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DOE HANDBOOK

ALARA TRAINING FOR TECHNICAL SUPPORT PERSONNEL

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

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This document is available on the Department of Energy
Technical Standards Program
Web site at http://tis.eh.doe.gov/techstds/

Foreword

This Handbook describes a recommended implementation process for training as outlined in the *DOE Radiological Control Standard (RadCon Standard)*. The Handbook is to assist those individuals within Department of Energy (DOE), Managing and Operating (M&O) contractors, and Managing and Integrating (M&I) contractors, identified as having responsibility for implementing the training recommended by the *RadCon Standard*. This training may also be given to technical support personnel to assist in meeting their job-specific training requirements of 10 CFR 835.

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

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

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

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

Appendices - This document contains appendices that augment the Instructor's and Student's Guides.

Overhead Transparencies - This document contains recommended overhead transparencies that may be used to augment classroom presentation.

This Handbook is available in Word and has been formatted for printing on an HP IV (or higher) LaserJet printer. The overheads are available 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/rst.htm) or the DOE Technical Standards Program Internet site (http://www.hss.energy.gov/NuclearSafety/techstds/standard/standard.html). Documents downloaded from the DOE Radiation Safety Training Home Page Internet site may be manipulated using the software noted above (current revision or higher).

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ALARA Training for Technical Support Personnel

Program Management Guide

Coordinated and Conducted for Office of Health, Safety and Security U.S. Department of Energy

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Table of Contents

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Introduction

Purpose and Scope

This program management guide provides guidance for proper implementation of training as outlined in the *DOE Radiological Control Standard (RadCon Standard).* The guide is meant to assist those individuals within the Department of Energy (DOE), Managing and Operating (M&O) contractors, and Managing and Integrating (M&I) contractors identified as having responsibility for implementing the training recommended by the *RadCon Standard.* Facilities should determine the applicability of this material to support existing programs meant to comply with the training required by 10 CFR 835. Facilities are encouraged to revise these materials as appropriate.

Management Guide Content

The management manual is divided into the following sections:

- Introduction
- Instructional Materials Development
- Training Program Standards and Policies
- Course-Specific Information

Training Goal

The goal of the training program is to provide a baseline knowledge for those individuals completing the training. Implementation of the training provides personnel with the information necessary to perform their assigned duties at a predetermined level of expertise.

Organizational Relationships and Reporting Structure

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

Organizational Relationships and Reporting Structure (continued)

The establishment of a comprehensive and effective Contractor site radiological safety training program is the responsibility of line management and their subordinates. The training function can be performed by a separate training organization, but the responsibility for quality and effectiveness rests with the line management.

Instructional Materials Development Next

Instructional Materials Development

Target Audience	Course instructional materials were developed for specific employees who are responsible for knowing or using the knowledge or skills for each course. With this in mind, the participant should never ask the question, "Why do I need to learn this?" However, this question is often asked when the participant cannot apply the content of the program. It is the responsibility of management to select and send workers to training who need the content of the program. When workers can benefit from the course, they can be motivated to learn the content and apply it on their jobs. Care should be taken to read the course descriptions along with the information about who should attend. Participants and DOE facilities alike will not benefit from workers attending training programs unsuitable for their needs.
Prerequisites	A background and foundation of knowledge facilitates the trainee in learning new knowledge or skills. It is much easier to learn new material if it can be connected or associated to what was previously learned or experienced. Curriculum developers who have been involved in preparing instructional materials for the additional standardized training know this and have established what is referred to as "prerequisites" for each course. Certain competencies or experiences of participants were also identified as necessary prior to participants attending a course. Without these competencies or experiences, the participants would be at a great disadvantage and could be easily discouraged and possibly fail the course. It is not fair to the other participants, the unprepared participant, and the instructor to have this misunderstanding.

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Instructional Materials Development (continued)

Training Materials

Training materials for this training program consist of a program management guide, an instructor's guide, a student's guide, appendices, and overhead transparencies. This material is designed to be supplemented with facility-specific information.

Supplemental material and training aids may be developed to address facility-specific radiological concerns and to suit individual training styles. References are cited in each lesson plan and may be used as a resource in preparing facility-specific information and training aids.

Each site is responsible for establishing a method to differentiate the facility-specific information from the standardized lesson plan material. When additional or facility-specific information is added to the text of the lesson plan material, a method should be used to differentiate site information from standardized material.

Exemptions

Qualified personnel can be exempted from training if they have satisfactorily completed training programs (i.e., facility, college or university, military, or vendor programs) comparable in instructional objectives, content, and performance criteria. Documentation of the applicable and exempted portions of training should be maintained.

Training Program Standards and Policies Next

Training Program Standards and Policies

Qualification of Instructors

The technical instructor plays a key role in the safe and efficient operation of DOE facilities. Workers must be well qualified and have a thorough understanding of the facility's operation, such as processing, handling, and storage of materials, and maintenance of equipment. Workers must know how to correctly perform their duties and why they are doing them. They must know how their actions influence other worker's responsibilities. Because workers' actions are so critical to their own safety and the safety of others, their trainers must be of the highest caliber. The technical instructor must understand thoroughly all aspects of the subjects being taught and the relationship of the subject content to the total facility. Additionally, the instructor must have the skills and knowledge to employ the instructional methods and techniques that will enhance learning and successful job performance. While the required technical and instructional qualifications are listed separately, it is the combination of these two factors that produces a qualified technical instructor.

The qualifications are based on the best industry practices that employ performance-based instruction and quality assurances. These qualifications are not intended to be restrictive, but to help ensure that workers receive the highest quality training possible. This is only possible when technical instructors possess the technical competence and instructional skills to perform assigned instructional duties in a manner that promotes safe and reliable DOE facility operations.

Technical Qualifications

Instructors must possess technical competence (theoretical and practical knowledge along with work experience) in the subject areas in which they conduct training. The foundation for determining the instructor's technical qualifications is based on two factors:

- the trainees being instructed and
- the subject being presented.

The following is an example of a target audience, subject to be taught, and instructor technical qualifications.

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TARGET AUDIENCE	SUBJECT BEING TAUGHT	INSTRUCTOR TECHNICAL QUALIFICATIONS
Personnel with job assignments that include or support the design of nuclear facilities, the planning of radiological work, or the production of procedures that govern radiological work.	ALARA Principles	Demonstrated knowledge and skills in radiation protection, above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance.

Methods for verifying the appropriate level of technical competence may include the review of prior training and education, observation, and evaluation of recent related job performance, and oral or written examination. Other factors that may be appropriate for consideration include DOE, NRC, or other government license or certification, vendor or facility certification, and most importantly, job experience. To maintain technical competence, a technical instructor should continue to perform satisfactorily on the job and participate in continuing technical training.

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Training Program Standards and Policies (continued)

Instructional Capability and Qualifications

Qualifications of instructional capability should be based on demonstrated performance of the instructional tasks for the specific course requirements and the instructor's position. Successful completion of instructor training and education programs as well as an evaluation of on-the-job performance is necessary for verification of instructional capability. Instructional capability qualification should be granted as the successful completion of an approved professional development program for training instructors. The program should contain theory and practice of instructional skills and techniques; adult learning; and planning, conducting, and evaluating classroom, simulator, laboratory, and on-the-job training activities.

Illustrated talks, demonstrations, discussions, role playing, case studies, coaching, and individual projects and presentations should be used as the principal instructional methods for presenting the instructional training program. Each instructional method should incorporate the applicable performance-based principles and practices. Every effort should be made to apply the content to actual on-the-job experience or to simulate the content in the classroom/laboratory. The appropriate methodology required to present the instructional content will indicate a required level of instructional qualification and skill.

Current instructors' training, education, and job performance should be reviewed to determine their training needs for particular courses. Based on this review, management may provide exemptions based on demonstrated proficiency in performing technical instructor's tasks.

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Training Program Standards and Policies (continued)

Instructional Capability and Qualifications (continued)

Through training or experience, technical instructors should be able to*:

- Review instructional materials and modify to fully meet the needs of the training group.
- Arrange the training facility (classroom/laboratory or other instructional setting) to meet the requirements for the training sessions.
- Effectively communicate (verbally and non-verbally) lessons to enhance learning.
- Invoke student interaction through questions and student activity.
- Respond to students' questions.
- Provide positive feedback to students.
- Use appropriate instructional materials and visual aids to meet the lesson objectives.
- Administer performance and written tests.
- Ensure evaluation materials and class rosters are maintained and forwarded to the appropriate administrative personnel.
- Evaluate training program effectiveness.
- Modify training materials based on evaluation of training program.

*Stein, F., *Instructor Competencies: The Standards.* International Board of Standards for Training, Performance and Instruction, 1992.

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Training Program Standards and Policies (continued)

Selection of Instructors

Selection of instructors should be based on the technical and instructional qualifications specified in the Course-Specific Information section of this guide. In addition to technical and instructional qualifications, oral and written communication skills and interpersonal skills should be included in the process of selecting and approving instructors.

Since selection of instructors is an important task, those who share in the responsibility for ensuring program effectiveness should:

- Interview possible instructors to ensure they understand the importance of the roles and responsibilities of technical instructors and are willing to accept and fulfill their responsibilities in a professional manner.
- Maintain records of previous training, education, and work experience.

Procedures for program evaluation will include documentation of providing qualified instructors for generic and facility-specific training programs.

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Training Program Standards and Policies (continued)

Test Administration

A test bank of questions for each course that has an exam should be developed and its content validated. As the test banks are used, statistical validation of the test banks should be performed to fully refine the questions and make the tests as effective as possible. The questions contained in the test banks are linked directly to the objectives for each course. In this way, trainee weaknesses can be readily identified, and remedial procedures can be put into place. The test outcomes can also be used to document competence and the acquisition of knowledge.

The test banks should also be used by the instructors to identify possible weaknesses in the instruction. If numerous trainees fail to correctly answer a valid set of questions for an objective, the instruction for that objective needs to be reviewed for deficiencies.

Written examinations may be used to demonstrate satisfactory completion of theoretical classroom instruction. The following are some recommended minimal requirements for the test banks and tests:

- Randomly generate tests from the test bank.
- Represent all course objectives.
- Validate the content of all test bank items by a subject matter expert.
- Secure test banks and do not release them either before or after the test is administered.

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Training Program Standards and Policies (continued)

Test Administration (continued)

- Provide feedback to trainees on their test performance.
- For the first administrations of tests, require a minimum of 80 percent correct for a passing score. As statistical analyses of test results are performed, a more accurate percentage for a passing score may be identified.

Test administration is critical in accurately assessing the trainee's acquisition of knowledge being tested. The following rules should be followed:

- Announce tests at the beginning of the training sessions.
- Instructors should continuously monitor trainees during examinations.
- Collect all tests and answers at the conclusion of each examination.
- No notes can be made by trainees concerning the test items.
- Efforts should be made to eliminate all noise during the test.
- Allow no talking, aside from questions.
- Provide answers to trainees' questions during a test, but not answers to test items.
- Where possible, produce multiple versions of each test from the test bank for each test administration.

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Training Program Standards and Policies (continued)

Test Administration (continued)	• After test completion, trainees may turn in their materials and leave the room while other trainees complete their tests. • Trainee scores on the tests are confidential.
Program Records and Administration	Training records and documentation shall meet the requirements of 10 CFR 835.704
Training Program Development/Change Requests	All requests for program changes and revisions should use the form “Document Improvement Proposal” provided at the end of this document.
Audit (Internal and External)	Internal verification of training effectiveness should be accomplished through senior instructor or supervisor observation of practical applications and discussions of course material. All results should be documented and maintained by the organization responsible for Radiological Control training. The training materials and processes should be evaluated on a periodic basis by DOE-HQ. The evaluation should include a comparison of program elements with applicable industry standards and requirements.
Evaluating Training Program Effectiveness	Verification of the effectiveness of Radiological Control training should be accomplished per DOE-HDBK-1131-98, Reaffirmation 2004, “General Employee Radiological Training,” and DOE-HDBK-1130-98, Reaffirmation 2004, “Radiological Worker Training”. In addition, DOE/HS has issued guidelines for evaluating the effectiveness of radiological training through the DOE Operations Offices and DOE Field Offices. For additional guidance, refer to DOE-STD-1070-94, Reaffirmation 1999, “Guide for Evaluation of Nuclear Facility Training Programs.”

