into two beams using static electric fields. The high voltages associated with these devices cause electrons to accelerate in the vacuum within the beamline. They emit x- or gamma rays.

V. Radiological and other controls

Controls are used at accelerator facilities to protect personnel from exposure to ionizing radiation and other hazards, which include:

- Electrical

- Mechanical
- Cryogenic
- Nonionizing radiation

The design of an effective safety program incorporates a combination of engineered and administrative controls.

A. Engineered controls

Engineered controls are the primary controls at an accelerator facility.

1. Active engineered controls

Active engineered controls include devices that sense changing conditions and can trigger a safety action. Examples may include:

- Status lights
- Alarms
- Interlocks
- Scram buttons

2. Passive engineered controls

Once installed, passive engineered controls are used to prevent personnel entry or reduce radiation dose and require no further action to perform their intended function. Passive engineered controls may include:

- Barriers
- Shielding

B. Administrative controls

Administrative controls require human interaction in order to be effective.

Key administrative controls include:

- Signs/postings
- Search and secure (sweep) procedures
- Controlled access procedures
- Configuration control procedures
- Radiological Work Permits (RWPs)

VI. Monitoring

Monitoring for radiation at accelerators can be complicated. Special techniques and instrumentation may be necessary due to the existence of:

- Mixed radiation fields (photons, protons, neutrons)
- Pulsed beams
- Very high-energy radiation
- High dose rates

A. Prompt radiation

Measurements of prompt radiation fields are required for occupational and environmental monitoring and for accident dosimetry and calibration of dosimeters, as well as for research purposes. In selecting measurement techniques

and instruments, it is important to consider the purpose of the measurement and the radiation field's parameters.

1. Mixed radiation fields

   The complexity of the radiation field and the radiation measurements increase with the energy of the accelerator.

2. Pulsed radiation

   Prompt pulsed radiation must be measured with specialized survey instruments. Ion chambers are typically used and are recommended.

3. Neutrons

   Neutron monitoring is complicated and must be conducted by highly trained individuals with specialized instruments.

B. Environmental monitoring

Environmental sampling/monitoring may include:

- Prompt radiation (neutrons, skyshine, muons)
- Sampling exhausted air from beam housings
- Surface/groundwater (on and off site)
- Monitoring of radiation levels at site boundary (from storage areas)

C. Personnel monitoring

Simple dosimeters, such as those used in personal dosimetry and simple survey instruments, should be calibrated when possible in radiation fields that are similar to those in which they will be used. To interpret

measurements made with these instruments, one must know as much as possible about the radiation field that is being measured.

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I. Introduction

Self assessment is part of an effective worker health and safety program. As such, there are many requirements related to conducting self assessments and maintaining quality assurance programs, such as those required under 10 CFR 830.120 ,or as part of an effective Integrated Safety Management program. This module focuses on the radiation protection required assessments and audits.

10 CFR Part 835, *Occupational Radiation Protection*, requires, in 10 CFR 835.102, that internal audits of the Radiation Protection Program be conducted at least every 36 months. The audits shall include all radiation protection functional elements.

DOE G441.1-1B, *Radiation Protection Programs Guide,* provides guidance on meeting the 10 CFR 835 requirement for audits. Section 4.2 of the Guide includes a listing of radiation protection functional elements and associated DOE guidance documents.

Article 134 of DOE-STD-1098-99, *Radiological Control*, provides additional guidance on radiological control assessments.

II. Types of assessments

It can be extremely damaging if we, as overseers, facility representatives, and assessors, violate the high standards of performance and rules that we are to assess. It is important to understand that we are constantly being monitored and that we must set the example with regard to radiological protection.

The methods used to gather or capture information can detract from the effectiveness of the assessment process.

Assessment techniques can be enhanced through training and practice. These techniques will improve the ability to see, observe, and better understand.

There are two types of assessments: unstructured and structured. "Unstructured" reviews means "not looking for one specific area or thing." "Minimum preparation" method is accomplished through going with workers on routines. These could be described as general assessments.

The more preparation put into the assessment, the more effective it is, no matter what type of assessment is conducted.

The second type of assessment is "structured," which involves looking specifically at one issue and reviewing it from every angle.

Two traditional methods within the structured inspection are the vertical and horizontal review.

Vertical review is the assessment of a narrow subject area in great detail, for example, assessing the Radiological Control Organization from top to bottom.

Horizontal review is the assessment of a broad range of related subjects in generally less detail, for example, assessment of radiological protection across all organizations at a nuclear facility.

III. Assessment guidance

A. Documents

IMPORTANT: Put the burden of producing documents on the site. If the site personnel state that it is not appropriate that they comply, they must provide DOE with written support for that position.

The DOE and site basic documents an assessor should have for radiological compliance include (determine the extent of applicability and site commitments to adhere to the documents):

- 10 CFR Part 835
- Site Radiation Protection Program
- DOE-STD-1098-99, *Radiological Control*
- Other applicable federal regulations
- Applicable DOE orders
- State regulations
- DOE Implementation Guides
- Site DOE contract
- Site commitments (corrective actions, DNFSB recommendation responses)
- Site reports (deficiency, occurrence)
- Site-Specific RadCon Manual

- Approved exemptions

- Peer group/industry group standards/recommendations
  – DOE standards
  – ANSI standards
  – NRC Regulatory Guides

B. Compliance issues

1. Compliance is only the tip of the iceberg.

2. What are the issues?

   - What happened?

   - Why did it happen?

   - Will corrective action prevent recurrence?

   - How can we ensure it will not happen again?

3. Determine the degree of consequence of noncompliance effects and ramifications of noncompliance.

4. Procedural compliance is only part of the overall commitment to excellence in radiological control.

   - Acknowledge good practices

     The DOE radiological control policy is that "continuing improvement is essential to excellence in radiological control."

   - Encourage what is good.

5. Need to distinguish between requirements ("shall" statements) and recommendations ("should" statements).

C. Compliance orders

Compliance orders are issued by the Secretary. They identify a situation that violates, potentially violates, or otherwise is inconsistent with the:

- Atomic Energy Act of 1954 as amended
- Nuclear statutes
- Nuclear Safety Requirements

Compliance orders mandate a remedy or other action, and state the reason for the remedy or other action.

Examine orders and responses to orders for:

- Timelines
- Accuracy
- Completeness (Was the problem solved?)

IV. Assessing radiological performance

A. Internal audits, inspections, reviews, investigations, and self-assessments comprise “assessments” and are part of the numerous checks and balances needed in an effective Radiation Protection Program.

Internal audits of the Radiation Protection Program shall be conducted such that over a three-year period, all functional elements are assessed for program performance, applicability, content, and implementation. These should be performed by individuals who are organizationally independent from the organization responsible for developing and implementing the Radiation Protection Program.

B. DOE-EM-STD-5505-96*; DOE Limited Standard Operations Assessments,* contains very good methodology for performing assessments.

There are three major components of an effective assessment program: management assessments, operational assessments, and quality assurance assessments. For each of these, functional areas are identified that represent specific areas of managerial or technical activity. Within each functional area, performance objectives are defined that represent essential characteristics or conditions of an effective safety program. The criteria associated with each performance objective are intended to serve as guidelines for the assessments.

Both management and operational assessments are operationally focused and performance-oriented. They deal with the safety culture of the facility, how safely it is being operated, and the condition of its documentation and equipment. The design of the facility and its process systems is presumed, for purposes of the management and operational assessments, to permit safe operation. This is based on the presumption of an appropriate selection and application of design standards by the architect-engineer and the operating contractor, and of appropriate independent reviews by DOE or its predecessor agencies of the design, the construction activities, and the Safety Analysis Report.

The criteria listed do not address every activity that might be relevant to a performance objective. Therefore, meeting all criteria does not necessarily ensure that the performance objective is fully met. Conversely, a specific facility might achieve the performance objective without meeting all criteria.

In part, because of the various ways in which the performance objectives can be met, effective assessments emphasize the performance objectives rather than the criteria. The methods for determining whether a criterion is met are not given. Consequently, considerable expertise and judgment are required to be exercised in conducting the assessments.

Although the quality assurance assessments have a broad perspective, covering the overall quality assurance program of the facility, they are relevant to assessing radiological protection performance.

DOE-STD-1070-94, Reaffirmed April 1999, *Guidelines for Evaluation of Nuclear Facility Training Programs,* provides guidance on evaluating training programs at nuclear facilities.

C. Radiation Protection Program deficiencies

Managers should encourage the positive view that identifying even minor deficiencies represents an opportunity for further improvement.

Radiological work practices should be continually scrutinized and questioned so that opportunities for improvement can be identified, assessed, and incorporated into the Radiation Protection Program.

The number of deficiencies, alone, does not measure the overall quality of the Radiation Protection Program.

D. Critiques

One assessment method is the critique. An honest review and establishment of facts, which are in chronological order, is necessary to arrive at the truth.