Course-Specific Information Next

Course-Specific Information

Purpose	This section of the program management guide is to assist those individuals assigned responsibility for implementing the *ALARA Training for Technical Support Personnel.*
Course Goal	Upon completion of this training, the student will have a basic understanding of the philosophy and principles of ALARA and their application to the facility and to facility and equipment design.
Target Audience	Personnel with job assignments that include or support the design of nuclear facilities, the planning of radiological work, or the production of procedures that govern radiological work. This training, or portions of it, may be appropriate for managers and supervisors of people in these categories.
Course Description	This course reinforces the skills and knowledge needed to apply ALARA principles (including optimization) to facility and operational designs and reviews. This course emphasizes application of ALARA principles by participation in group exercises. It also provides an overview of radiological fundamentals that may be presented by alternative methods. This course is developed in accordance with Articles 652/653 of the RadCon Standard.
Prerequisites	This training material is designed to augment the DOE Radiological Worker training. As a refresher, this course includes Radiological Worker training material, but is not intended to replace Radiological Worker training. The first three modules may be issued as a self-study. It is a general overview of Radiological Worker topics. The presentation of the remainder of the course may be adjusted accordingly.

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Course Specific Information (continued)

Prerequisites (continued)	The facility training program should determine the appropriate prerequisites. However, it is recommended that students complete Radiological Worker training prior to taking this course.
Length	The suggested course length is two days; however, the scope and amount of training should be evaluated by each site based on probable average dose savings.
Test Bank	On a site-by-site basis.
Retraining	Retraining is not required for this course unless it is used to meet 10 CFR 835 training requirements. In that case, retraining every two years is required. Since some of the content is based on facility-specific information, retraining should also be provided as facility-specific information changes.
Instructor Qualifications	Instructors of this course have a major role in making it successful and meeting the specified objectives. Instructors must have related experience and be technically competent. In this course it is imperative that the instructor have the background and experience of working in radiological facilities. Instructors must be able to relate their own work experience to the facility workers. Instructors must be able to answer specific questions and use a variety of instructional material to meet the objectives. Education: Minimum of B.S. degree in Health Physics or related discipline is preferred. Certification: Certification by American Board of Health Physics (ABHP) or National Registry of Radiation Protection Technologists (NRRPT) is preferred.

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Course Specific Information (continued)

Instructor Qualifications (continued)

Experience: At least five years of applied radiological protection experience in an operating radiological facility including experience in radiological protection and the applicable ALARA principles is preferred. The areas of experience should include:

- Radiological Systems
- ALARA Principles
- ALARA Optimization Processes

The instructor must also be knowledgeable in Federal regulations and guidance, and best nuclear industry practices pertaining to radiological protection.

Materials Checklist

The following checklist should be used to ensure all training materials are available. The Program Management Guide, Instructors Guide, and Student Guide are provided in Word 2003 format. The Overheads and Student Handouts are provided in PowerPoint 2003 format.

- Program Management Guide
- Instructor's Guide
- Student's Guide
- Appendices
- Overheads/Student Handouts

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Course Specific Information (continued)

Equipment Checklist

The following checklist should be used before training is provided to ensure equipment is available and working.

- Overhead projector
- Screen
- Flip chart, chalkboard, or white board
- Markers or chalk

Bibliography Next

Bibliography: **<u>DOE standards, handbooks, and technical standards lists (TSLs).</u> The following DOE standards, handbooks, and TSLs form a part of this document to the extent specified herein.**

U.S. Department of Energy, *Guide to Good Practices for Training and Qualification of Instructors*, DOE-HDBK-1001-96, Washington, D.C., 1996.

U.S. Department of Energy, *Proceedings of the Department of Energy ALARA Workshop, Held at Brookhaven National Laboratory, Upton, NY 11973, April 1992*, Conf-920468, Brookhaven National Laboratory, Upton, NY.

U.S. Department of Energy, Training Resource and Data Exchange, TRADE, *ALARA for Design and Operations Engineers*, Oak Ridge Institute for Science and Education, Oak Ridge, TN, April 1993.

U.S. Department of Energy, *Radiological Control Standard*, DOE-STD-1098-99, Ch. 1, Washington, D.C., March 200.

U.S. Department of Energy, *Occupational ALARA Program Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*, DOE G-441.1-1B, March 2007.

U.S. Department of Energy, *Health Physics Manual of Good Practices for Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)*. PNL-6577, Pacific Northwest Laboratory, Richland, WA.

U.S. Department of Energy, DOE Order 5400.5, Ch. 2, *Radiation Protection of the Public and the Environment*, Washington, D.C.

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<u>Other government documents, drawings, and publications.</u> The following government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise indicated, the issues of these documents are those cited in the contracting document.

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, Washington, DC, September 1988.

<u>Non-Government documents</u>

Baum, John W., Health Physics Society, *Proceedings of the Twenty-Fourth Midyear Topical meeting of the Health Physics Society, Raleigh, NC*, "ALARA at Nuclear Power Plants," January 1991.

International Commission on Radiation Protection, ICRP Publication 37, *Cost- Benefit Analysis in the Optimization of Radiation Protection*. Pergamon Press, New York, NY, 1982.

International Commission on Radiation Protection, ICRP Publication 55, *Optimization and Decision-Making in Radiological Protection*, Pergamon Press, New York, NY, 1990.

Jorgensen, David B., et al., editors, Health Physics Society, *Proceedings of the Twenty Fourth Midyear Topical meeting of the Health Physics Society, Raleigh, NC*, "Implementation of Current NCRP and ICRP Guidance and Revised 10 CFR Part 20," January 1991.

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ALARA Training for
Technical Support Personnel

Instructor's Guide

Coordinated and Conducted
for
Office of Health, Safety and Security
U.S. Department of Energy

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Table of Contents

DEPARTMENT OF ENERGY – COURSE PLAN

COURSE MATERIAL

Course Goal	Upon completion of this training, the student will have a basic understanding of the philosophy and principles of ALARA and their application to the facility.
Target Audience	Personnel with job assignments that include or support the design of nuclear facilities, the planning of radiological work, or the production of procedures that govern radiological work. This training, or portions of it, may be appropriate for managers and supervisors of people in these categories.
Description	This course reinforces the skills and knowledge needed to apply ALARA principles (including optimization) to facility and operational designs and reviews. This course emphasizes application of ALARA principles by participation in group exercises. It also provides an overview of radiological fundamentals that may be presented by alternative methods. This course is developed in accordance with Article 652/653 of the Radiological Control Standard.
Prerequisites	This training material is designed to augment the DOE Radiological Worker training. As a refresher, this course includes Radiological Worker training material, but is not intended to replace Radiological Worker training. The first three modules may be issued as a self-study. It is a general overview of Radiological Worker topics. The presentation of the remainder of the course may be adjusted accordingly.

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Prerequisites (continued)	The facility training program should determine the appropriate prerequisites. However, it is recommended that students complete Radiological Worker training prior to taking this course.
Length	The suggested course length is two days; however, the scope and amount of training should be evaluated by each site based on probable average dose savings.

Course Objective Next

COURSE OBJECTIVE

Terminal Objective:	At the end of this course, the participant should be able to demonstrate a basic understanding of the ALARA philosophy, types of radiation, special topics concerning ALARA, and the principles of ALARA used to minimize and control radiation and contamination levels.
Enabling Objectives:	Module 101 1. Define the acronym ALARA 2. List the ALARA recommendations outlined in the DOE Radiological Control Standard (RadCon Standard), and 3. Identify which groups should participate in the ALARA design reviews. Module 102 Be able to define and identify the penetrating abilities in body tissue of: 1. Alpha, 2. Beta, 3. Gamma and X-rays , and 4. Neutron radiation. Module 103 1. List four ways radioactive material enters the body. 2. Define the terms "crud" and activation products. 3. Discuss controls for airborne radioactive material. 4. Discuss methods to process radwaste. 5. Define the terms "Controlled Area" and "Radiological Area." Discuss types of radiological areas. 6. Identify types of contamination control measures, and 7. Define scattering and streaming.

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Enabling Objectives (continued)

Module 104

1. Identify the six fundamental principles used to reduce radiation doses and the release and spread of radioactive materials.
2. Identify applications of the fundamental principles.
3. Identify shielding materials used to reduce radiation exposures.

Module 105

During the presentation of Module 105, participants should demonstrate the application of ALARA principles of source term reduction and control.

Module 106

During presentation of Module 106, participants should demonstrate the application of ALARA principles to system design.

Module 107

Participants should demonstrate the application of ALARA principles in structural design.

Module 108

Participants should demonstrate the application of ALARA principles in design reviews.

Module 109

Participants should demonstrate the application of ALARA principles in operations.

Module 110

During the presentation of Module 110, participants should demonstrate the application of optimization techniques.

Training Aids Next

TRAINING AIDS	Overhead transparencies (may be supplemented or substituted with updated or facility-specific information).
Equipment Needs	• Overhead projector • Screen • Flip chart, chalk board, or white board • Markers or chalk
Student Materials	Student's guide and copy of overhead transparencies.

Lesson Summary Next

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LESSON SUMMARY

Introduction

Welcome students to the course.

Show OT INTRO-1.

Introduce self to the participants and establish rapport.

Define logistics:

- safety briefings - exits
- restrooms
- hours
- breaks
- sign-in sheets
- test - accountability
- end of course evaluation

Terminal Objective

At the end of this course, the participant should be able to demonstrate a basic understanding of the ALARA philosophy, types of radiation, special topics concerning ALARA, and the principles of ALARA used to minimize and control radiation and contamination levels.

State Enabling Objectives.

Show OT INTRO-2 and INTRO-3.

Course Content

Briefly review the content of the course, noting that there is a logical sequence (“flow”) and that you will relate the material covered to the circumstances they can expect to find in the facility workplace and procedures. (You will be inserting site-specific and facility-specific information.)

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Course Content (continued)

This course is designed to introduce technical support personnel to the fundamentals of radiation and contamination control and reduction when designing, modifying existing facilities, or planning and scheduling activities. The first three modules are a review of and enhancement to the Radiological Worker training. Course content is as follows:

Note: The first three modules may be issued as a self-study in class or before class. Adjust presentation accordingly. The student guide is arranged to reflect this.

1. Introduction to ALARA
2. Types of Radiation
3. Selected Topics in Radiation Protection
4. ALARA Fundamental Principles
5. Applications of ALARA to Source Term Reduction and Control
6. Application of ALARA to Facility or System Design
7. Application of ALARA For Various Engineering Disciplines
8. ALARA Design Reviews
9. ALARA Operational Reviews
10. Optimization Analysis

Note: It is critically important to set the proper tone. Outline the reasons for the importance of this course. For example, radiologically safe designs typically result in dollar savings, efficient operations, mission performance improvements, and improved health and safety attitudes by workers and the public. Discuss the impacts of failure to control radiation and radioactive materials (e.g., health effects, civil liabilities, property damage, company image, performance reviews, loss of project funding, etc.

Lesson Plan and Instructor's Notes Next

Lesson Plan	Instructor's Notes
I. MODULE 101	Show OT 101-1
1. INTRODUCTION TO ALARA	
A. Objectives. Following self-study and classroom review, participants will be able to: 1. Define the acronym ALARA, 2. List the ALARA recommendations outlined in the DOE Radiological Control Standard (RadCon Standard), and 3. Identify which groups should participate in the ALARA design reviews.	Show OT 101-2
2. DEFINITION AND PHILOSOPHY OF ALARA **A. ALARA.** ALARA stands for "As Low As Reasonably Achievable."	Show OT 101-3 Objective 1
B. Definition. ALARA is defined as an approach to radiation protection to manage and control doses (both individual and collective) to the work force and the general public such that the doses are kept as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but a process, which has the objective of maintaining dose levels as far below applicable limits of 10 CFR 835 and DOE Order 5400.5 as is reasonably achievable.	Show OT 101-4

Lesson Plan	Instructor's Notes
C. Discussion. The current system of radiological protection reflected in the National Council on Radiation Protection and Measurements (NCRP) Publication 116, *Limitation on Exposure to Ionizing Radiation* (NCRP 1993), is based on three general criteria. 1. The need to justify any activity which involves radiation exposure on the basis that the expected net benefits to society exceed the overall societal cost. 2. The need to ensure that the total societal detriment from such justifiable activities or practices is maintained ALARA, economic and social factors being taken into account. 3. The need to apply individual dose limits to ensure that the procedures of justification and ALARA do not result in individuals or groups of individuals exceeding levels of acceptable risk. Although DOE has not formally adopted the recommendations of NCRP 116, these criteria are reflected in the RadCon Standard and 10 CFR 835.	Show OT 101-5

Lesson Plan	Instructor's Notes

D. Linear Nonthreshold Hypothesis.
The linear nonthreshold hypothesis assumes the risk of detriment from radiation is directly proportional to the dose and no threshold exists below which there is no detriment (damage). This theory is controversial because it is derived from extrapolation of low dose and low dose rate effects from high dose and high dose rate data. To ensure adequate protection, national and international groups have recommended, and DOE has adopted, a system of regulatory limits and an emphasis on ALARA to keep exposures as far below the limits as is reasonable.

E. No Fixed Numerical Criteria.
The ICRP states that there is no one set of numerical criteria universally applicable in determining whether a measure or practice is ALARA. Instead, such criteria should be derived on a case-by-case basis. Sometimes the criteria are applicable to one site or facility, and sometimes to a single task. ALARA measures should not be implemented without careful consideration of associated costs and benefits. Failure to evaluate the costs and benefits of a protective measure can be a waste of resources, or even result in unjustifiably increased dose along with its associated risk. An example of such a case is presented in Appendix F.

Lesson Plan	Instructor's Notes
F. Responsibility. According to DOE Orders, the responsibility for controlling exposures lies at every organizational level, including management, supervision, engineering, the radiological control department, and individual employees. This includes occupational doses AND doses to the public and the environment from DOE operations.	
3. POLICIES, REGULATIONS, AND OTHER GUIDANCE The principal objective of the ALARA policy is to reduce the dose to facility personnel and the public, and to reduce the levels of radioactive materials released to the environment to the lowest levels in keeping with sound operating and economic practices.	
DOE directives and technical documents that require that ALARA measures be incorporated into nuclear facility design include:	Show OT 101-6 Show OT 101-7
A. 10 CFR 835, "Occupational Radiation Protection." Section 10CFR 835.1001 requires that: "(a) Measures shall be taken to maintain radiation exposure in controlled areas as low as is reasonably achievable through engineered features and administrative controls. The primary methods used shall be engineered features (e.g., confinement, ventilation, remote handling, and shielding). Administrative	

Lesson Plan	Instructor's Notes
controls and procedural requirements shall be employed only as supplemental methods to control radiation exposure; (b) For specific activities where use of engineered features are demonstrated to be impractical, administrative controls and procedural requirements shall be used to maintain radiation exposures ALARA." Facility design and modification per 835.1002: 1. In areas of continuous occupational occupancy (2,000 hours per year) the design objective shall be to maintain dose rate levels below an average of 0.5 mrem (5 μSv) per hour and as far below this average as is reasonably achievable. 2. The design objectives for exposure to a radiological worker where occupancy differs from that above shall be ALARA and shall not exceed 20 percent of the applicable standards (10 CFR 835) 10 CFR 835.101(c) requires that the Radiological Protection Program shall include formal plans and processes for implementing ALARA. Also, DOE O 420.1, *Facility Safety*, sets ALARA design criteria.	

Lesson Plan	Instructor's Notes
B. DOE Radiological Control (RadCon) Standard.	Show OT 101-8
1. The RadCon Standard recommends the following:	Objective 2
a. Individual worker dose should be less than 500 mrem/yr;	
b. Discharges of radioactive liquid to the environment are covered by DOE 5400.5 and should not degrade the ground water;	
c. Control of contamination should be achieved by containment of radioactive material (Note: Ventilation is an alternative, if filtered, for control of particulates);	
d. Efficiency of maintenance, decontamination, operations, and decommissioning shall be maximized;	
e. Components should be selected to minimize the buildup of radioactivity;	
f. Support facilities shall be provided for donning.	

Lesson Plan	Instructor's Notes
removal of protective clothing and for personnel contamination monitoring, when required; and	
2. The RadCon Standard emphasizes engineered controls over administrative controls, especially to minimize the need for respiratory protection.	Show OT 101-9
3. Operational planning and review of work is emphasized.	
4. ALARA training for procedure writers, engineers, and planners is specifically recommended.	
5. Records of ALARA planning are to be kept.	
C. DOE Order 5400.5. DOE Order 5400.5, Ch. 2, “Radiation Protection of the Public and the Environment,” gives specific dose limits for the general public, such as limits on the releases of radioactive materials in airborne and waterborne effluents from DOE nuclear facilities to the environment. This order also requires contractors to implement the ALARA process (i.e., cost benefit/ optimization analysis) for all DOE facilities that cause public dose. The actual doses should be as far below the limits as is reasonably achievable.	

Lesson Plan	Instructor's Notes
D. PNL-6577.	Show OT 101-10
PNL-6577, "Health Physics Manual of Good Practices for Reducing Radiation Exposures to Levels that are ALARA," states that ALARA should be incorporated into the earliest stages of the design of a building or operation and that a radiological engineer or ALARA specialist should be on the design team from the beginning. The design or operation should be reviewed at each of the appropriate stages, and any team reviewing the design or operation should include representatives from: 1. Maintenance, 2. Operations, 3. Research, 4. Safety, and 5. Appropriate engineering disciplines. PNL-6577 also states that design and operations engineers, as well as other groups, should be trained in the principles of ALARA. Engineers must be aware of pitfalls or questionable practices to participate intelligently in ALARA reviews, and all disciplines should understand any radiological implications their equipment or operations may have. Much design time can be saved if the engineer knows some of the good practices in advance, and the engineer trained in ALARA becomes more aware of what is contained in available	Objective 3

Lesson Plan	Instructor's Notes
references regarding good design or operation. Radiological engineers probably will not have the necessary expertise to make ALARA judgments in all engineering areas (e.g., HVAC, electrical, mechanical, architectural); this will most often be a consensus decision of a facility or operational project or a design team.	
4. SITE SPECIFIC ALARA DESIGN REQUIREMENTS Add materials here based on review of site procedures relating to safety reviews and design criteria.	

Lesson Plan	Instructor's Notes
II. MODULE 102	Show OT 102-1
1. TYPES OF RADIATION	Show OT 102-2
A. Objectives. Following self-study and/or classroom review, participants will be able to define and identify the penetrating abilities in body tissue of: 1. Alpha, 2. Beta, 3. Gamma and X-rays, and 4. Neutron radiation.	
2. RADIOACTIVITY AND RADIATION	Show OT 102-3
A. Radioactivity. Radioactivity may be defined as spontaneous nuclear transformations that result in the formation of new elements. It is this spontaneous decay or disintegration of an unstable nucleus that may result in the emission of ionizing radiation.	
B. Radioactive Half-life. Different radionuclides decay at different rates. The time required for any given radionuclide to decrease to one-half of its original quantity is a measure of the rate with which the radionuclide undergoes radioactive decay. This period of time is called the half-life, and is unique to the individual radionuclide.	
C. Radioactive Material. Radioactive material contains atoms whose nuclei have excess energy (unstable) and reduce their energy by	Show OT 102-4

Lesson Plan	Instructor's Notes
decaying or transforming and releasing the excess energy in the form of ionizing radiation.	
D. Ionizing Radiation. Ionizing radiation is the actual particle or photon (packet of electromagnetic energy) emitted by the nucleus or atom during the process of radioactive decay. These radiations interact with and cause ionizations within the materials through which they pass. In the field of radiation protection, the primary concern is radiation interacting with the body, causing biological damage to living tissue. Engineers are also concerned with evaluating whether potential radiation damage to materials or equipment may compromise function.	Show OT 102-5
E. Particles and Photon Radiations. The two general categories of ionizing radiation are particulate (alpha, neutron, beta), which consists of subatomic particles ejected from the nucleus, and photons (X and gamma rays), which also have particle like properties. Alphas and betas are electrically charged particles, while neutrons and photons have no charge.	Show OT 102-6
3. TYPES OF RADIATION **A. Alpha Particles.** 1. Alpha particles are highly energetic helium nuclei that are emitted from the nucleus of a heavy atom (e.g., Uranium-235).	Show OT 102-7 Objective 1

Lesson Plan	Instructor's Notes
2. They are made up of two protons and two neutrons, giving them a charge of +2 and a mass about four times that of a neutron or proton.	
B. Beta Particles.	Show OT 102-8 Objective 2
1. A beta particle is an energetic electron that is ejected from the unstable nucleus.	
2. Beta particles carry an electric charge of -1 or + 1 and have a mass much smaller than that of a neutron or proton.	
C. Gammas and X-Rays.	Show OT 102-9 Objective 3
1. Gammas and X-rays are chargeless and massless waves of electromagnetic energy. They both consist of discrete packets of energy called "photons."	Show OT 102-10
2. Gammas and X-rays radiation are identical except for where they originate.	
a. Gamma rays come from the nucleus of the atom, and	Show OT 102-11
b. X-rays come from two sources. One is from the movement of an electron from one atomic orbital energy level to another, and the second is from the slowing down of a free electron when it passes close to a large nucleus. In the latter case, the X-rays are called	

Lesson Plan	Instructor's Notes
"bremsstrahlung" (braking radiation); these are an important consideration in the shielding of beta particles.	
D. Neutron.	Objective 4
1. Neutrons are uncharged particles that reside in the nucleus of the atom along with protons. A neutron has about the same mass as a proton.	
2. Sources of neutron radiation include nuclear reactors, accelerators, natural neutron emitters (e.g., transuranic radionuclides) and mixtures of alpha emitters and radionuclides that absorb alpha particles and subsequently emit neutrons.	
4. PENETRATING ABILITY IN TISSUE	Show OT 102-12
A. Alphas.	
1. Alpha particles will not penetrate the dead layer of skin and are not even considered from an external radiation standpoint. Alphas travel no more than a few inches in air.	Objective 1
2. Alphas are considered to be a hazard only when the radioactivity emitting them is inside the body, where the very localized deposition of the high alpha energy can be significantly damaging.	
B. Betas and Electrons.	Objective 2
1. A beta particle will travel several feet through the air and through several layers of skin depending on its energy.	

Lesson Plan	Instructor's Notes
2. Beta radiation, therefore, is considered to be both an external (predominantly the skin or eyes) and an internal exposure hazard.	
C. Gammas and X-Rays.	Objective 3
1. Primarily because they have no charge, gamma and X ray radiation are highly penetrating in tissue and are termed "penetrating radiation."	
2. They will pass deeply into or completely through the whole body, possibly causing biological damage to internal organs they interact with.	
D. Neutrons.	Objective 4
1. Because they carry no charge, neutrons are very penetrating and may travel long distances in air.	
2. Neutrons are more readily stopped by materials that contain hydrogen, such as tissue, and other materials with low atomic mass. Neutrons are generally considered an external hazard.	
3. Low-energy neutrons eventually are absorbed by another nucleus, and the resulting nuclide may be radioactive. The latter process is called neutron activation. In the absorption process, excited nuclei are created which subsequently emit gamma radiation. This radiation may also result in added dose.	

Lesson Plan	Instructor's Notes
III. MODULE 103	Show OT 103-1
1. SELECTED TOPICS IN RADIATION PROTECTION **A. Objectives.** Following self-study and/or classroom review, participants will be able to: 1. List four ways radioactive material enters the body. 2. Define the terms "crud" and activation products. 3. Discuss controls for airborne radioactive material. 4. Discuss methods to process radwaste. 5. Define the terms "Controlled Area" and "Radiological Area." Discuss types of radiological areas. 6. Identify types of contamination control measures. 7. Define scattering and streaming.	Show OT 103-2
2. RADIATION EXPOSURE MODES **A. Radiation Dose.** Radiation interacts with the body by depositing its energy in the cells of the tissue. Deposition of this energy causes chemical alterations which may cause biological damage. This energy is delivered to the tissue from the decay of radioactive material deposited inside the body or from radiation emitted from external sources.	Show OT 103-3
Appendix C discusses certain dosimetry calculations using the dosimetry quantities provided in 10 CFR 835.	Discuss Appendix C to an appropriate level of detail.