This is a formal process established to obtain pertinent facts following an unusual radiological situation or at the satisfactory conclusion of a new or unusual operation involving radiological controls.

The process should be used to quickly establish facts in chronological order so that the underlying reasons or causes for the success or failure are well understood. Work force participation should be encouraged. Critiques are a management tool and should not be used to “fix blame” or “shoot the messenger.” This process complements the *Occurrence Reporting and Processing* of DOE Order 231.1-2.

In developing corrective action plans, managers should address basic underlying reasons for the identified deficiencies or concerns, not just the specific symptoms identified by the reviewer.

E. Radiation Protection Assessment Program

To accurately assess the performance of the Radiation Protection Program, an assessment program should be formalized, created, and implemented.

Elements of a Radiation Protection Assessment Program

F. Radiation Protection Program Performance

The contractor senior site executive should establish, approve, and maintain a radiological performance goals program. The performance goals should be measurable, achievable, auditable, challenging, and meaningful in promoting improvement. Chapter1, part 3 of DOE-STD-1098-99, *Radiological Control*, provides guidance on appropriate radiological goals.

Goals need to be developed primarily by those responsible for performing the work. Forming a Radiological Awareness Committee that includes the active participation of the work force is encouraged.

Radiological performance goals should be reviewed at least annually and revised as appropriate. Normally, more stringent goals should be set annually to reflect the improved radiological performance at the facility. Occasionally, the goals may be made less stringent to accommodate changes in work load or mission.

G. Performance indicators

To evaluate performance, one needs to be able to measure change. This means dimensions must be identified. One must be able to track, trend, post, paint, count, look at, and assign numbers. What gets measured, gets done.

I. Introduction

II. Assessments

A. Reasons for conducting assessments include the following:

- Determine regulatory compliance.
- Formally document Radiation Protection Program strengths and weaknesses.
- Investigate a specific incident.
- Document conditions that need a follow-up assessment.

B. Basic elements of a Radiation Protection Program

- Organization and administration
- Personnel training and qualification
- Quality assurance
- ALARA
- Radiological work control
  - Procedures
  - RWPs
- Posting and labeling
- Radioactive material control
  - Source control
  - Release of materials
  - Receipt and transportation

- Radiation-generating devices
  - Sealed source
  - X-ray machines
- Entry control
- Contamination control
- Instrumentation and alarms
- Monitoring
  - Workplace
  - Effluent
  - Environmental
- Dosimetry
  - External
  - Internal (bioassay)
- Respiratory protection
- Facility-specific features
  - Uranium
  - Plutonium
  - Tritium
  - Accelerators
- Radioactive waste management
- Emergency response
- Records
- Assessments/performance indicators

C. Indications that an assessment is needed

- Exceeding administrative dose control levels or regulatory limits
- Loss of control of radioactive material

- Unmonitored/excessive release of radioactive material to the environment
- Excessive numbers of skin contamination incidents
- Uptakes of radioactive material by employees
- Excessive numbers of radiological incidents
- Inadequate training
- Ineffective work control systems
- Incomplete or inaccurate radiological surveys
- Incomplete or inaccurate records

III. Preparing for the assessment

To adequately prepare for the assessment:

- Review operating history
- Examine previous assessment reports
- Collect input from person(s) assessed
- Determine applicability of industry issues
- Review policies and procedures
- Assemble regulations and guidance documents
- Prepare an assessment plan

A. Operating history

Review the operating history. The following documents can be extremely helpful in preparing for the assessment:

- Occurrence reports
- Radiological deficiency reports
- Violations/citations
- Facility design changes

B. Previous assessments

Examine previous assessment reports. Documents that could be helpful are:

- DNFSB Recommendations
- Self-assessments
- Corporate quality assurance reports
- External audits

C. Input from person(s) to be assessed

- Management
- Radiological Control Manager
- Radiological Control Organization's "customers"

D. Industry issues

- Emerging technical issues
- Application of best industry standards to site program

E. Policies and procedures

- Operating procedures
- Radiological control policies

F. Regulations and guidance documents

- Federal
- State
- Site
- Industry or peer group

G. Assessment plan

- Identify elements to be assessed.
- Generate specific questions and/or standards against which to measure performance.
- Develop record sheet for assessment responses, data, and field notes.
- Allocate time for each assessment activity.
- Intentionally leave unscheduled time.

IV. Conducting the assessment

A. General guidance

Remember the assessment is a positive activity, designed to help those being appraised. Follow the plan, but be flexible.

Include nothing in the assessment findings that is not based on fact, requirement, or commitment. If in doubt, leave it out (but raise it, informally as a matter deserving a closer look).

Share the findings with the point(s) of contact each day. There should be no surprises at the daily Radiological Control Manager debriefing or at the final debriefing.

B. Announced versus unannounced assessments

1. Announced assessments are scheduled through a pre-assessment memorandum. The following information should be addressed:

   - Assessment objectives
   - Assessor(s)
   - Assessment duration
   - Request for a site point of contact
   - Any special needs
   - Recommended time and place for pre- and post-assessment conferences

2. Unannounced assessments

   - Used to determine “real” program performance
   - Back-shift, off-hours tours may reveal relaxation in program standards
   - Vary the assessment schedule

   Note: Contact the Radiological Control Manager and line management immediately if there is a serious problem.

3. Available methods for conducting an assessment include:

    - Document reviews
    - Personnel interviews
    - Field observations

4. Recommended assessment approach (in order)

    - Review upper-tier procedures describing the Radiation Protection Program.
    - Conduct a short (one hour or less) tour of the site/facility.
    - Interview Radiological Control Organization staff and "customers."
    - Conduct detailed and follow-up tours, interviews, and document reviews.

5. Perform document reviews of:

    - Operating procedures
    - Records for:
        - Dosimetry
        - Work control Radiological Work Permit
        - Surveys (contamination, radiation level, air, special)
        - Occurrence, deficiency reports, and critiques
        - Regulatory reports
        - Radioactive effluent reports
        - Training and qualification
        - Instrument calibration and response testing
    - Special studies

6. Site/facility tour

   - Tour the site/facility, preferably with an experienced individual from the site.

   - Make notes of housekeeping and facility condition. Items to look for include:
     – Leaks, spills
     – Dirt, rust, and clutter
     – Poor equipment maintenance
     – Radiological control posting
     – Radiological Control Technician and Radiological Worker interface
     – Employee morale

7. Conduct interviews with the following:

   - Radiological Control Manager

   - Radiological Control Supervisor(s)

   - Radiological Control Technical Leads

   - Qualified Radiological Control Technicians

   - Radiological Control Organization's "Customers"

   - DOE Site Representatives

   - Facility Manager

   The following are the details:

   - Radiological Control Manager
     – Knowledge of current radiological control regulations, industry standards
     – Identification of program deficiencies and priorities
     – Obstacles to improving program performance

- Radiological Control Supervisor(s)
  - Level of support given Radiation Protection Program and Radiological Control Manager
  - Identification of program deficiencies and priorities
  - Obstacles to improving program performance

  Note: Compare responses to those from Radiological Control Manager.

- Radiological Control staff members responsible for major technical functional areas.

  Examples of these functional areas include:
  - Organization and administration
  - Personnel training and qualification
  - Quality assurance
  - ALARA
  - Radiological work control
    + Procedures
    + RWPs
  - Posting and labeling
  - Radioactive material control
    + Source control
    + Release of materials
    + Receipt and transportation
  - Radiation-generating devices
    + Sealed source
    + X-ray machines
  - Entry control
  - Contamination control
  - Instrumentation alarms
  - Monitoring
    + Workplace
    + Effluent
    + Environmental
  - Dosimetry
    + External
    + Internal (bioassay)
  - Respiratory protection

  - Facility-specific features
    + Uranium
    + Plutonium
    + Tritium
    + Accelerators
  - Radioactive waste management
  - Emergency response
  - Records
  - Assessments/performance indicators

  Document their responses to incidents in their technical area.

  Discuss impediments to improving their programs.

- Qualified Radiological Control Technicians
  - The depth and breadth of knowledge of radiation protection
  - Technical issues unique to the site/facility
  - Effectiveness of the working relationship between Radiological Control Technicians and their "customers"

- Radiation Protection Program "customers"
  - Knowledge of fundamental radiation protection concepts and good Radiological Worker practices
  - Working relationship with the Radiological Control Technicians
  - Obvious or hidden problems
  - Poor communications
  - Division of work problems
  - Overall, how the Radiological Control Organization is regarded ("policeman" vs. team member)

- DOE Representatives
  - If the Radiological Control Organization staff solicits his/her input on technical decisions affecting Radiation Protection Program performance
  - If the relationship is one of mutual respect or adversarial in nature

- Facility Manager
  - Whether the Facility Manager has made a written commitment and is striving to achieve excellence in the Radiation Protection Program
  - His/her perspective on how the Radiation Protection Program should be improved, and the necessary priorities

8. Observe Radiological Workers/Radiological Control Technicians in the workplace

   - Recommendations for observing work include:
     - Dress as the individuals being observed are dressed.
     - Work the same hours they work.
     - Stand away from the immediate work area, but close enough to watch the work proceed.
     - Resist the urge to get involved in the work.
     - Be professional and courteous, but not familiar.