Lesson Plan	Instructor's Notes
B. External Dose. All or part of the body can receive dose delivered by a source that is outside the body. Typical sources include radioactive materials in flasks, pipes, and sealed containers, and air or water containing radioactive materials.	Show OT 103-4
C. Internal Dose. Internal dose is delivered to the body tissue from radioactive material present inside the body. It may involve large or small portions of the whole body or specific organs to which the isotope is attracted. Radionuclides can enter the body in four ways:	Show OT 103-5
1. Inhalation: worker breathes in air containing airborne radioactive materials.	Objective 1
2. Ingestion: worker swallows some radioactive material.	
3. Absorption: a few radioactive materials can be absorbed through the skin.	
4. Injection: radioactive materials may be carried into the body through wounds or punctures in the skin.	
D. Whole-Body Dose. Whole-body dose normally results from penetrating radiation such as gammas, X-rays, or neutrons. An exception is the whole-body dose delivered by some radioactive material, such as tritiated water, that is	Show OT 103-6

Lesson Plan	Instructor's Notes
dispersed throughout the body. The gammas and X-rays may interact with the body in two ways:	
1. They interact with body material and deposit all or part of their energy in local tissues, or	
2. They pass through the body without interaction. With no deposition of energy, there is no dose.	
E. Skin Dose. In addition to the dose from penetrating radiation, skin dose may also be delivered by weakly penetrating radiation such as low-energy gamma rays, X rays, and beta particles.	Show OT 103-7
F. Extremity Dose. Extremities include hands, arms below the elbow, feet, and legs below the knees. (The head is considered to be part of the whole body). High dose to an extremity without a correspondingly high dose to the body can result from work in non-uniform radiation fields or proximity to a small, strong radiation source. The extremities are not as sensitive to radiation damage as the rest of the whole body and can tolerate higher doses. Due to this fact, extremity dose limits have been established at levels higher than the whole-body limits.	Show OT 103-8
3. CRUD AND OTHER RADIOACTIVE SOURCES	Show OT 103-9
A. Crud. Originally, crud was considered to be activated debris or fuel bits in the coolant piping of reactors. Because many people apply the term to any contamination in	Objective 2 Note: The term "CRUD" may have originated at a

Lesson Plan	Instructor's Notes
liquid systems that may deposit as solids in unfavorable spots, we will use it for convenience in this expanded sense as well. Crud deposition problems are thus potentially present for all facilities and equipment that have liquids containing radioactive material circulating in them. Such deposits can be a prime contributor to "hot spots" (small, localized areas with dose rates significantly higher than general area dose rates) in piping, valves, pumps, and tanks.	Canadian power reactor. It is thought that "CRUD" is an acronym for "Chalk River Unidentified Deposit."

B. Radiation Levels from Crud.

The radiation from crud does not go away when the facility shuts down. The radiation levels usually decrease over time as a result of radioactive decay, with the rate depending on the half-lives of the radionuclides composing the crud. But, radiation levels may actually increase in cases when the radionuclide decays to a "daughter" nuclide that is also radioactive. The "parent" may be an alpha, beta, or weak gamma emitter, producing little or no dose rate outside the container, but the daughter(s) may emit strong gammas, neutrons, or even betas, producing significant bremsstrahlung.

C. Crud Production.

Crud can be produced in two ways:

1. Corrosion or erosion of equipment in or near a neutron-emitting source (e.g., a reactor core neutron-generating devices) may produce small free bits of steel or other metal that are near or can be carried near the source and activated by the neutron flux. These new radioactive bits (called activation products) can then be

Lesson Plan	Instructor's Notes
transported out of the vicinity of the neutron flux to plate out or be deposited on wet surfaces. Crud can be removed from the liquid by a filtration system.	
2. The second method of crud production occurs at production, test, and research reactors. The fuel rods, fuel assemblies, or target materials contain the plutonium or uranium atoms to be fissioned and radioactive fission products. The fission products or activated target materials can leak, allowing some of the uranium and the fission products to escape into the reactor coolant. In nonreactor facilities, a leakage of radioactive materials into fluid transport systems can result in unwanted deposition of contamination.	
D. Decontamination. Advanced decontamination techniques are being studied. Decontamination of inner surfaces may reduce deposits, but they will usually build up again. Anti-deposition measures, such as metal passivation and electro-polishing treatments, inhibit crud from redepositing on surfaces.	
E. Reducing Crud. The best means to reduce the production of crud include:	Show OT 103-10
1. Using low-activation materials.	

Lesson Plan	Instructor's Notes
2. Preventing corrosion and erosion of equipment, and	
3. Avoiding crud traps such as low-flow areas,	
4. Providing equipment with smooth internal surfaces, and	
5. Preventing fuel or target leaks.	
4. AIRBORNE RADIOACTIVE MATERIAL	
A. Production. Radioactive materials can become airborne in the following ways:	
1. <u>Normally Gaseous Forms</u>: Some radionuclides, such as krypton, xenon, and argon, naturally exist in a gaseous form. Other radionuclides may be chemically combined with other elements to form a gas. Note that most gases mix readily with the air unless contained in some manner.	
2. <u>Volatile Liquids, Droplets, and Sprays</u>: Some radionuclides are in the form of volatile liquids, either naturally or as part of a compound. If leaked or exposed to the air, these can also become airborne. Some liquids containing radionuclides, while not volatile, can become airborne in processes that produce droplets or sprays.	
3 <u>Airborne Particulates</u>: Radioactive material in a particulate form can become suspended in air and be transported by air currents, sometimes	

Lesson Plan	Instructor's Notes
after adhering to dust particles, until they eventually settle. Operations such as grinding, welding, etc., may create airborne particulates.	
B. Radiological Protection Against Airborne Radioactivity. Airborne radioactive materials can deliver both external and internal doses. External doses result from the worker being surrounded by a radioactive cloud; whereas internal dose results from the radioactive material entering the worker's body and organs.	Show OT 103-13
Protection measures against airborne radioactive materials include the following:	Show OT 103-14
1. For external doses, a protective plastic suit can be worn as shielding against weakly penetrating radiation from airborne radioactive materials. This shielding will stop alphas and most betas and radioactive material, such as tritium, that can be also absorbed through the skin.	Objective 3
2. For internal doses, one can: – Wear a respirator, or – Wear a nonporous suit in atmospheres containing absorbable radionuclides.	
3. Engineered features, which are the primary defenses against airborne radioactive materials, include: – ventilation cleanup systems, – liquid filtration and processing systems,	Appendix A of this training discusses the application of ALARA to facility system design.

Lesson Plan	Instructor's Notes
– containment devices, and – airborne radioactive monitoring systems.	
Appendix A of this training guide discusses the application of ALARA to facility system design and decontamination and decommissioning operations.	Show OT 103-15 Reference 10 CFR 835 Appendices A, C Show OT 103-16
C. Derived Air Concentration (DAC). DOE's limits on airborne radioactivity are expressed in terms of the Derived Air Concentrations (DACs) that are given in 10 CFR 835, Appendices A and C. Breathing 1 DAC for 2,000 working hours (1 year) would result in the annual limit on intake (ALI), corresponding to 5 rem committed effective dose (CED) or 50 rem committed equivalent dose (CED), whichever is more limiting. An equivalent DAC for a mixture of radionuclides can also be calculated. Areas with atmospheres containing a radionuclide or a mixture of radionuclides > the DAC or where an individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week must be posted as Airborne Radioactivity Areas.	

Lesson Plan	Instructor's Notes
D. Design Criteria. The 10 CFR 835 design objective for airborne radioactive material states that "under normal conditions, to avoid releases to the workplace atmosphere, and in any situation, to control the inhalation of such materials to levels that are ALARA." If airborne radioactivity cannot be avoided, it is best to design an operation to try to stay below the 10 percent DAC level. At levels >10 percent DAC, more restrictive administrative and/or increased engineered controls may become necessary.	
E. Respirator. The primary method of controlling airborne contamination should be to use reasonable engineering design features. Good work practices and contamination control at the source should also be performed (e.g., flushing a pipeline to remove the radioactive source prior to maintenance). Only when these features and controls are not feasible or effective (or while they are being evaluated) should respirators be prescribed. To be ALARA, routine respirator use must be kept to a minimum. Design that requires the constant use of respirators in frequently or regularly occupied areas or during routine work is not acceptable.	
F. Time Versus Respirator Usage. In specific situations, the use of respiratory protection may not be suitable due to physical limitations or the potential for increased external exposure.	Show OT 103-17

Lesson Plan	Instructor's Notes
It is often generally perceived that personnel should not be allowed to work in an Airborne Radioactivity Area without a respirator. However, brief entries in airborne radioactivity areas may result in doses negligible compared to the risk of heat stress or the risk associated with not doing the job. Also, it has been shown that in Airborne Radioactivity Areas with elevated external dose rates, total doses (i.e., internal plus external) to workers without respirators may be lower than total doses to those workers with respirators. This is due to the extra length of time it takes the worker with respirators to perform tasks as a result of restricted movement, blurred vision, impaired breathing, and limited communication. In such cases, the radiological control staff and the operational supervisor may agree to waive respirator use.	
5. DECONTAMINATION	Show 103-18
A. Decontamination. Decontamination is any process or method of removing contamination. Frequently, there is a need for decontamination to reduce the radioactive source, and thus avoid more significant exposures to workers or, if the radioactive material escapes from the facility, to the public. Unfortunately, the process of decontamination itself may involve some dose to workers, e.g. radioactive material may enter the body through broken skin.	
	Show 103-19
B. Design Criteria. 10 CFR 835 has a design Objective that the design or modification of a facility and the selection of materials shall include features that facilitate operations, maintenance, decontamination, and decommissioning.	

Lesson Plan	Instructor's Notes
Provision for decontamination must be made in the design of any component, system, or area where the potential for leakage of radioactive materials exists. Facilities may be released for public use if contamination levels meet established limits (not zero).	
C. Planning. Planning for the likelihood of decontamination should be done for any operation which may involve the spread or generation of significant amounts of radioactive materials.	
D. Methods. Factors that affect the choice of decontamination method include type and quantity of radioactive leakage, item to be decontaminated, expense, practicality, etc.	
E. Fixed and Removable Equipment. Potential decontamination must be considered for fixed and removable equipment. Laundries and decontamination cells may be necessary for such items as respirators, clothing, or removable pumps. For equipment that must be decontaminated in place, provisions must be made for decontamination supplies (water, chemical, air) and electrical power.	Show OT 130-20
6. RADIOACTIVE WASTE (RADWASTE)	
A. Definition. Radwaste is any radioactive material or substance that is not considered useful and must be disposed of. Useful materials that can be decontaminated and reused are not considered radwaste; however, the liquid and solid by-products of the decontamination process may	

Lesson Plan	Instructor's Notes
be radwaste, such as rags, cleaning solutions, and filters.	
B. Types of Radwaste. By physical form	Show OT 103-21
1. Solid dry waste, also called "dry active waste" (DAW)	
2. Liquid	
3. Gaseous	
By legal terms	
4. Mixed waste	
5. Low level and High level radioactive waste and	Show OT 103-22 Objective 4
6. Transuranic waste.	
C. Processing of Radwaste. Radwaste can be processed in several ways:	
1. Filtration: Mechanical removal of radioactive contamination from liquid or gaseous waste.	
2. Ion Exchange Processes: Chemical removal of radioactive contamination with demineralizers or filter-demineralizers.	
3. Volume Reduction: Methods that reduce the volume of waste that must be disposed of, such as incineration, compaction or evaporation.	
4. Decay Tanks: Containers that allow contents to undergo radioactive decay to decrease radioactivity levels before further processing or disposal.	

Lesson Plan	Instructor's Notes
5. Dilution: Radioactive liquids or gases may be mixed with a large volume of air or water upon release (there are many restrictions on such releases).	
D. Disposal. Radwaste, either in its original form or after processing, is placed in tanks, drums, casks, or other appropriate sealed containers and disposed of through storage, burial, or release (when allowed).	
E. Segregation. Wastes containing oil, detergent, and many different chemicals must often be processed separately.	
F. Mixed Waste. Mixed waste is waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act. Special considerations must be given to reducing generation of mixed waste because of the many restrictions on storage and disposal.	Show OT 103-23

Lesson Plan	Instructor's Notes
G. Methods of Collecting and Dealing with RadWaste. (INSERT FACILITY-SPECIFIC INFORMATION)	
7. CONTROLLED AREAS **A. Controlled Areas.** For the purposes of radiological access control, a facility can be divided into radiological areas according to the type and extent of the radiological hazard. When designing a new facility, anticipated dose rates are calculated or estimated; then, a radiological engineer or other radiological specialist divides the facility into radiological areas.	Show OT 103-24
1. Controlled Area: means any area to which access is managed by or for DOE to protect individuals from exposure to radiation and/or radioactive material.	Objective 5 Ref. 835.2(a)
(Insert facility-specific information concerning controlled and uncontrolled areas.)	Show OT 103-25
2. Radioactive Materials Area: any area within a controlled area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in appendix E of this part.	
(a) Areas may be excepted from the posting requirements of § 835.603 for periods of less than 8 continuous hours when placed under	

Lesson Plan	Instructor's Notes
continuous observation and control of an individual knowledgeable of, and empowered to implement, required access and exposure control measures.	
(b) Areas may be excepted from the radioactive material area posting requirements of § 835.603(g) when:	
(1) Posted in accordance with § 835.603(a) through (f); or	
(2) Each item or container of radioactive material is labeled in accordance with this subpart such that individuals entering the area are made aware of the hazard; or	
(3) The radioactive material of concern consists solely of structures or installed components which have been activated (i.e. such as by being exposed to neutron radiation or particles produced in an accelerator).	
(c) Areas containing only packages received from radioactive material transportation labeled and in non-degraded condition need not be posted in accordance with § 835.603 until the packages are monitored in accordance with § 835.405. ref. 835 Subpart G	Ref. 835 Subpart G
B. Area Designations.	
The following area designations are defined in 10 CFR 835 and DOE directives:	
1. Radiological Area: any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the source or from any	Show OT 103-26 Objective 5

Lesson Plan	Instructor's Notes
Contamination Area, Airborne Radioactivity Area, or High Radiation or Very High Radiation Areas. (Insert facility-specific information concerning radiological division of areas by type of hazard.)	
2. Radiation Area: any area, accessible to individuals, in which radiation levels could result in an individual receiving ~~a deep~~ an equivalent dose ~~equivalent~~ to the whole body in excess of 0.005 rem (0.05 ~~millisievert~~ mSv) in 1 hour at 30 centimeters from the source or from any surface that the radiation penetrates.	Show OT 103-27
3. High Radiation Area: means any area, accessible to individuals, in which radiation levels could result in an individual receiving ~~a deep~~ an equivalent dose ~~equivalent~~ to the whole body in excess of 0.1 rems (0.001 ~~sievert~~ Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.	Show OT 103-28 Show OT 103-29
4. Very High Radiation Area: any area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.	