   - Key areas to watch for include:
     - Procedure violations
     - Failure to follow RWP requirements for:
       + Dosimetry
       + Protective clothing
       + Respiratory protection
       + Radiological Control Technician coverage
       + Surveys
       + Special instructions

  - Poor Radiological Worker practices:
    + Reaching across radiological boundaries
    + Scratching body with gloved hand
    + Inadequate frisking
    + Loitering in a high radiation field
  - Lack of organization or formality in the work process
  - Poor housekeeping, disorderly work area
  - Wasted time and effort due to ineffective work planning
  - Communication problems
  - Poor relationships between Radiological Workers and Radiological Control Technicians

C. Post-assessment actions

At the post-assessment conference, summarize the findings identified during the assessment. This is an opportunity for additional questions about the findings. Any requests for corrective actions, dates, or a need for follow-up assessments can be identified at this time. Thank everyone for cooperation and support during the assessment.

1. Publish assessment findings.

2. Receive site responses, which should include the following:

   - Action items

   - Responsible individuals/groups

   - Action item due dates

3. Accept/reject/modify responses.

4. Develop corrective action tracking list.

5. Publish a periodic action item status report.

6. Maintain a separate file of open action items.

7. Personally verify the closure of action items.

8. Evaluate the adequacy of actions taken to close open findings:

   - Has root cause been correctly identified and corrected?

   - Are follow-up assessments needed?

D. Follow-up assessments

1. Qualifying conditions

   - Widespread problem
     – Problem occurs at several locations in the same facility or several facilities at the same site.
     – Problem identified by the assessment is only part of a larger, more generic deficiency.

   - Recurring problem: earlier efforts to resolve the problem have been ineffective.

2. Actions

   - Widespread problem
     – Take a longer sample to confirm/refute a widespread problem
     – Look for related problems in the same work unit.

   - Recurring problem
     – Scrutinize root cause analysis.
     – Try a different approach to solving the problem.
     – Solicit outside help. Perhaps others have “lessons learned”.

3. Incorporate follow-up assessment information into corrective action tracking system.

V. Marginal radiological performance

When radiological control performance is less than adequate, strengthen line management's commitment to radiological control by notifying the Radiological Control Organization to obtain their support in improving radiological support.

In cases where the work force does not have the required level of sensitivity for radiological work practices, additional management attention is needed to assure the proper outcome. Line management should be held accountable for implementation of the Radiation Protection Program.

Initial actions should include:

- More direct line supervision in the work space
- Curtailment of work schedules
- Addition of extra radiological control personnel
- Conduct of additional training

I. Introduction

II. Case studies guidance

Point to remember: If each root cause is not adequately treated/corrected by a corrective action, recurrence of the event or some variation of it is likely.

Review a reconstruction of events from the available data.

A proper investigation report or occurrence report reconstructs the events as they occurred.

III. Description of occurrence (edited from investigation report)

A. Incident

The layout of the buildings and equipment at this site are included.

Two employees at the Paducah Gaseous Diffusion Plant (PGDP) received skin and clothing contamination from Thorium-234 (^{234}Th) and Protactinium 234m (^{234m}Pa) while disconnecting a used uranium hexafluoride (UF_6) cylinder at the C-337-A building, UF_6 Feed Vaporization Facility, on August 23, 1991.

B. Scenario of events

Starting at shift change, 12 employees, one of them a Health Physics Technician, found contamination on shoes and clothing. The incident was initially identified during routine monitoring of the C-337-A facility by a Health Physics Technician at 0900 (two hours after the shift change). Efforts were initiated by Health Physics to survey the area, identify the source, and control the spread of contamination. Surveys indicated widespread contamination in both radiological and nonradiological areas of C-337 (adjacent to C-337-A) and C-337-A.

At some unspecified time, a critique was conducted by the Assistant Shift Superintendent and all personnel involved in the accident were interviewed.

All personnel who had been in the facility on the day shift were contacted and surveyed. One individual was found to have contaminated shoes and skin contamination on the elbow and was taken to a change house in C-337 for decontamination. Later this employee's personal clothing was also found to be contaminated, and through further investigation it was learned that this contamination occurred in the change house. A thorough survey was conducted in the change house, and it was discovered that, in addition to a few articles in the change house itself,

two locks and lockers used by Employee No. 1 (who performed the pigtail changes on the previous shift) were contaminated. This employee returned to work at 1830 on August 23, 1991. Surveys of the locker contents indicated contamination on company-issued clothing worn the previous shift. The employee was also found to have skin contamination of 6500 dpm/100 cm^2 on the arm, 4500 dpm/100 cm^2 on the knee, and 2750 dpm/100 cm^2 on each ankle.

A survey of the employee's coworker's (Employee No. 2) locker revealed contaminated items (both company-issued and personal). Personal surveys conducted when Employee No. 2 returned to work showed the presence of skin contamination of 4500 dpm/100 cm^2 on hair, 5000 dpm/100 cm^2 on neck, and 40,000 and 15,000 dpm/100 cm^2 on wrists. Later (2130 hours on August 23 for Employee No. 2, and 1900 hours on August 24 for Employee No. 1) surveys were conducted at the employees' homes. Monitoring of one employee's home found one T-shirt and one pillowcase slightly contaminated. A pair of shoes at the other employee's home was found slightly contaminated. This employee's (No. 2) coveralls had already been sent to the laundry, since it was not recognized they were contaminated. After laundering, significant contamination was still present (up to levels of 250,000 dpm/100 cm^2 at ankles, and lower levels at other places). A survey of the laundry equipment did not indicate any contamination.

Based on statements from the involved employees, they utilized the required personal protective clothing and equipment for the job at the time. The autoclave area is designated as a Contamination Zone. Anti-contamination clothing designated for cylinder changes at the time of the incident consisted of company-issued coveralls (blues), gloves, and shoe scuffs. Operational procedures require the use of a respirator when disconnecting pigtails. Surveys conducted as part of this investigation did not show any contamination on the

employees' respirators or respirator cartridges.

The actual incident began between the hours of 0130 and 0415 on August 23, 1991, at the PGDP C-337-A Feed Vaporization Facility.

The operators routinely assigned to C-337-A for the period of 1900 hours on August 22, 1991, through 0700 hours on August 23, 1991, were not available due to the illness of one and an alternate work assignment of the other at another facility (C-360). Two operators who are not routinely assigned to the area were then assigned to cover C-337-A. One operator (No. 2) was qualified for operation of the facility while the other (No. 1) was in training for qualification. (This is in compliance with facility Operational Safety Requirements.) Supervisor interaction was minimal, with only one brief visit around the middle of the shift.

The operations in process at the time of the incident were the routine disconnection and removal of emptied UF_6 feed cylinders and subsequent replacement with full cylinders. This operation consists of disconnecting a short length of connecting pipe between the cylinder and the system piping that leads to the diffusion process equipment. This pipe is called a pigtail; it has threaded connections and gaskets on each end. Since pigtails are routinely reused, each cylinder change requires replacement of gaskets on pigtails to minimize the possibility of UF_6 releases during heating and feeding of the UF_6 into the diffusion process. At times these gaskets can be difficult to remove from the pigtail. A special tool is available to assist in the removal of these gaskets; however, difficulty can still be encountered. The pigtails used that night had been used for several feeding cycles, as is normally the case. The exact number of cycles could not be determined.

There are levels of ^{234}Th and ^{234m}Pa that occur naturally from the decay of ^{238}U present in the cylinder pigtail, pigtail gaskets, and cylinder valves. Approximately one curie each of those two radioisotopes builds up in a cylinder within a few months. These materials are less volatile than UF_6, so they remain as solids at the autoclave temperature, but some small amounts are entrained in the UF leaving the cylinder and small quantities are deposited in the cylinder valve and pigtail as the UF passes through it. These materials are present as removable surface contamination in these components, as well as being present in quantity in the cylinder heels (the material remaining in the cylinder after feeding). No containment of the ends of the pigtail during the gasket removal process was required by procedure. Additionally, the facility-specific training program does not address the specific contamination hazard the cylinder/pigtail change represents.

The operators changed four cylinders on the shift. The cylinder number, autoclave used, and approximate time of change (from logs and recorder data) are shown below:

Cylinder Number	Autoclave Number	Approximate Time
K-438	3 West	0130 08/23/91
K-505	5 West	0320 08/23/91
K-472	1 West	0500 08/23/91*
AC-1090	4 West	0500 08/23/91

*Time is very approximate. Operator statements place the change late in shift.

There was a portable fan temporarily positioned to cool employees just north of the 5 West autoclave control panel, inside the Contamination Zone. The fan had only been in place a few weeks. It was operating during the shift in question. Apparently no one had questioned the use of this fan in the area prior to the event. Circumstantial evidence places one operator exiting from either the 4 West or 5 West autoclave in the path of this fan while trying to remove a pigtail gasket. The area of highest surface contamination was spread along a line from the fan (located by 5 West autoclave), past the 4 West autoclave to the 3 West autoclave control panel in the direction that the fan blows.

Self-monitoring performed by the employees upon exiting the Contamination Zone where the job was performed was inadequate, in that the employees did not recognize the contamination present on their skin and/or clothing. The employees performed their other duties during the remainder of the shift, thereby spreading this contamination to both radiological and nonradiological areas. This spread of contamination to nonradiological areas through failure to recognize personal contamination at exit monitoring stations caused other personnel to become contaminated when the shift change at 0700 on August 23, 1991, brought new personnel into these areas.

Based on the interview with Employee No. 1, the employee traveled to C-337 around 0400 for a break. Upon exiting the vaporizer Contamination Zone and going to the C-337-A Operation's Monitoring Room, the Bicron frisker was indicating high but not alarming due to high ambient background radiation levels. The employee reset the monitor and remonitored. The employee indicated that the reading was elevated, but was not alarmed this time. The employee stated this was normal since the background in that area is often high.

At approximately 0600 on August 23, 1991, both operators left C-337-A bound for the C-337 change houses and the C-337 Area Control Room for shift turnover. Both operators stated they used Bicron friskers to check for contamination prior to entering the nonradiological (green) pathway in C-337. Training previously received by each operator for each type of frisking equipment was documented. Employee No. 1 noted that the Berthold hand-and-foot monitor previously used was "not operating properly," so the employee used the Bicron frisker. Neither operator noted any contamination. Employee No. 2 monitored hands and feet only, based on subsequent interviews, which indicated that the employee did not know that a whole-body frisk was required when exiting a radiological area. Based on statements from both employees, they showered, changed into personal clothing, completed the shift turnover activities, and exited the building after monitoring hands and feet at the building exit, as required.

Since some personnel exit monitoring data is regularly recorded, this data was reviewed. The operators passed between the C-337-A Operation's Monitoring Room and the C-337 Area Control Room several times during the shift and should have performed a whole-body frisk for contamination each time. Data for Employee No. 2 was not available, as the employee used a Bicron frisker. (These instruments do not have the added feature of storing monitoring data for later review.) Data for employee No. 1 shows 0414 hours on August 23, 1991, as the first time a monitor station evaluated this operator as contaminated. This station would normally be used when passing from C-337-A to the C-337 nonradiological walkway when going to the maintenance shops and change houses (restrooms, lockers, and showers).

This same employee was also known to be contaminated at the C-337 building exit on two separate monitors (twice on one, once on the other) when leaving after the shift change approximately 0700 on August 23, 1991. The employee stated that the first monitor alarmed, but that the second monitor did not indicate the contamination.

No monitoring data was found for the second employee, since he did not utilize equipment capable of storing this information.

Personal egress monitoring data from the facility was also reviewed, and individuals from prior shifts were contacted and monitored. An operator who was in the C-337-A area extensively from 0700 to 1830 hours on August 22, 1991, had a new pair of company-issued shoes, which were found to be free of contamination. This operator had left the C-337-A facility at 1830 hours on August 22, 1991. Additionally, routine surveys on August 19, 1991, did not indicate a similar contamination problem. Since no significant contamination problems were identified prior to 1900 hours on August 22, 1991, the investigation focused on the activities from 1900 hours on August 22, 1991, to 0700 hours on August 23, 1991.

Urinalysis, as well as *in vivo* internal dosimetry assessments, was performed on these employees and did not indicate any evidence of internal contamination. Personnel whole-body external radiation dosimeters worn by both employees, although externally contaminated, did not indicate that abnormal doses to ionizing radiation were received.

Skin dose calculations showed less than 0.10 rem for Employee No. 2 and 1.50 rem for Employee No. 1, compared to an annual limit of 50 rem.

It was noted that in the occurrence report of Reference 2, there had been 26 similar occurrence reports (in 1991) at the facility.

IV. Compensatory measures

Following the detection of contamination, several actions were taken by facility management in order to determine the source and type of contamination, the personnel and areas which may have been contaminated, and actions which could be taken to minimize additional spread of contamination. The following list of significant actions were accomplished after the event:

1. A critique of the incident was conducted, interviewing all individuals involved.

2. All nonradiological areas were decontaminated, and contamination levels within the radiological areas were reduced.

3. Personal protective equipment requirements in C-337-A were upgraded to require full anti-contamination protective clothing within the Contamination Area.

4. A full-time Health Physics Technician was stationed at C-337-A and required to monitor all personnel and equipment leaving the radiological area.

5. The two operators involved in the incident were sent to the Fernald, Ohio (DOE), facility for *in vivo* (whole-body) monitoring.

6. The fan was removed from the facility.

7. *In vitro* urine bioassay samples were obtained from the individuals involved in the incident, as well as other individuals who were either contaminated on previous shifts or involved in surveying and decontaminating the area.

8. Dosimeters were collected and monitored to assist in determination of radiation dose.

9. A walkdown of all plant boundary control stations was performed by senior management to determine location of substandard boundary control stations.

10. Efforts were initiated to determine other possible sources of Th^{234} and Pa^{234m} at other plant locations.

11. Actions were initiated to reduce the potential for the spread of contamination from the UF_6 cylinder pigtails during disconnection, gasket replacement, and reconnection activities.

12. Surveillance was established by line management of exit monitoring stations.

13. An investigation for an organizational finding was initiated.

14. A news release was issued.

15. A plant announcement was made and a plant bulletin was issued to emphasize the seriousness of the situation and the need for proper monitoring.

16. Complete locker room surveys were performed by Health Physics Technicians.

17. Meetings with union membership were conducted by union leadership to emphasize the importance of monitoring.

18. A letter, jointly signed by PGDP management and union leadership, was issued to all PGDP employees.

19. A DOE visit from Headquarters (HQ) Health and Safety personnel was conducted. They concluded that the breadth and scope of the organization finding investigation was appropriate.

20. The Portsmouth Gaseous Diffusion Plant was notified of the incident for possible application at its site.

21. Operators involved in the incident were not allowed to work in radiological areas until Radiation Worker retraining had been completed.

22. All fact sheets were put into “operator-required reading” files.

23. Development of a training film to review monitoring requirements and techniques was initiated. Upon completion, review of this film will be mandatory for all employees.

Analysis - Contamination Levels on Gaskets and Pigtails

Sample Number	Nuclide Analyzed	Concentration (dpm)
C-337-A Gaskets (2 gaskets combined for one sample)	^{234}Th and ^{234m}Pa	11,000,000 Beta*
	U activity	156,000 Alpha
C-310 Burp Station Gasket (1 gasket)	^{234}Th and ^{234m}Pa	163,000 Beta
	U activity	140,000 Alpha
C-310 Product Withdrawal Gasket (1 gasket)	^{234}Th and ^{234m}Pa	40,000 Beta
	U activity	1,900 Alpha
C-315 Tails Withdrawal Gasket (2 gaskets)	^{234}Th and ^{234m}Pa	117,000 Beta
	U activity	20,600 Alpha
C-360 Sampling and Transfer Facility Gasket (3 gaskets)	^{234}Th and ^{234m}Pa	1,500,000 Beta
	U activity	78,000 Alpha
SP-8757, Pigtails coupling, feed header end of pigtail	^{234}Th and ^{234m}Pa	see Note 1 Beta*
	U activity	see Note 1 Alpha
SP-8758, Pigtail coupling, cylinder end of pigtail	^{234}Th and ^{234m}Pa	see Note 1 Beta
	U activity	see Note 1 Alpha
SP-8759, Material knocked loose from SP-8757	^{234}Th and ^{234m}Pa	2,300,000 Beta
	U activity	27,000 Alpha
SP-8760, Material knocked loose from SP-8758	^{234}Th and ^{234m}Pa	2,300,000 Beta
	U activity	75,000 Alpha

*Each radionuclide contributes 50 percent to this total activity.

Note 1: Beta/gamma levels were too high to be accurately counted on the spectrometer due to detector dead time (saturation).

I. Introduction

II. Writing assessment findings

A. Organization of findings

There may be considered to be three categories of assessment findings in order of increasing severity:

- Surface findings (Type I) are usually indicators of underlying issues that may be more significant. Note that a common problem is treating or correcting only the surface issue while ignoring the underlying problem—this results in problem recurrence.

- Substantial findings (Type II) are typically issues that are underlying and more significant. Note that correcting the underlying problem results in solving the problem.

- Organizational findings (Type III) deal with programmatic or global issues. Note that correcting these is very difficult if they involve system, organizational, or institutional problems.

First, group like, related, or similar findings into a broader issue.