Lesson Plan	Instructor's Notes
5. Radiological Buffer Area: An intermediate area established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure.	Show OT 130-30 Ref. RadCon Standard
6. Contamination Area: Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in appendix D of 10 CFR 835, but do not exceed 100 times those values. (Insert facility-specific information concerning areas of potential surface and airborne contamination.)	Show OT 130-31 Show OT 130-32 Show OT 130-33
7. High Contamination: Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in appendix D of this part.	
8. Airborne Radioactivity Area: An area, accessible to individuals, where: (1) The concentration of airborne radioactivity, above natural background, exceeds or is likely to	Show OT 130-34

Lesson Plan	Instructor's Notes
exceed the derived air concentration (DAC) values listed in appendix A or appendix C of 10 CFR 835; or (2) An individual present in the area without respiratory protection could receive an intake exceeding 12 DAC hours in a week.	
C. Entry Controls. Some common entry control measures include signs, barricades, control devices on entrances, visible or audible alarms, locks, allowing entry to only necessary personnel, and administrative control procedures. 10 CFR 835 requires special access controls on High Radiation and Very High Radiation Areas.	Ref. 835 Subpart F Show OT 103-35
(Insert facility-specific entry control method.)	
D. Contamination Controls. Some common types of contamination control measures include area posting; step-off pads; protective clothing; containments (such as gloveboxes and hot cells); and effective ventilation cleanup, filters, and flow rates.	Show OT 103-36 Objective 6
(Insert facility-specific information concerning contamination controls.)	
E. Potential or Intermittent Radiological Areas. An area may remain posted as a Radiological Area even when conditions are potential or intermittent. Care must be taken in designing facilities and planning	Show OT 103-37

Lesson Plan	Instructor's Notes
operations that such conditions are identified and appropriate controls (such as alarms, flashing lights, etc.) are specified to alert workers to changes.	
8. SCATTER AND STREAMING **A. Scatter.** Scatter is the reflection of a neutron or photon resulting from the interaction of the radiation with matter. Basic concrete can reflect up to 1-3 percent of the gamma rays incident upon it. X-rays and neutrons, also, can be significantly reflected.	Show OT 103-38 Objective 7
B. Skyshine. Outside air can provide significant scatter, particularly for neutrons. This is referred to as "skyshine."	Show OT 103-39
C. Streaming. Streaming results when radiation passes through an opening, void, or low-density region in shielding. Gaps in radiation shielding may exist because of doorways, penetrations, or air pockets. Most shielding installations will require at least some penetrations for electrical power, plumbing, personnel access, remote sensing, ventilation, and/or process fluid transfer.	Show OT 103-40
D. Dose Rates. Radiation scatter and streaming may create a significant dose rate outside the shield (non-source side). For example, a dose rate may be acceptable if the shield wall goes up to the ceiling, but may be unacceptable -	Show OT 130-41

Lesson Plan	Instructor's Notes
due to scatter off the ceiling - if the wall stops short of the ceiling.	
E. Exposure Control. Scattering and streaming should be considered where applicable.	
1. A labyrinth entrance can be a scatter path; so can a penetration.	Show OT 103-42 Show OT 103-43
2. Removable, overlapping block walls may be used to minimize streaming.	Show OT 103-44
3. Shield slabs and plugs may be used to minimize exposure. Pass-through ports should be placed near the floor or ceiling.	Show OT 103-45 Show OT 103-46
4. Proper door or shield slab arrangement can reduce scatter.	Show OT 103-47
(Insert facility-specific information concerning scattering and streaming exposure control.)	

Lesson Plan	Instructor's Notes
IV. MODULE 104	Show OT 104-1 Show OT 104-2
1. ALARA PRINCIPLES **A. Objectives.** Following self-study and classroom review, participants will be able to: 1. Identify the six fundamental principles used to reduce radiation doses and the release and spread of radioactive materials. 2. Identify applications of the fundamental principles. 3. Identify shielding materials used to reduce radiation exposures.	
B. Six Fundamental Principles. Six fundamental principles should be considered for every facet of the design or operation. The six principles are: 1. Eliminate or reduce the source of radiation, 2. Contain the source, 3. Minimize time in a radiation field, 4. Maximize distance from a radioactive source, 5. Use radiation shielding, and	Show OT 104-3 Objective

Lesson Plan	Instructor's Notes
6. Optimize manpower since using more workers to cut the time will increase the collective dose.	Show OT 104-4
Note: It is important to consider the potential dose to the public, which may be increased by measures introduced to reduce worker dose.	Objective 2
C. Hierarchy of Controls. Emphasis should be placed on engineered controls instead of procedures, administration, or personal practices. The objective is to design an inherently safe radiological facility.	Show OT 104-5
(Insert facility-specific applications for the six fundamental ALARA principles, as appropriate.)	
2. ELIMINATE OR REDUCE THE RADIOACTIVE SOURCE The first ALARA design principle is to eliminate or reduce the source of radiation exposure.	
A. Source Elimination. Eliminate the use of the source by substitution of other appropriate technologies or materials. A good example of this is the use of an ultrasound exam (sonogram) in prenatal examinations rather than an X-ray exam or flushing a pipe to remove radioactive material.	
B. Source Reduction. A reduction in source means a reduction in dose rate. In planning a job or operation involving radiation exposure, consideration should be given to reduction of as much of the radioactive source(s) as possible. This may include:	
1. Installing filtration and processing equipment to clean liquids;	

Lesson Plan	Instructor's Notes
2. Removal of nonessential radioactive material or equipment from the vicinity;	
3. Selection of appropriate materials to minimize activation and deposition;	
4. Draining and/or flushing of radioactive liquids from fluid systems; or	
5. Ventilation of airborne radioactivity areas (with appropriate filtering of the air to reduce the concentration of airborne material and minimize deposition).	
6. If practical, allow the radionuclide source(s) to decay for several half-lives to decrease the radiation field.	
3. CONTAINMENT AND CONFINEMENT The second ALARA design principle (which some view as a subset of the first principle) is to control and contain radioactivity by the use of containment, ventilation, and processing systems.	Show OT 104-6
A. Methods to Control and Contain.	Show OT 104-7
The methods one can use to control and contain radioactive sources are:	

Lesson Plan	Instructor's Notes
1. <u>Containment:</u> Leak-tight or controlled-opening enclosure to keep radioactive materials confined within (e.g., fuel cladding, piping, hot cells, and curbing around tanks that contain radioactive materials). a. Examples of temporary containments are tents and glove bags. b. Examples of structural containments for the control of radioactive materials are walls, windows, doors, floors, transfer ports, and ceilings, with appropriate gaskets, caulking, etc.	
2. <u>Ventilation:</u> Provision of air and other gas flow direction and rate such that airborne materials are captured and directed to filters and an appropriate release point. Radioactive gases will not be captured or filtered. Note that negative pressure is an important aspect of control for some contaminants. Compare this function of ventilation (controlling and conveying of airborne material) to that of ventilation under the first principle (essentially dilution of airborne material).	Compare this function of ventilation (controlling and conveying of airborne material) to that of ventilation under the first principle (essentially dilution of airborne material).
3. <u>Filtration:</u> The capture of airborne material on a medium, thus confining them to a small and disposable volume.	
B. Protective Designs. Protective designs include such items as:	Show OT 104-8

Lesson Plan	Instructor's Notes
1. Ventilated fume hoods,	
2. Gloveboxes for handling radioactive material,	
3. Exhaust systems,	
4. Water filtration and processing systems,	
5. Conservatively sized ventilation cleanup systems, and	
6. Double-walled pipes and tanks, canned pumps, and leak-tight valves.	
4. MINIMIZING TIME The third ALARA design principle is to eliminate or reduce the time a worker must spend in the vicinity of a radioactive source.	Show OT 104-9
The amount of dose received is directly proportional to the amount of time spent in a given radiation field; therefore, dose is minimized if time is minimized.	
A. Design Factors. Appendix A discusses the application of ALARA in facility system design in greater detail. Design factors to reduce time spent in radiation fields include:	Show OT 104-10 Discuss Appendix A to an appropriate level of detail.
1. Installing reliable equipment to reduce maintenance,	
2. Choosing equipment that requires less frequent calibration,	

Lesson Plan	Instructor's Notes
3. Providing adequate clearance for maintenance and inspection around components,	
4. Utilizing special tools to speed maintenance and access,	
5. Using robots or remote equipment,	
6. Removing components from the radiological area for repair or calibration, and	
7. Installing permanent lighting and platforms.	
8. Use mock-ups to allow practicing of tasks in nonradiological areas.	Show OT 104-11
5. MAXIMIZING DISTANCE The fourth ALARA design principle is to maximize the distance from the source. **A. Dose Rate Versus Source Size.** 1. <u>Point Source</u>: For a point source (in which the size of the source is very small compared to the distance from it), radiation intensity varies inversely with the square of the distance from the source. This is called the inverse square law. 2. <u>Large Source</u>: Reduction in dose rates with distance from large sources such as pipes, tanks, floors, and walls is somewhat less	Note: Greater detail as outlined below may be included as it is in the Study Guide. Show OT 104-12 Inverse square law: $I_2 = I_1 (d_1/d_2)^2$ where I_1 and I_2 are the intensities (dose rates) of the radiation at points 1 and 2, respectively, and d_1 and d_2 are the distances from the source at

Lesson Plan	Instructor's Notes
dramatic, but the dose rate will still decrease with the distance from the source.	points 1 and 2. For example, if the dose rate from a small valve is 100 mrem/hr at 1 foot, it will be 25 mrem/hr at 2 feet and 11 mrem/hr at 3 feet.
B. Design Factors. Design factors to maximize the distance from radioactive sources include:	Show OT 104-13
1. Remote operation (process, maintenance, surveillance, decontamination, sampling, remote tools and controls).	
2. Locating all nonradioactivity-bearing instruments and readouts in low-dose areas;	
3. Provision for removal of components to low-dose areas for maintenance;	
4. Use of cameras, microphones, and wireless transmitters to perform remote surveillance and inspections; and	Show OT 104-14
5. Layout of equipment so as to maximize the distance between workers and the radioactive source.	
In the design phase it is important to consider ALARA for both workers and the public.	

Lesson Plan	Instructor's Notes
6. USE OF RADIATION SHIELDING The fifth ALARA design principle is to provide shielding between the worker and the radiation source by providing permanent or temporary shielding between sources and the workers.	Show OT 104-15
In general, any material through which ionizing radiation passes absorbs some or all of the radiation. This attenuation depends on the type and energy of the radiation, as well as the thickness and composition of the shielding material.	
A. Design Factors. Considerable thought should be given to incorporating adequate shielding structures during the design phase of a nuclear facility. This shielding can be quite elaborate in some cases and may even consist of several layers of different materials best suited for different types of radiation. Considerations for shielding design include: 1. Anticipation of crud buildup and hot spots; 2. Use of labyrinths for entrances and offset shielding penetrations, 3. Installation of special shields such as hot spot covers, leaded windows, and shielded carts and forklifts;	Show OT 104-16

Lesson Plan	Instructor's Notes
4. Allow for adequate space and access for installing temporary shielding for anticipated hot spots or in frequent jobs; and	
5. Use of appropriate shielding materials based on the type and level of radiation.	
B. Shielding Materials. The choice of shielding material depends on the type(s) of radiation to be shielded.	Show OT 104-17
1. Alpha (can be stopped by a single sheet of paper): Due to the extremely low penetrating ability of alpha particles, shielding is not considered necessary.	
2. Beta (can be stopped by 1/2-inch Plexiglas; 1/4-inch aluminum, wood, rubber): Due to the potential creation of bremsstrahlung when the beta particles are slowed or stopped, consideration must be given to shielding these X-rays whenever beta radiation is present. This phenomenon is strongest when beta particles are stopped by materials with a high atomic number (such as steel or lead), making these materials inappropriate for shielding beta particles unless they are sufficiently thick to stop the bremsstrahlung also.	
Note: Electrons from accelerators are high energy (Mev) particles and require extensive shielding.	