Then, review the overall list of groupings for priority. The bases are:

1. Imminent danger
    - Life Safety Code
    - Personnel Safety
    - Facility Safety
    - Criticality
    - Confined Space
    - Traps
2. Not imminent, but potential danger
    - Environmental monitoring, e.g., inadequate stack monitors
3. Violations of regulations, laws, orders
4. Areas where adverse public opinion may reside
5. Performance and effectiveness issues
    - Usually a large number of findings fall into this category, which captures effectiveness and quality issues.

Finally, establish what is most important and what should be brought to the attention of the senior DOE and contractor management.

B. Writing of findings

When it has been established what issues will be brought to site management, review techniques for writing about the findings:

There is an established style or method often used in industry for writing findings. It consists of the following three steps:

1. List the requirement

2. State what was observed (different from requirement)

3. State the concern

III. Presentation of Findings

After findings are prepared in written form, it is important that they be presented properly. Skills for presenting findings are directly related to the techniques used for writing findings.

Some rules to keep in mind when presenting findings are listed below.

- Identify the assessment team leader and members, and their organizational affiliation.

- Explain the reason for the assessment.

- NEVER, NEVER read the findings in a close-out. Most senior management can read as well as the presenter.

- Present the most significant findings first.

- Be prepared to present additional information to support the finding. In most cases, there is much more material in the file than is appropriate to be included in the write-up. Be prepared to use that material to support the finding.

- In some cases, this is the time to cover material in the report that was not written for public consumption.

- It may be appropriate to discuss other material such as related findings from previous reports or audits.

- Maintain proper perspective by including both positive and negative findings.

- Start with the positive findings, then make a clear, shift to the negative findings or concerns.

- Explain the concerns/findings enough so that senior management will understand the issue.

- Thank the site contact person and most senior manager(s) for help and hospitality extended during the assessment.

I. Introduction

II. Compliance-based versus performance-based evaluations

A. Compliance-based audits

A compliance-based audit is a comparison of the requirements laws, rules, orders, guidance, policies, procedures, and other documentation with site practices to confirm implementation of the specific requirements. For example, determining whether bioassay samples were collected in accordance with site procedure requirements.

B. Performance-based assessments

Assessment is fundamental to the operation of a satisfactory Radiation Protection Program.

A performance-based assessment is a review of how the actual performance of the task is accomplished and assessing whether the intent of the requirement is being met. For example, determining whether bioassay samples were being analyzed for the appropriate isotopes given the workplace environment.

III. Assessment process

The assessment process is one of the evaluation methods used to determine the status and effectiveness of an overall management system.

With this perspective, the assessment process should be planned and scheduled to accomplish the following:

- Evaluate the effectiveness of program implementation in order to meet compliance requirements
- Provide input for assessment process improvement.

The assessment process consists of four phases:

1. Planning
2. Performance
3. Reporting
4. Response evaluation, follow-up, and close-out

A. Planning

Planning is the key to a successful assessment. It is possible to go immediately to the field to observe, work with, and find out how things are being done. That is one element and approach to the process, but there is a greater advantage to be made with proper planning and preparation.

The most successful assessments start with a checklist. The checklist development is critical to the success of the assessment and serves as a commonly accepted method for documenting what was looked at and what the results were. It also serves as a guide to the person performing

the assessment and provides objective evidence that an assessment was performed.

In performing the assessment, several types of checklists can be used. The preferred style of a checklist is the question-and-answer variety. With this kind of checklist, the assessor has to write-in an evaluation of the answer to each question and any qualifying remarks. The question-and-answer format is more difficult to review, but provides more information with which to judge the performance level of a system element.

B. Performance

The elements of conducting an effective Radiation Protection Program assessment are:

- Overall plan (annual)
- Establish weekly, daily, breakdown
- Actually write a plan (modify later)
- Preparations-obtain material
- Use protocol for entry, conduct, exit
- Keep contact informed/no surprises

C. Report

Documentation of the findings and observations (note taking) in the field will involve some combination of the following:

- Record book
- 3 x 5 cards
- Actual times, logistics
- What, when, who, why, where, how

- Documents reviewed
- Interviews

Then comes the time to start to put the report together, whether a weekly report or the inspection report of some other type. The following are suggested:

- Distill as information is gathered, while memory fresh
- Start draft report early

D. Post-assessment actions

- Evaluate assessment responses
- Establish corrective actions and due dates
- Track the status of open action items
- Perform follow-up assessments as necessary

I. Introduction

II. Field exercise guidelines

A. Briefing for field exercise

The field instructors have prepared to take their participants to the field. They have visited the facility and areas for review, and have compiled information for their participants to use in preparation for the field exercise.

B. Preparations to go to field

A tendency exists to identify surface issues and seek correction of the many items found while walking through the facility. It is vital that personnel who assess be able to sort the issues noted and categorize them so effective use of resources can be made. In other words, identification of symptoms leads to contractors working on the symptoms and not on the underlying, substantive problems.

It can be extremely damaging if we (as overseers, facility representatives, auditors, or assessors) violate the high standards of performance and rules that are being assessed.

Personal safety and facility safety are first and foremost.

C. Findings

Each person will make a presentation to the group. The team leaders will introduce the group, tell where you went, and introduce each presenter. Each person should take no more that one and one-half minutes for the presentation of a finding. Some of the “cats and dogs,” or other findings and observations, will be covered at the end of the individual findings.

The Lead Field Instructor will monitor the overall presentation and comment as appropriate.

We hope to see presentations in this form:

1. List the requirement.

2. State what was observed.

3. State the concern.

I. Summary

(Insert individualized summary.)

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Radiological Assessor Training
DOE-HDBK-1141-2008

CONCLUDING MATERIAL

Review Activity:

DOE
NNSA
HSS
EM
NE
SC
GC
IA
RW
NN

Field Offices
ID
SR
OH
RL

National Laboratories
BNL
LLNL
LANL
PNL
Sandia
ANL
New Brunswick
ORNL
SRNL

Operations Offices
AL
NV
OAK
OR
CH

Site Offices
Amarillo Site Office
Kirtland Site Office
Princeton Site Office
Fernald Site Office
Kansas City Site Office
Miamisburg Site Office
Y-12 Site Office

Preparing Activity:

DOE-HS-11

Project Number:

TRNG-0015

Part 5 of 5

Radiological Assessor Training
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Handouts

Office of Health, Safety and Security
U.S. Department of Energy

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Radiological Assessor Training
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Dosimetric Quantities in 10 CFR Part 835

Term	Definition
Absorbed dose (D)	The average energy imparted by ionizing radiation to the matter in a volume element divided by the mass of the matter in the volume. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).
Equivalent dose (H_T)	$H_T = D_{T,R} \times w_R$ The product of absorbed dose ($D_{T,R}$) in rad (or gray) in tissue and a radiation weighting factor (w_R). Equivalent dose is expressed in units of rem (or sievert) (1 rem = 0.01 sievert).
Deep equivalent dose	The equivalent dose derived from external radiation at a depth of 1 cm in tissue.
Lens of the eye equivalent dose	The external exposure of the lens of the eye taken as the equivalent dose at a tissue depth of 0.3 cm.
Shallow equivalent dose	The equivalent dose derived from external radiation at a depth of 0.007 cm in tissue.
Committed equivalent dose ($H_{T,50}$)	The equivalent dose calculated to be received by a tissue or organ over a 50 year period after the intake of a radionuclide into the body ($H_{T,50}$). Committed equivalent dose is expressed in units of rem (or sievert).
Committed effective dose (E_{50})	The sum of the committed equivalent doses to various tissues in the body ($H_{T,50}$), each multiplied by the appropriate tissue weighting factor (w_T)--that is, E_{50} = sum of $w_T H_{T,50}$. Committed effective dose is expressed in units of rem (or sievert).
Effective dose (E)	The summation of the products of the equivalent dose received by specified tissues of the body (H_T) and the appropriate weighting factor (w_T)--that is, H_E = sum of $w_T H_T$. It includes the dose from radiation sources internal and/or external to the body. For purposes of compliance with this part, equivalent dose to the whole body may be used as effective dose for external

	exposures. The effective dose is expressed in units of rem (or sievert).
Total effective dose (TED)	The sum of the effective doses (for external exposures) and the committed effective dose (for internal exposures).

Radiological Control Program Elements

Management oversight

- Management commitment and policy
- Management responsibilities
- Resource and budget development
- Directives, procedures, and manuals
- ALARA and other safety committees
- Emergency response organization
- Control of experimental activities

Radiological control organization

- Organizational independence
- Responsibilities, authorities, and functions
- Staffing levels

Training

- General requirements
- General employee training
- Radiological Worker training
- Radiological control staff qualification
- Operations personnel
- Manager and supervisor
- Respiratory protection
- Medical personnel

Radiological Control Program Elements (cont.)

- Visitors
- Emergency response personnel
- Occupational Safety and Health Administration (OSHA) training

Reviews, audits, and evaluations

- Management overview practices
- Review of incidents
- Internal audits
- Quality assurance program
- Safety analyses and assessments

Oversight of radiological design criteria

- General requirements
- Structural and facility design
- Ventilation systems
- Instrumentation and equipment
- Special tools and enclosures
- Containment systems

Radiological work practices and administrative controls

- ALARA concepts and controls
- Establishment of dose limits
- Emergency plans and procedures

Radiological Control Program Elements (cont.)

- Contamination control work practices
- Planning work
- Posting and access control
- Protective clothing and laundry
- Respiratory protection
- Radiation procedures
- Emergency response actions

Radioactive materials control

- Feed, process, and output materials
- Collection and control of radioactive samples
- Radwaste management
- Contamination materials and equipment
- Sealed radiation sources/calibration sources
- Packaging and labeling for transportation

Dosimetry programs

- General requirements
- External dosimetry
- Internal dosimetry
- Nuclear accident dosimetry
- Quality control

Radiological Control Program Elements (cont.)

Instrumentation and alarms

- General requirements
- Air monitoring and sampling systems
- Effluent monitoring and sampling systems
- Fixed and portable monitoring systems
- Nuclear accident monitoring systems
- Warning and alarm systems

X-ray and source radiography

- General requirements
- Radiological safety
- Testing, operations, and calibration
- Emergency response
- Transporting and receiving sources

Workplace surveys and monitoring

- General requirements
- Dose rate surveys
- Contamination surveys (personnel, airborne, surface)
- Documentation

Radiological Control Program Elements (cont.)

Reporting

- Occurrences
- Operational events and emergency notifications
- Reports on employees' exposure
- OSHA complaints involving radioactive material

Radionuclide-specific guidance

- Uranium
- Plutonium
- Tritium
- Fission products

Radiation-producing machines

- X-ray machines
- Accelerators
- Radiography equipment

Emergency response

- Contamination of workplace
- Contamination of individuals
- Radiation overexposures
- Criticality accidents

Radiological Control Program Elements (cont.)

- Environmental releases
- Loss of radioactive material

Records

- Identification of required records
- Records management program
- Record media
- Record storage criteria
- Computerization of records

Conduct of operations

- Features and controls depend on specifics:
  - Site
  - Job
  - Radionuclide

Data and trend analysis

- Features and controls depend on specifics:
  - Site
  - Job
  - Radionuclide

Elements of a Radiological Control Program

The following pages list typical elements of a Radiological Control Program. The listing of these elements is intended to describe the magnitude of a complete protection program. These elements were derived from several sources.

The list is a generic compilation of program elements and is not intended to describe the program at any specific facility. Effective Radiological Control Programs will vary from site to site and facility to facility based on many factors. These factors include:

- The specific facility mission
- The types and quantities of radioactive materials in use at the site
- The physical and chemical forms of radioactive materials in use at the site
- The physical location of the site in relation to the population centers
- The size of the work force
- The age of the facility
- The original facility design criteria

Some of the elements of a Radiological Control Program are dependent on the specific radionuclides present at a site. For example, internal dosimetry methods are specifically dependent on the type of radionuclide being tested for.

The purpose of this list is to allow the user to compare a specific program with the elements identified here. It is up to the user to integrate the appropriate elements into his/her own site's programs.

Elements of a Radiological Control Program (cont.)

Management oversight of the Radiological Control Program

- Management commitment and policy
- Management responsibilities, authorities, and functions
- Resource and budget development
- Policy communications, directives, procedures, and manuals
- ALARA and other radiological safety committees
- Emergency response organization and responsibilities
- Control of experimental activities involving radioactive materials

Radiological control organization

- Organizational independence and reporting level includes:
  - Organizational charts
  - Reporting chain of the Radiological Control Organization
  - Methods to maintain independence from the operating level
  - Radiological Control Organization's interfaces with the operating organizations
  - Specification of corporate personnel to augment the plant's emergency staff
  - Augmentation by contractor personnel
- Responsibilities, authorities, and functions
- Authorized staffing levels

Training

- General requirements
- General employee training

Elements of a Radiological Control Program (cont.)

- Radiological control staff qualification and training requirements and methods for the following categories of workers:
  - Health Physics Technicians
  - Support technicians (bioassay, dosimetry, count room, calibration)
  - Supervisors
  - Managers
  - Technical support staff

- Radiological Worker training requirements and methods for the following categories of workers:
  - Reactor and nonreactor nuclear facility operators
  - Maintenance personnel
  - Construction personnel
  - Supervisors of radiological workers
  - Exempt personnel and contractor personnel

- Additional radiological training for the following operations personnel:
  - Reactor operators
  - Nonreactor nuclear facility operators
  - Instrument and electronics technicians
  - Fissile material handlers

- Manager and supervisor training requirements

- Respiratory protection training

- Medical personnel training for radiological protection

- Visitor training requirements

- Emergency radiological response training

- OSHA training and instruction

Reviews, audits, and evaluations

- Management overview practices for the following:
  - Triennial management review of procedures
  - Peer review of procedures
  - Management appraisals

Elements of a Radiological Control Program (cont.)

- Review of incidents, exposure data, and industry information

- Internal audits
  - Internal audits
  - Functional appraisals
  - Operational readiness reviews
  - Inspection of construction and operating activities

- Quality assurance program

- Safety analysis and assessment reviews

Radiological control organization's oversight of radiological design criteria

- General requirements

- Structural, surface, and facility design
  - Compartmentalization
  - Layout to regulate flow of material and personnel
  - Permanent and temporary shielding
  - Control of traffic patterns
  - Radiological zoning
  - Drainage basins
  - Design location of change rooms and shower facilities
  - Decontamination facilities

- Ventilation system design, air cleanup systems, and other design elements, including:
  - Exhaust systems
  - Piping systems for radioactive liquids
  - Ducts
  - Conduits
  - High Efficiency Particulate Air (HEPA) Filters
  - Valves
  - Pumps

Elements of a Radiological Control Program (cont.)

- Instrumentation and equipment design or selection for the following:
  - Computer systems
  - Process control instrumentation
  - Alarms and warning systems
  - Auxiliary lighting
  - Communication systems

- Design of special tools and enclosures including:
  - Glove boxes
  - Hoods
  - Tents
  - Robotics
  - Remote manipulators
  - Portable temporary ventilation systems

- Containment systems

Radiological safety work practices and administrative controls

- General ALARA concepts and controls, including:
  - Overall concept of keeping exposures ALARA
  - Setting and reestablishing person-rem goals
  - General methods of achieving ALARA goals
  - Basic principles of time, distance, and shielding
  - Documenting and maintaining trend analyses of historical exposure data, job-specific dose estimates, and experiences

- Establishment and control of individual and collective dose limits, including:
  - Regulatory limits to workers
  - Administrative limits to workers
  - Derived air concentrations
  - Limits of radionuclides in drinking water in controlled areas and external sources
  - Limits for annual effective dose equivalent for fetuses (for consistency with instructor's guide), students, and those under 18 years of age
  - Limits and policies for controlling exposure to pregnant women
  - Documentation of planned special exposures exceeding annual effective dose limits in unusual situations (nonemergency)
  - Limits for emergency rescue and recovery operations

Elements of a Radiological Control Program (cont.)

- Emergency plans and procedures
  - Guidance on the periodic conduct of emergency drills
  - Basic requirements for the availability and accessibility of emergency equipment and supplies
  - Lifesaving procedures

- Radiation and contamination control work practices
  - Adherence to procedures, Radiological Work Permits, status boards, and special job plans
  - Designating low-dose waiting areas
  - Location of drinking water fountains
  - Eating, smoking, and drinking in controlled areas
  - Assigning health protection inspectors for radiological job coverage
  - Personnel decontamination methods
  - Miscellaneous work performance methods, preparation of work areas, cutting of systems and components, and venting and draining methods
  - Radiological maintenance exposure reduction methods
  - Practices to avoid skin contamination (other than protective clothing)
  - Log for shift and daily activities

- Planning, preparing, and scheduling work
  - Developing exposure estimates based on previous history on time and dose rate estimates
  - Using accurate exposure estimates
  - Controlling the number of personnel used to perform work
  - Determining the stay time of workers
  - Providing adequate equipment, tools, and procedures at the task site
  - Establishing a collective exposure level
  - Establishing facility-specific radiological exposure goals for each job estimated to exceed a preestablished exposure action level, maximum individual radiological exposure, and person-rem received in repetitive jobs that result in a significant accumulation of exposure
  - Conducting pre- and post- job briefings
  - Using mock-up equipment and performing dry runs
  - Establishing a plan to document pertinent information for an ultimate decontamination and decommissioning activity

Elements of a Radiological Control Program (cont.)