Lesson Plan	Instructor's Notes
3. Gamma (lead, concrete, steel): The denser the material, the better it is suited for attenuation of gamma and X-rays.	
4. Neutron (water, polyethylene, concrete, boron): Neutron-absorbing radionuclides (such as boron-10) and materials that contain large amounts of hydrogen make efficient neutron shields. The production of "capture gammas" in some materials must also be considered.	
C. Fortuitous Shielding. Fortuitous shielding should be used when possible. Fortuitous shielding is material placed in an area for reasons other than shielding but acting as a shield because of its location, composition and thickness. Steel cabinets, steel security doors, concrete columns, and similar objects can serve as fortuitous shielding. These objects should be permanently mounted if relied on as shielding, however.	Show OT 104-18
D. Sequence of Shielding. Shielding should be correctly layered for structural integrity and attenuation of different types of radiation. For example, with gammas and strong betas, a layer of plastic might precede a layer of lead, so that betas would be captured in the plastic and not produce bremsstrahlung in the lead.	

Lesson Plan	Instructor's Notes
E. Concrete. The use of concrete can be considered for stopping any type of radiation when space, weight, and cost are not limiting, because it is the best all-purpose shield. .	Shielding may be increased by using denser concrete or concrete mixed with lead or steel shot.
7. OPTIMIZATION The sixth ALARA design principle is optimization. ALARA design uses methods such as cost-benefit analysis to balance competing factors in dose reduction. It is important to maintain a separation between those concepts related to keeping radiation exposures below limits and those aimed at optimization or ALARA. The purpose of an optimization analysis is to show that the expense (in terms of money, person-hours, dose, etc.) of a project or feature of a project is justified in terms of the benefit received. This is in accordance with the idea of balancing ALARA considerations against technical, social, operational, and economic considerations. Optimization is further addressed in Module 110. Both formal and informal methods of optimization analyses are addressed. In Appendix F, examples of analyses are performed.	Show OT 104-19
8. SUMMARY Following self-study and/or classroom review, participants will be able to: **A. Module 101 Objectives.** 1. Define the acronym ALARA,	Show OT 104-20

Lesson Plan	Instructor's Notes
2. List the ALARA recommendations of the RadCon Standard, and	
3. Identify which groups should participate in ALARA design reviews.	
B. Module 102 Objectives.	
1. Identify the penetrating abilities in tissue:	
a. alpha,	
b. beta,	
c. gamma and X-ray, and	
d. neutron radiation.	
C. Module 103 Objectives.	Show OT 104-21
1. List four ways radioactive material enters the body.	
2. Define the terms "crud" and activation products.	
3. Discuss controls for airborne radioactive material.	
4. Discuss methods to process radwaste.	Show 104-22
5. Define the terms "Controlled Area" and "Radiological Area." Discuss types of radiological areas.	
6. Identify types of contamination control measures, and	
7. Define scattering and streaming.	

Lesson Plan	Instructor's Notes
D. Module 104 Objectives.	
1. Identify the six fundamental principles used to reduce radiation doses and the spread of radioactive materials,	
2. Identify applications of the fundamental principles, and	
3. Identify appropriate shielding material used to reduce radiation exposures.	
V. MODULE 105	Show OT 105-1
1. APPLICATIONS OF ALARA	Show OT 105-2
A. Objectives. During the presentation of Module 105, participants should demonstrate the application of ALARA principles of source term reduction and control by actively participating in the group exercises.	
2. CRUD PRODUCTION AND RADIOACTIVE MATERIAL DEPOSITION REDUCTION IN LIQUID SYSTEMS	Show OT 105-3
A. Reduce Crud Production. Reduce crud production by avoiding the use of nickel, cobalt, and other readily activated materials in areas of high neutron radiation, such as:	Show OT 105-4
1. On wetted surfaces that may come into contact with reactor coolant.	

Lesson Plan	Instructor's Notes
2. Near spontaneous or man-made neutron emitters.	
3. In accelerators that produce neutrons as a result of beam interactions (including component cooling systems).	
Where wear-resistant facings are essential, the use of stellite, inconel, and some stainless steels are undesirable from this standpoint.	
Note that other radioactivity in liquid systems (i.e., not produced by neutron activation of loose particles) may stick to loose, eroded, or corroded particles and thus collect in places where such particles are deposited.	
(Insert facility-specific information concerning crud buildup, including dose rates and locations.)	
B. Reduce Erosion. Reduce the loss of material by erosion:	Show OT 105-5
1. Use good flow geometry.	
2. Avoid sharp bends, reducers, and rough internal surfaces.	
C. Reduce Corrosion Loss. Reduce the loss of material by corrosion:	Show OT 015-6
1. Use corrosion resistant material.	

Lesson Plan	Instructor's Notes
2. Pretreat or precoat surfaces.	
3. Use pH and other chemistry controls.	
4. Provide for wet layup during maintenance and shutdown periods.	
D. Reduce Deposition. Reduce the deposition of crud and/or other radioactive material circulating in a system:	Show OT 105-7
1. Select a flow velocity appropriate for the stream to keep solids in suspension and to ensure representative sampling.	
2. Provide strainers, if practical, upstream of a neutron source (in reactors, before the coolant reaches the core).	
3. Ensure that all equipment and piping runs are drainable and flushable.	
4. Minimize crevices, elbows, low points, sharp bends, and dead legs (low flow areas in which deposition may occur).	
5. Generally use butt welds, consumable inserts, and freeze fits that usually produce smoother welds than socket welds and backing rings.	Show OT 105-8
6. Generally use full-ported valves (plug, gate, or ball valves instead of globe valves).	

Lesson Plan	Instructor's Notes
7. Choose straight-tube, vertical heat exchangers rather than U-tube, horizontal ones.	
8. Consider temperature or chemistry controls that can inhibit deposition (e.g., control of pH to inhibit a particular chemical deposition reaction).	
3. CONTAMINATION CONTROL AND DECONTAMINATION	
A. Contamination Control Measures. Provide for proper contamination control measures.	Show OT 105-9
Within radiological areas, contamination should be controlled as follows:	
1. Contamination in one area should not result from minor or moderate incidents that occur in other radiological areas.	
2. Outside radiological areas, radioactive surface contamination should not exceed the release values specified in 10 CFR 835 for Controlled Areas or DOE 5400.5 for uncontrolled areas.	
3. Select equipment that can be readily, easily, and completely dismantled and allow sufficient space for dismantling the equipment.	

Lesson Plan	Instructor's Notes
B. Equipment Decontamination. Provide for equipment decontamination. There are many methods that can be used for decontamination, but not all methods will be suitable for a particular radionuclide or surface. Keep in mind that it is ALARA to select a method that reduces the dose to the worker (including both the external and the internal dose) while reducing the volume of radwaste produced and the cost of the decontamination, but there may be some tradeoffs that must be weighed.	Show OT 105-10

Lesson Plan	Instructor's Notes
VI. MODULE 106	Show OT 106-1
1. APPLICATION OF ALARA TO FACILITY AND SYSTEM DESIGN	
A. Objectives. During presentation of Module 106, participants should demonstrate the application of ALARA principles to system design by participating in group exercises.	Note: Class Exercises are optional depending on the audience.
A designer or operations planner must consider which systems or components are likely to produce worker doses and select types that minimize dose. He/she must also consider which components may require a great deal of maintenance or may prove unreliable. He/she must select types that are highly reliable, easy to maintain, and consistent with the necessary functions.	Show OT 106-2
Finally, he/she must keep in mind the types of jobs that are associated with the operation and maintenance of each system or component and consider which ones may account for the most individual and collective dose over the operation or the life of the equipment. This is important when there are tradeoffs between, for example, cost and maintenance time.	
2. RELIABILITY AND EQUIPMENT QUALIFICATION	Show OT 106-3
A. Choose Reliable Equipment.	
1. Select equipment for ease and low frequency of maintenance.	
2. Select equipment for length of service life under the expected conditions.	

Lesson Plan	Instructor's Notes
B. Choose Qualified Equipment.	Show OT 106-4
1. Select materials that are qualified for the expected use (i.e., that will not degrade unduly under the expected combination of conditions of temperature, humidity, pressure, harsh chemicals and especially radiation level).	
2. Avoid using aluminum in High or Very High Radiation Areas where it may be in contact with fluids or concrete due to the potential for adverse chemical reactions to occur over time.	
3. Avoid locating microelectronics, rubber, cork, and other radiation-sensitive items in radiation areas. If necessary, place them in low-field areas only.	
3. AIRBORNE RADIOACTIVITY AND HVAC Airborne sources should be reduced or eliminated as much as possible. Where airborne levels may still be significant, well designed ventilation systems should be provided to limit the possibility of intake of airborne radioactive material.	Show OT 106-5
Such systems should be designed considering both normal and abnormal conditions. Routinely requiring workers to wear respiratory protection generally is not an acceptable solution to reducing intakes of radioactive material.	
A. Essential Features. As noted before, ventilation systems are provided to direct airborne contamination away from personnel and over to filters or other collection points; to reduce	Show OT 106-6

Lesson Plan	Instructor's Notes
airborne concentrations; and to prevent or limit the release of airborne materials through necessary openings.	
To attain these objectives, ventilation systems usually incorporate the following features:	Show OT 106-7
1. Airflow:	Show OT 106-8
a. A system of differential pressure should be used to direct flow. The flow rate should be sufficient to ensure that airborne particles or gases are adequately captured or diluted.	
b. Airflow should go from areas with no or less potential contamination to areas with greater potential for contamination.	Show OT 106-9
c. Air should be exhausted from areas with greatest potential for contamination.	
d. Room air may be recirculated if adequate filtration and monitoring are provided.	Show OT 106-10
e. When transporting potentially contaminated air, the exhaust duct should be routed away from frequently occupied areas.	Show OT 106-11

Lesson Plan	Instructor's Notes
2. <u>Filtration:</u> a. Filters should be selected to match the chemical and physical form of the radionuclide(s). For example, High Efficiency Particulate Filters (HEPAs) should generally be used for particulate forms and charcoal filters for iodines. b. Prefilters, moisture removal devices, and the like should be provided as necessary to prevent overloading the filter with dust, degrading it with moisture, etc. These provisions can increase the life and effectiveness of the radionuclide filter. c. Local filtration (e.g., for hoods) should be provided where appropriate to maximize capture of particles near where they are produced. d. Filters should be located upstream of fans and most of the ductwork to minimize contamination of ventilation system internal surfaces.	Show OT 106-12
B. Area-Specific Requirements. Even apparently similar areas do not always require identical ventilation characteristics, especially differential pressure and filtration. Ventilation design criteria need to accommodate a measure of flexibility	Show OT 106-13

Lesson Plan	Instructor's Notes
because conditions may change as work changes and local or portable ventilation may be effective in reducing local airborne levels sufficiently. (Insert facility-specific information.)	
C. Maintenance. Design ventilation systems for ease of maintenance, inspections, testing, and operations.	
D. Monitoring and Sampling. Design of ventilation systems should address monitoring and sampling requirements, such as inclusion of sampling ports.	
4. CONTAINMENT **A. Containment.** A containment is an area enclosed by a set of barriers. These can be passive barriers, like walls, or active barriers, like valves and ventilation flow. 1. Primary Containment: is the barrier or set of barriers most intimately in contact with the radioactivity. 2. Secondary Containment: encloses the primary and receives and handles any leakage from it. The room(s) or vault enclosing the tank and piping are the secondary containment and should be so designed; the outer wall of a double-walled tank may be the secondary.	Show OT 106-14 Show OT 106-15 For example, for a tank containing radioactive liquid, the tank itself is the primary containment, together with its intake and outlet piping up to the nearest isolation valves. When these valves are open, the primary containment extends to the next valve and so on. Also, a tank farther along my be a separate primary containment but can be considered, while the valves between it and the first tank

Lesson Plan	Instructor's Notes
3. <u>Tertiary Containment (may also need to be provided)</u>: The building, itself, may be the tertiary containment.	
One constraint on defining these is that it usually must not be possible for a single failure to compromise two containments at once (e.g., a primary and its secondary).	Show OT 106-16
B. Gloveboxes/Glovebags. Gloveboxes and other handling enclosures are primary containments when radioactivity in them is not completely enclosed or is enclosed in containers that cannot be assumed to be well-sealed. Gloveboxes are secondary containments when the radioactivity is actually contained in a piping system, vessel, instrument, etc., inside the box. In the latter case, the room may be designed as the tertiary containment.	
C. Primary Containment Penetrations. Primary containment penetrations must be carefully laid out and minimized in number and size. They should be carefully sealed with regard to radiation streaming, airflow control, fire protection, and flooding as applicable. Permeation of radioactivity through these seals should be considered. Transfer ports for passing items in and out should, in general, be airlocks or mini-airlocks, with purging capabilities.	