- Radiological posting and access control
  - Identification of entrances to radiological areas and establishment of entrance requirements for each type of area
  - Placement and use of step-off pads
  - Radiation level marking on tags and status boards
  - Consistency of measurements used when marking radiation levels
  - Specification of airborne contamination limits
  - Tagging, roping, and barricading radiological areas
  - Posting and maintaining radiation symbols and status boards
  - Using interlock and air lock functions
  - Posting types and policies for use
  - Meaning of alarm signals and actions to be taken

- Protective clothing and laundry
  - Conditions under which protective clothing is worn
  - Types of protective clothing
  - Donning protective clothing (proper dressing out)
  - Removal of protective clothing
  - Proper disposal of protective clothing
  - Use of change rooms and clothing bins
  - Storage, laundering, monitoring, and reuse of protective clothing
  - Proper segregation of contaminated clothing
  - Laundry facilities, responsibilities, and procedures

- Respiratory protection program
  - Respirator protection factors
  - Application of types of respirators
  - Physical limitations for a proper seal (e.g., eyeglasses, beards)
  - Storage and use of respiratory equipment

- Policy and methods for the development of radiological safety and operating procedures

- Emergency response actions

Elements of a Radiological Control Program (cont.)

Radioactive materials control

- Feed, process, and output materials

- Practices for the collection and control of radioactive samples
  - Types of samples to be collected
  - Analyses performed on each sample
  - Sampling and analysis schedule
  - Sample collection points (access, shielding, ventilating)
  - Liquid and gaseous samples
  - Routine grab samples
  - Remote systems to collect containment and dry well samples
  - Chain-of-custody records for each sample

- Radioactive waste and waste management
  - Segregation of uncontaminated waste from contaminated waste
  - Waste processing systems (including operational envelope for decontamination factors, radionuclide concentrations, and equipment specifications)
  - Disposal methods, burial grounds
  - Waste-handling capabilities for decontamination solutions, contaminated oil and organics
  - Release rates, compliance with technical specification limits, total activity release, total volume release
  - Sanitary waste segregation
  - Drainage from personnel decontamination and safety shower water runoff
  - Labeling of waste containers, such as 55-gallon drums
  - Record keeping

- Contaminated materials and equipment
  - Tagging of tools and materials
  - Vacuum cleaners in contaminated areas or potentially contaminated areas

- Sealed radiation sources/calibration sources
  - Inventory practices
  - Leak testing
  - Record keeping

- Packaging and labeling for transportation of radioactive material

Elements of a Radiological Control Program (cont.)

Dosimetry program

- General requirements
  - Components of a dosimetry program
  - Monitoring the dosimetry program
  - Maintenance of exposure records

- External dosimetry
  - Selection and testing of the proper dosimetry device DOE Laboratory Accreditation Program
  - Control and use of:
    + Thermoluminescent dosimeters (TLDs)
    + Pocket dosimeters, self-reading dosimeters
    + Personnel alarm dosimeters
    + Nuclear track emulsions
    + Track etch
    + Whole-body dosimetry
    + Extremity dosimetry
    + Neutron dosimetry
  - Actions for lost dosimetry, unexpected results, or other abnormal situations

- Internal dosimetry
  - Selection of the proper internal dosimetry methods
  - Policies and methods for:
    + Whole-body counting
    + Thyroid counting
    + Lung counting
    + Urinalysis
    + Fecal analysis
    + Blood activity
    + Nasal swipes
    + Use of air monitoring results

  - Determination of dose based on internal dosimetry results

- Nuclear accident dosimetry

- Quality control for dosimetry

Elements of a Radiological Control Program (cont.)

Radiological safety instrumentation and alarms

- General requirements
  - Acquisition
  - Receipt and testing
  - Implementation
  - Maintenance and functional checks
  - Calibration and calibration facility requirements
  - Audible and visual indicator alarms
  - Documentation and record keeping requirements

- Air monitoring and sampling systems
  - Policies and use for:
    + Continuous air monitors
    + High-volume air samplers
    + Low-volume air samplers
    + Halogen-absorbing cartridge or filter
    + Silver zeolite cartridge or filter
    + Impingers
    + Personnel label samplers
    + Kanne chambers and other tritium monitors
    + Leak detectors
    + Breathing zone sampling equipment
  - System design and performance to national consensus standards
  - Airflow studies and source characterization
  - The use and control of filtering media
  - Source-term characteristics
  - Proper placement and operation of equipment
  - Documentation and record keeping requirements

- Effluent monitoring and sampling systems for:
  - Stack monitors
  - Off-gas monitors
  - Exhaust fans
  - Filter compartments
  - Filter flappers
  - Dampers

Elements of a Radiological Control Program (cont.)

- Fixed and portable dose rate and contamination monitoring instruments
  - Policies and controls for the use of radiation detectors
    - Photon, neutron, beta, alpha monitors
    - Proportional and scintillation counters
    - Count rate meters
    - Ion chambers
    - Geiger-Mueller tubes and counters
    - Hand and shoe counters, pancake monitors
    - Portal monitors
    - Chest counters
    - Area radiation monitors
    - Small dimension probes for wound monitors
  - Testing
  - Calibration schedule and standards
  - Functional checks
  - Maintenance
  - Storage
  - Inventory
  - Documentation and record keeping

- Nuclear accident monitoring systems
  - Nuclear incident monitors
  - Criticality monitors
  - Emergency radiological instrumentation systems for criticality incidents

- Warning and alarm systems
  - Periodic testing of the alarms
  - Alarm use in practice drills
  - Alarm panels and indicators
  - Type and placement for each facility/area
  - Calibration
  - Audible and visual indicators
  - System backup in the event of loss of power

Elements of a Radiological Control Program (cont.)

X-ray and source radiography

- General requirements
- Radiological safety
- Testing, operations, and calibration
- Emergency response
- Transporting and receiving radiography sources

Workplace surveys and monitoring

- General requirements
  - Survey frequencies (continuous monitoring, follow-up surveys)
  - Survey of routine and nonroutine activities
  - Monitoring conditions
  - Points at which monitoring will be required
  - Survey and monitoring techniques and methods
  - Implementation of a comprehensive routine surveillance program for radiation, contamination, and airborne surveys
- Schedules, policies, and control of dose rate surveys (routine, nonroutine, emergency)
- Schedules, policies, and practices for contamination surveys (personnel, airborne, and surface)
  - Monitoring workers during and following work
  - Surveys of gloves
  - Techniques for self-monitoring upon exit
  - Accessibility of exit monitoring equipment, surveys for loose surface contamination
  - Accuracy of detection (amount and source identification)
  - Personnel air sampling (breathing zones)
  - Procedures to follow when contamination is detected
  - Participation of health physics staff in developing, implementing, and auditing the survey and self-monitoring program
  - Smearable radioactive contamination
  - Surveys of injured personnel
- Documentation and record keeping requirements

Elements of a Radiological Control Program (cont.)

Reporting

- Unusual occurrences
- Operational events and emergency notifications
- Reports on employee exposures
- Occupational safety and health complaints involving radioactive material

Development of radionuclide-specific guidance for:

- Uranium
- Plutonium
- Tritium
- Fission products

Radiation-producing machines

- X-ray machines
- Accelerators
- Radiography equipment

Elements of a Radiological Control Program (cont.)

Radiological accidents and emergency response

- Contamination of workplace
- Contamination of individuals
- Radiological overexposures
- Criticality accidents
- Environmental release
- Loss of radioactive material

Records maintenance requirements

- Identification of required records
- Records management program
- Record media
- Record storage criteria
- Computerization of records

Conduct of operations as it relates to radiological protection

Data and trend analysis

Typical Safety Analysis Report (SAR) Contents

Introduction

Site Characteristics

Principal Safety Criteria (Success Criteria)

Process/Operations Descriptions

Waste Processing and Handling

Buildings, Structures, and Support Systems

Safety- and Nonsafety-Class Components (including engineered safety features)

Comparison with Criteria (including backfitting)

Special Safety Interest

Hazard Analysis and Classification

Assessment of Normal Operations

Analysis of Abnormal Conditions and Accidents

Derivation of Technical Safety Requirements

Management and Institutional Safety Provisions

Facility Safety Programs

Conduct of Operations

Maintenance Management

Testing and In-Service Surveillance

Procedures

Employee Selection and Training

Typical Safety Analysis Report (SAR) Contents (cont.)

Human Factors–Machine Interface

Emergency Preparedness

Provisions for Decontamination and Decommissioning

Quality Assurance

Technical Safety Requirement (TSR) Format and Content

Format/sections (hierarchy of requirements)

1. Use and Applications
2. Safety Limits
3. Operational Limits
4. Surveillance Requirements
5. Administrative Controls
6. Appendices

1. Use and application

   This section should contain basic information and instructions for using and applying the individual TSRs. Use and application include the following elements:

   a. Definitions (Specifically defined terms are to appear in uppercase type throughout the TSR document.)
   b. Operational Modes
   c. Logical Connections
   d. Completion Times
   e. Frequency Notations

2. Safety Limits (SLs)

   SLs should describe as precisely as possible the parameter being limited and state the limit in measurable units.

   a. Applicability

      Each SL is to have a mode applicability statement.