Lesson Plan	Instructor's Notes
D. Isolation Systems. A principle of good confinement is good isolation: systems with widely differing levels of actual or potential radioactivity content should be isolated from one another by check valves or other reverse-flow control devices. Pressure-relief devices should be required, and leak- detection devices should be provided as appropriate to the process.	
5. MECHANICAL AND ELECTRICAL SYSTEMS This section will discuss six areas: piping, valves, pumps, filters, tanks, and heat exchangers.	Show OT 106-17
A. Piping Piping is used for fluid flow, pressure boundaries, and heat transfer. Piping can trap radioactive crud which can result in dose to personnel and potential for spread of contamination.	
B. Valves. Since operation and maintenance of valves can be two of the major contributors to workers' dose, the design engineer should carefully select and locate valves. It is generally recommended to use full-ported valves such as plug, gate, or ball valves.	Show OT 106-18 Show OT 106-19
C. Pumps. Many pumps circulate radioactive water and other types of fluids and can trap radioactive crud. Maintenance and operation can thus present problems in minimizing dose and the spread of contamination. For example, crud can be trapped in piping elbows. Consider	Show OT 106-20

Lesson Plan	Instructor's Notes
whether flooding due to leakage or backup may cause contamination of equipment.	
D. Filters, Strainers, Evaporators, and Ion Exchangers Filters, strainers, evaporators, and ion exchangers provide cleanup of radioactive fluid systems. Since these systems concentrate radioactivity, it is important that maintenance be reduced. Also, remote handling and shielding should be considered.	
E. Tanks, Sumps, and Drains Tanks, sumps, and drains prevent plugging in transfer systems. This equipment must be chosen carefully, considering decontamination and eventual decommissioning.	
F. Heat Exchangers. Heat exchangers may cause radiation dose during their cleaning, repair, inspection, and replacement. Design, modification, or replacement of heat exchangers carrying radioactive fluids should address shielding and placement.	
6. ELECTRICAL POWER SYSTEMS. Even something as seemingly simple as the type of light bulbs used to illuminate areas can be an ALARA and waste consideration. The use of long-life bulbs can decrease maintenance time in elevated dose rate areas by requiring less frequent replacement; the number used up over the life of the facility will be fewer than for shorter-lived bulbs.	Show OT 106-21

Lesson Plan	Instructor's Notes
VII. MODULE 107 **1. APPLICATION OF ALARA FOR VARIOUS ENGINEERING DISCIPLINES** **A. Objective.** Participants should demonstrate the application of ALARA principles in design by actively participating in group exercise(s).	Note: Class exercises are optional, based on the audience Show OT 107-1
B. Introduction. This module addresses radiation dose assessment and radiological design considerations of new facilities and the modification of existing facilities. Once a facility is built, changes in shielding or facility layout are difficult to accomplish and often cannot bring about the desired dose rates without considerable added cost and loss of usable work space.	
Thus, it is more cost effective to design for anticipated and possible future radiological conditions rather than designing for near-term limited functions. In many cases, existing facilities must be modified. The resultant need to avoid impact on existing operations and activities may present a major challenge to the engineer.	Show OT 107-2
C. Civil/Structural Design Considerations. The support structures within a facility can act as shielding devices and reduce doses. On the other hand, support structures may make maintenance difficult because of inaccessibility and may consequently result	Show OT 107-3

Lesson Plan	Instructor's Notes
in increased doses. Therefore, facility design and layout can make a big difference in occupational doses.	
2. ASSESSING RADIOLOGICAL DOSES Radiation designs should provide for anticipated dose by including analysis of the tasks and processes that occur in these areas, the anticipated dose rates for the area, and the proposed inventories of radioactive materials.	Show OT 107-4
A. Worker and Time. The numbers of workers and the amount of time they are expected to spend in the area should be taken into consideration.	
1. For example, general (low-level) operations areas consist of those areas with small or moderate inventories of radioactive materials or low dose rates. Examples are general radionuclide research labs, rooms containing shielded X-ray diffraction and spectroscopy units, and operation areas with low contamination and low dose-rate potential.	Show OT 107-5
2. Work in higher-level operation areas, however, typically involves more radioactive material or higher dose rates than does work in general operation areas. Examples of higher-level operation areas are glovebox and hot cell operating areas, control areas for high-dose rooms, and selected areas of accelerator facilities where experiments with moderate	Show OT 107-6

Lesson Plan	Instructor's Notes
dose or contamination potential cannot be remote-controlled.	
B. Multiple Sources. It is important in building layout to minimize simultaneous dose from multiple sources at locations where maintenance personnel may be required to work. Similarly, individual work stations should be shielded from one another if work by one individual may expose others in the same area to unnecessary dose. Multiple sources must be taken into account when assessing possible doses.	Show OT 107-7
C. Isolation of Areas. Areas with high dose rates or airborne contamination levels should be isolated. Unauthorized and unmonitored entry in these areas is forbidden, and design features shall prevent the unauthorized entry of personnel. All personnel are prohibited from entering when conditions in the area present an immediate hazard to human life. Physical controls are required to limit doses when these areas are occupied. The ability to isolate areas with high dose rates should be taken into account when assessing possible doses.	Show OT 107-8
3. ACCESS CONTROL Access to radiological areas can be prevented by active (personnel) or passive (e.g.locks) controls. Interlocks are recommended because the source is moved or shielded when the interlock is tripped. Building layout is an important factor in controlling personnel dose by regulating the flow of personnel and material. Proper layout reduces casual or transient exposures to radiation fields by segregating heavily used corridors and the work areas of nonradiological workers from the areas of elevated dose rate and potential contamination. The layout should effectively limit	Show OT 107-9

Lesson Plan	Instructor's Notes
occupational dose to areas where the performance of an assigned task requires some receipt of radiation dose.	
Radiological areas should be made as small as possible to aid in access and contamination control. Eventual decontamination and decommissioning (D&D) activities should be considered.	Show OT 107-10
Controlled areas defined in 10 CFR 835 or the RadCon Standard are addressed in Module 103. A general discussion follows.	
A. Sequential Areas. An acceptable technique for achieving proper building layout is to establish a system of sequential areas. This means that Radiological Areas have been laid out in a way that will minimize dose and reduce the spread of contamination. This concept is frequently used because it is adaptable to the physical control of external and internal dose.	Show OT 107-11
B. General Access and Controlled Areas. Two major types of areas are included in any nuclear facility: general access areas and controlled areas.	Show OT 107-12
1. General access: General access areas are normally places to which public access is restricted but where radiation exposure is not necessary for job performance, such as the work areas of administrative and nonradiological support personnel. These areas include conference rooms, file rooms, clerical	

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and other support offices, lunch rooms, and rest rooms. There is no potential for exposure in General Access Areas.

Ref. 10 CFR 835.602

2. Controlled areas: Controlled areas are areas to which access is managed to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter only the controlled areas without entering radiological areas are not expected to receive a total effective dose of more than 100 mrem (0.001 Sv) in a year. Note that the limit for a member of the public outside the facility is for all sources and pathways combined.

   Controlled areas may include corridors that are adjacent to, or connected with, areas that contain radioactive materials, change rooms, or special offices for radiation workers.

Show OT 107-13

C. **Traffic and Access.**

1. Traffic: Locate frequently used pathways in low-dose rate and noncontaminated areas, but use common sense and logic; if the pathway is through "clean areas" but in a long and illogical route, people will not use it and may take "short cuts" through hot areas. Place inspection, control and readout instrumentation in low dose areas.

2. Access: Ensure that doorways are wide enough and large enough and access areas are provided for readily removing and servicing equipment.

Lesson Plan	Instructor's Notes
4. CONTAMINATION CONTROL DESIGN Contamination control measures may consist of curbs, gutters, drains, catch tanks and other liquid controls. Special attention needs to be given to drains not only for collection of radioactive liquids but also as potential inadvertent release points. Gloveboxes and use of proper ventilation are examples of contamination control devices/practices for non-liquids. Contamination control designs should address eventual decontamination/ decommissioning with focus on a specific endpoint (e.g., completely clean or elevated contamination to be re-used as contaminated). .	Show OT 107-14 Show OT 107-15 Show OT 107-16
5. RADIOACTIVE WASTE Locations for the temporary storage of radioactive wastes must be designed into both the building plan and the plan for each area where radioactive materials are handled. To prevent accumulations of waste in operating areas if normal disposal methods are temporarily interrupted, the waste storage area should be large enough to accommodate more than the expected volume of waste. Additional considerations include transportation, drainage of liquid systems, monitoring, and fire suppression.	Show OT 107-17 Show OT 107-18
6. SHIELDING, PENETRATIONS, AND ROUTING **A. Shielding.** Obtain information on shielding types, thicknesses, and layout from a radiological specialist (a radiological engineer, ALARA specialist, or health physicist, as appropriate for your project or operation). **B. Penetrations.** Have experts from all affected disciplines review a planned penetration before the hole is made. Offsets can be designed where radiation streaming is possible.	Show OT 107-19

Lesson Plan	Instructor's Notes
C. Routing of Ducts, Pipes, Cables, and Conduit (DPCs). Don't route DPCs containing radioactive materials through general access areas, and don't route clean DPCs through potentially contaminated or high-doserate areas. Do not regard the X-Y-Z grid as sacred. Minimize runs of piping by routing diagonally, using bends other than 90 degrees, and sloping lines, where appropriate.	
7. SEPARATION, SEGREGATION, PLACEMENT, AND ISOLATION OF EQUIPMENT	Show OT 107-20
A. Separation. Put shield walls between components sharing the same cubicle to reduce the dose to a worker maintaining one of them (the equipment should be placed so that the worker does not have to pass close to one to get to the other).	Show OT 107-21
B. Segregation. Segregate highly radioactive equipment from moderately radioactive equipment, and both from clean equipment. Similarly, segregate equipment with high airborne potential from equipment with less airborne potential, and both from clean equipment.	Show OT 107-22
C. Placement. Even with shielding, lay out equipment in an area or equipment cubicle so that from the point that the worker enters, he progresses from low-dose rate areas to moderate to high-dose-rate areas, and from active to passive equipment.	Show OT 107-23

Lesson Plan	Instructor's Notes
D. Isolation. The interconnections between systems of different radioactivity potential must be carefully considered. 1. Properly place isolation valves so as to minimize dead legs. 2. Minimize pipe runs in valve aisles (consider reach rods and valve operators).	Show OT 107-24
E. Redundancy. Provide adequate redundancy and backup capability, especially in systems of high radioactivity content and safety systems. Provide appropriate cross-connections to achieve this.	Show OT 107-25
8. ACCESSIBILITY, LAYDOWN, AND STORAGE Allow adequate working space around major components, usually at least 3 feet. Do not allow this space to be filled by reach rods, shields, pipes, scaffolds, etc. Provide laydown space in a low-dose-rate area (besides equipment, consider such items as tool boxes, carts, and hoses). (Insert facility-specific information.)	Show OT 107-26
9. SNUBBERS, STRUTS, HANGERS, AND ANCHORS Holding devices should be designed and located to facilitate removal and not interfere with inspections and maintenance.	
10. HUMAN FACTORS Design should address human factors such as vision, hearing, and physical limitations. These factors should be considered	Show OT 107-27

Lesson Plan	Instructor's Notes
when the use of protective equipment is evaluated. For instance, heat stress, restricted vision, impaired hearing and speech are all associated with full-face respirators. Working in elevated dose rate areas requires special considerations for lifting devices and access to equipment.	Show OT 107-28
See Appendix B for supplemental information concerning ALARA civil/structural design principles.	Discuss Appendix B to an appropriate level of detail.

Lesson Plan	Instructor's Notes
VIII. MODULE 108 **1. ALARA DESIGN REVIEW** This lesson provides guidance to the design engineer to determine through a dose assessment if an ALARA design review should be performed, and to incorporate radiation and contamination reduction considerations into a design or modification.	Note: Class exercises are optional depending on the audience.
A. Objective. Participants should demonstrate the application of ALARA principles in design reviews.	Show OT 108-1
B. Definitions. An ALARA design review is a systematic review of the design, modification, or construction of equipment and facilities to ensure that ALARA considerations are evaluated, incorporated if reasonable, and documented.	
C. Requirements for ALARA Designs. Part 835.1001 requires that engineering features and administrative controls be used for facilities and equipment to keep radiation exposures in controlled areas ALARA.	Show OT 108-2
D. Phases. The ALARA design review is conducted in five discrete phases: 1. Dose assessment. 2. Determination of need to conduct or not to conduct.	Show OT 108-3 (Insert facility-specific information.)