Technical Safety Requirement (TSR) Format and Content (cont.)

b. Actions

Action statements are to completely describe the actions to be taken in the event that the SL is not met.

c. Selection of SLs

SLs are those limits which, if exceeded, could directly cause the failure of one or more of the barriers that prevent the uncontrolled release of radioactive or other hazardous materials.

Combined Section 3/4

Within the TSR document, Section 3 delineates the Operational Limits, and Section 4 describes the Surveillance Requirements. There is usually a one-to-one correlation between the operational limits and the surveillance related to each. Thus, for convenience, each limit is typically presented at the same place as its related surveillance, and the combined information is designated Section 3/4.

This combined section should contain the Limiting Control Settings and the Limiting Conditions for Operation, as well as mode applicability information, Action Statements, and Surveillance Requirements, for each requirement.

3. Operational Limits (OLs)

The initial conditions of the safety (accident) analyses upon which the authorization to operate is based are the least conservative limits of acceptable operation. These initial condition values must be adjusted for both instrument error and the expected instrument drift between surveillances, and an allowance should be made for calculational uncertainties prior to being used as limits in the TSRs.

The most conservative value for each parameter contained in the safety analyses makes up the envelope within which the facility must operate in order to ensure that the SAR analyses found safe operations. Provided the facility is operated within these SAR initial condition limits, the SAR results accurately demonstrate that the consequences of accidents/transients/incidents are acceptable.

Technical Safety Requirement (TSR) Format and Content (cont.)

a. Limiting Control Settings (LCSs)

   LCSs should describe, as precisely as possible, the parameter being controlled and its limits, or the limiting setting of the device to control it.

b. Limiting Conditions for Operation (LCOs)

   The LCO statement describes, as precisely as possible, the lowest functional capability or performance level or equipment required for continued safe operation of the facility.

   Other elements to be address under OLs include:

c. Applicability (mode applicability)

d. Action (Action Statement in the event the LCS or LCO is not met)

e. Surveillance Requirements

f. LCSs of instruments that monitor process variables at nonreactor nuclear facilities (NNFs) are the settings that either initiate protective devices themselves or sound an alarm to alert personnel to take action in order to protect barriers that prevent the uncontrolled release of radioactive materials.

g. Selection of LCOs (for NNFs) should be written only for systems and equipment that meet one (or more) of the following descriptions:

   - Installed instrumentation that is used to detect and indicate in the control room or other control location an inadvertent criticality or a significant degradation of the physical barriers that prevent the uncontrolled release of radioactive materials

   - Structures, systems, and components that are relied upon in the SAR to function or actuate to prevent or mitigate accidents, or transients that either involve the assumed failure of, or present a challenge to, the integrity of a physical barrier that prevents the uncontrolled release of radioactive materials

Technical Safety Requirement (TSR) Format and Content (cont.)

- Process variables that are initial conditions for those design basis accidents or transient analyses which involve the assumed failure of, or present a challenge to, the integrity of a radioactive material barrier.

- Systems and equipment that are used for handling fissile material

The term **unusual conditions** is made clear in the final rule by specifying that alternatives which would preclude exposures higher than the prescribed dose limits must be either unavailable or impractical.

h. Special test exceptions may be allowed under controlled conditions.

4. Surveillance Requirements (SRs)

SR Statements consist of short descriptions of each requirement and its frequency of performance. A frequency of performance is mandatory. These statements should be as brief as possible, but should identify those requirements needed to ensure compliance with the LCS or LCO. Each Surveillance Requirement should begin with a verb. Consistency in the use of terms and sentence structure between requirements is important.

5. Administrative controls (ACs)

This section should impose administrative requirements necessary to control operation of the facility such that it meets the TSRs. These include:

- Contractor Responsibility
- Contractor Organization
- Procedures
- Programs
- Minimum Operations Shift Complement
- Operating Support
- Staff Qualifications and Training
- OPERABILITY Definition and Implementation
- TSR Basis Control
- Reviews and Audits
- Reporting Requirements

Technical Safety Requirement (TSR) Format and Content (cont.)

6. Appendices

- The Bases Appendix shall provide brief summary statements of the reasons for the SLs, OLs, and associated SRs. The bases shall show the numeric values, the conditions, the surveillances, and the Action Statements that fulfill the purpose derived from the safety documentation. The primary purpose for describing the basis of each requirement is to ensure that any future changes to the requirement will not affect its original intent or purpose.

- The purpose of the Design Features Appendix is to describe in detail those features not covered elsewhere in the TSRs which, if altered or modified, would have a significant effect on safety. Three areas should be addressed: vital passive components, configuration and physical arrangement, and materials.

Numbering System within the TSR Document

Safety Limits

SLs should begin with 2.1 and continue with 2.2, 2.3, etc.

Operational Limits

OLs begin with 3.1 and continue with 3.2, 3.3, etc. Any subdivision of OLs should be numbered with an additional number added to the number of the LSC, i.e., 3.2.2, 3.2.3, etc. OLs should be grouped by principal system or function, and each OL within a group should be numbered sequentially. LCSs are normally the first requirement within a group.

For NNFs, a standardized grouping of requirements may be difficult because of the diversity of facility types. However, many will have the following subdivisions:

Technical Safety Requirement (TSR) Format and Content (cont.)

- Applicability
- Criticality, Radioactivity, and Hazardous
- Confinement/Ventilation
- Fire Detection and Suppression
- Emergency Power
- Chemical Systems
- Instrumentation
- Experimental Facilities

Surveillance Requirements

SRs should be designated with numbers beginning with 4. The second number should correspond to the same grouping scheme utilized for the LCS or the LCO, and the third number in the sequence indicates the LCS or the LCO that this surveillance supports. Hence, the SR will have numbers the same as the corresponding LCS or LCO, except for the first number, which will be a “4” instead of a “3.”

Bases (Bases Appendix)

Bases are numbered in accordance with the SL, LCS, or LCO that they support.

Field Exercise Guidelines for Participants

You are to apply performance-based assessment techniques in the field. It is important that the exercise be flexible and broad. Therefore, you should be given the "controlled" freedom to move about in the facility. Sufficient personnel should be available for interaction and to answer any questions.

- After being issued security and dosimetry badges, you will observe a practice radiological control assessment performed by your field instructor.

- Following lunch, you will have the opportunity to conduct the assessment under the observation of your field instructor. He/she will give you "on the spot" guidance and help you individually at times.

- The aim of this field exercise is to demonstrate recommended methods and techniques of conducting radiological control assessments in the field by giving you some practice.

- You will spend several hours in a facility. The emphasis shall be on assessing proper radiological protection practices, policies, and procedures.

- You are to practice assessing by selecting an item or area and delving into it. It is important to practice the identification of surface issues (Type I), but more important to deal with the underlying issues (Types II and III).

- You will be performing a review of an issue, procedure, program (like ALARA), or system walk-down. You may observe a routine evolution, a test, or some maintenance job.

- Be alert to any routines, tests, or maintenance taking place during your facility visit. These give the best opportunity to see how the people do their jobs.

- Be alert to waste minimization and prevention. Always question material use and the discharge of materials to waste streams or the environment.

- Be alert to leaks or discharges of any kind.

- Work at looking at the big picture for issues such as minimization of controlled areas and control of work, personnel, and dose.

- During the evening, you will be writing one item as a concern or finding to present at the debrief on Friday morning. Therefore, you need to support the finding with what requirement exists and why your concern or finding is valid.

Field Exercise Guidelines for Participants (cont.)

- In the morning debrief, you will present your finding or issue for practice.
- It is important that you coordinate with the other members of your group so you present different findings/observations.
- You will have one and one-half minutes or so to present your finding.
- You should present your finding in this format:

    1. This is the requirement.
    2. Contrary to the requirement, this is what was noted.
    3. Therefore, I/we have the following concern/finding.

- Don't count on the people to whom you are presenting your finding to recognize what is wrong; you must justify it in enough detail that there is no doubt (make your case).
- Your field instructor will take care of thanks to the facility personnel during the debrief. (It takes too much time if each person does it.)
- Your instructor will collect your completed written finding at the completion of the class debrief.

Radiological Assessor Training
DOE-HDBK-1141-2008

CONCLUDING MATERIAL

Review Activity:

DOE

Field Offices

HS
ID
EM
SR
NE
OH
SC
RL
GC
IA
RW
NN

~~National Laboratories~~

BNL
LLNL
LANL
PNL
Sandia
ANL
New Brunswick
ORNL
SRNL

~~Operations Offices~~

AL
NV
OAK
OR
CH

~~Site Offices~~

Amarillo Site Office
Kirtland Site Office
Princeton Site Office
Fernald Site Office
Kansas City Site Office
Miamisburg Site Office
Y-12 Site Office

Preparing Activity:

DOE-HS-11

Project Number:

TRNG-0060