Lesson Plan	Instructor's Notes
3. Selection of reviewers or review team.	
4. Selection of criteria and conduct of review.	
5. Documentation of the ALARA process.	
2. DOSE ASSESSMENT	
A. Initial Dose Assessment. The first step in the ALARA Design Review is to perform an initial dose assessment, if this has not already been done in the course of design.	
B. Information for Determining Dose. The information should be supplied to the radiological engineer (or another qualified person on the project) as early as possible in each design stage even though some of this information will be tentative or sketchy in the early stages of the project. Include such details as:	
1. Layouts and location diagrams;	Show OT 108-4
2. Number and types of workers in each known or possible radiological area associated with the facility or system;	
3. Nature of each task workers are to do;	
4. Time spent by each worker on each task;	
5. Paths to and from the radiological area(s) and the transit time;	

Lesson Plan	Instructor's Notes
6. Physical features such as ladders, manholes, hoods, etc.; and	
7. Any dose rates, radioactive source strengths, and shield thicknesses, and the like that are known or recommended by a vendor.	
The above information will allow the radiological engineer (or other qualified person), with the help of other radiation protection personnel, to estimate doses and dose rates associated with the project.	
C. Detailed Dose Assessment. During later stages of the project, when the details of the design are known, a more detailed dose estimate may be performed.	Show OT 108-5
1. At this point, it may prove to be of value to perform a walk down of the installation with construction and radiological personnel. This will aid in the estimation of the installation dose, as well as scoping and planning installation.	
2. Detailed dose information is needed for selection of design alternatives or to determine if the cost to incorporate an ALARA consideration is cost-beneficial.	
3. The detailed dose assessment involves identification and estimation of the dose for the work tasks that involve radiation exposure for	

Lesson Plan	Instructor's Notes
operation, maintenance, inspection, and installation of the equipment, similar to the initial dose assessment.	
3. IS AN ALARA DESIGN REVIEW REQUIRED? Following the initial dose assessment, the cognizant engineer should determine if an ALARA design review should be conducted. This is a two-step process.	Show OT 108-6
First, the engineer or planner must determine if the facility design or design change involves work on a radioactive or potentially radioactive system. If not, an ALARA Design Review need not be performed.	
Then the engineer or planner should use the information from the dose assessment to answer questions such as these:	Show OT 108-7
1. Will this design change create a new radiological area or increase the exposure from an existing source?	
2. Will this design change create or increase routine maintenance, operations, or inspection requirements in an area?	
3. Will this design change cause workers to receive a total of 1 rem in a year or greater?	Insert facility-specific number as replacement for "1 rem."
If any of these criteria are met, additional occupational dose will result from the design change, and a review of design features	

Lesson Plan	Instructor's Notes
that can reduce dose and the spread of contamination should be initiated.	
If the answer to all three questions is "no," an ALARA design review need not be performed. However, this determination should be documented.	Show OT 108-8
For those design changes where there is one-for-one replacement of equipment or if the design change does not present the practical opportunity to incorporate dose reduction improvements or ALARA considerations, the ALARA design review need not be performed.	
4. ALARA DESIGN REVIEW TEAM The material below is included as an example of the Team Member process and conduct of an ALARA Design Review. Site-specific information should be substituted where applicable.	Show OT 108-9
A. Key Personnel. For a review of a simple facility or process, a radiation protection or ALARA representative may provide the review. The radiation protection and/or ALARA representative(s) should be qualified to provide an overall review of the facility design and should evaluate and approve the completeness of the designed safeguards, including redundancy, fail-safe features, interlocks, and alarms. However, for an extensive and complex review, other disciplines must be involved. The scope of the review should be determined either by	

Lesson Plan	Instructor's Notes
procedure or by the project manager in consultation with radiation protection personnel. Others who may participate include:	

1. Design Team: the group of people providing input into the project. It is composed of members from all appropriate engineering and other technical disciplines and should include a radiological member with safety expertise such as a radiological engineer or ALARA engineer.

2. Contributor Group: other groups who may not provide formal design input to the project but whose comments and suggestions are considered relevant to the project, such as:

   – Maintenance,
   – Production, and
   – Research groups.

   Both the members of the design team and representative members of the contributor group should participate in the ALARA Design Review, even if some of the latter may not be trained in the ALARA design review process.

3. ALARA Review Coordinator: ALARA engineer, radiological engineer, or even a qualified operations representative who with other project and safety personnel will provide radiological input to the project. The ALARA Review Coordinator, together with the project

Lesson Plan	Instructor's Notes
engineer, is responsible for seeing that the ALARA Review is performed, completed, and documented.	
5. SELECTION OF CRITERIA AND CONDUCT OF ALARA DESIGN REVIEW The following methods are suggested as a practical way of accomplishing and documenting the review. A simplification of this process is appropriate for small, uncomplicated projects and system modifications.	
A. Stages Recommended for Review. An ALARA Design Review should be performed at each important stage of design or modification of a facility, building, or system, unless there is no radiologically significant change between stages (see PNL-6577).	
B. Radiological Design Criteria. In conjunction with production of the Functional Design Criteria, the radiological engineer may produce, at her/his discretion and depending on the size of the project, either a set of Radiological Design Criteria or a memorandum containing radiological design considerations. This will be used by the design team beginning at the Conceptual Design Stage, and it should be updated in subsequent stages.	
C. Minimum Criteria. During the review, the review team should assess the features of the design against the Radiological Design	

Lesson Plan	Instructor's Notes
Criteria and other applicable criteria to determine whether provision of an ALARA working environment is ensured. The review team should review the facility operation plan and determine if the radiological engineer has done a complete assessment of potential dose.	
In the following review processes, different alternatives should be identified, differential costs and dose should be estimated, and cost-benefit analyses conducted to evaluate the alternatives.	
1. Show that the public and facility personnel are protected from hazards associated with the use of radioactive and other hazardous materials as a result of: – Normal operations, – Anticipated operational occurrences, and – Design basis accidents.	Show OT 108-10
2. Protection should be provided for normal operation and for those accidents that can be anticipated as occurring during the facility lifetime, such as radioactive material spills and small fires involving radioactive materials.	
3. Review the general facility layout, considering traffic patterns, radiation zoning, change room location and size, adequacy of personnel decontamination facilities, location of fixed	

Lesson Plan	Instructor's Notes
survey equipment, and provision of adequate space for anticipated maintenance needs.	
4. Verify that the ventilation system design provides the required level of protection from airborne contamination, with particular attention to air flow patterns and locations of air inlets and exhausts.	
5. Evaluate and confirm the adequacy of specific radiological control devices for reducing occupational exposures, including hoods, gloveboxes, shielded cells, decontamination areas, and remote operations.	Show OT 108-11
6. Verify that shielding is adequate to support ALARA operation of the facility, system, or component.	
7. Assess the adequacy of planned radiation monitoring and nuclear criticality safety instrumentation, including whether the proposed instrumentation is appropriate for the radiation types and intensities, and whether it has suitable redundancy and capability for operation both under normal operating conditions and in emergency situations.	
8. Radiological requirements and ALARA considerations should be balanced against the total risk, including industrial safety and industrial hygiene requirements. The	

Lesson Plan	Instructor's Notes
requirements must also be balanced with operational productivity.	
D. Design Basis. Occupational exposure to radiation should be limited according to 10 CFR 835. This primarily addresses the way people operate and use existing facilities and sites. Designs for new facilities and major modifications to existing facilities should be based on the following additional radiological control design criteria:	Show OT 108-12 Show OT 108-13
1. Individual worker dose in radiological areas should be ALARA and less than 500 mrem per year;	
2. Discharges of radioactive liquid to the environment are covered by provisions in DOE Order 5400.5, which requires doses to the public to be maintained ALARA, and other regulatory documents, and should not degrade the ground water;	Note: Other regulatory documents may include the Clean Water Act, The Safe Drinking Water Act, facility-specific permits, etc.
3. Control of contamination should be achieved by containment of radioactive material;	
4. Efficiency of maintenance, operations, decontamination and decommissioning should be maximized;	
5. Components should be selected to minimize the buildup of radioactivity; and	Show OT 108-14

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6. Support facilities should be provided for donning and removal of protective clothing and for personnel monitoring, where appropriate.	
E. ALARA Design Review Checklist. (Insert facility-specific checklist.)	Show OT 108-15
To serve as an aid in performing the ALARA Design Review, a checklist such as the one in Appendix D may be used. The first part is a list of preliminary questions called	
"First Level Screening Questions" which identify appropriate questions from the main checklist.	
The second part is the main checklist, a series of questions grouped by subject.	
The last part is a disposition sheet on which individual answers may be discussed and resolutions may be recorded.	
F. Performing the Review. (Substitute facility-specific information as applicable.)	
Near the end of each stage, the ALARA Design Review for that stage will take place.	Show OT 108-16
Each ALARA reviewer may obtain a copy of the ALARA Design Checklist and fill it out according to her/his knowledge of the project. If the reviewer recognizes any issues of potential radiological impact	

Lesson Plan	Instructor's Notes
not covered by the checklist, these issues should be noted on an attached sheet.	
G. Existing Features and Nonradiological Additions. The review is to consider not only new or newly added features, but also existing features which might be affected. The impact of nonradiological additions on radiological items must be considered.	Show OT 108-17
H. Optimization Analysis. As part of the design or modification, an optimization analysis may have been performed. This should also be examined in case anything has changed in the course of the design. However, the ALARA Design Review may show the need for an optimization analysis as well, and this analysis may be done as part of the review. Optimization is covered in Module 110.	Show OT 108-18
I. Completed Review. (Substitute facility-specific information, as applicable.) When each reviewer has filled out the checklist, it is sent to the ALARA Review Coordinator.	
6. DOCUMENTATION AND APPROVAL **A. Review Documentation.** (Substitute facility-specific information, as applicable.) When all comments are returned, the ALARA Review Coordinator makes a final resolution of all comments and issues a memorandum report. The report lists all reviewers, describes the areas covered, summarizes the conclusions of the Design	Show OT 108-19

Lesson Plan	Instructor's Notes
Review, highlights any conflicts, and gives any recommendations the ALARA Review Coordinator may have.	
B. Review Approval. (Insert facility-specific information.)	
The report (with associated documentation) may then be reviewed and approved by the site Radiological Control Manager (RCM) or Radiological Engineering Manager (REM), if she/he elects to do so.	
The written waiver of review and approval by the RCM/REM constitutes approval of the project ALARA design.	
C. Copies of the Report. (Insert facility-specific information.)	
Copies of the report (with associated documentation) should also be sent by the ALARA Review Coordinator to relevant management and technical review committees, and to appropriate health and safety groups. The ALARA Committee(s), who may also need to review the design, should be sent copies.	

Lesson Plan	Instructor's Notes
IX. MODULE 109 **1. ALARA OPERATIONAL REVIEWS** **A. Objective.** Participants should demonstrate the application of ALARA principles in operations.	(Insert facility-specific methods. If there is no formal method at your site, you may present this as a way of covering all aspects of a review.) Note: Class exercises are optional depending on the audience.
B. Definitions and Purpose of Review. An ALARA operational review (sometimes referred to as an ALARA job/experiment review) is a systematic pre- and post-job review of activities with the potential for significant dose, contamination, or airborne concentrations to ensure that ALARA controls are planned, evaluated, implemented where reasonable, and documented. An ALARA operational review serves to document the use of ALARA and to show any compromises or adjustments made in balancing ALARA against operational, practical, and other considerations.	Show OT 109-1
C. Requirements. 10 CFR 835.1003 requires that during operations, the combination of engineered controls and administrative controls shall ensure that the total effective dose to an individual does not exceed 5 rem in a year and that the ALARA process is used.	Show OT 109-2
2. WHEN TO PERFORM A REVIEW **A. Operational Review.** An Operational Review can be done when required by procedure or requested by the operational group, facility manager, ALARA Committee, or other groups such as the Facility Review Committees. Reviews should also	

Lesson Plan	Instructor's Notes
be performed if the site-specific trigger levels (as identified in articles 312.3 and 312.6 of the RadCon Standard) are exceeded.	
In addition, an ALARA review should be performed for the following cases:	Show OT 109-3
1. Nonroutine jobs, operations, or campaigns in which any individual might receive a dose of 100 mrem or more, or where there is any uncertainty in the predicted dose;	
2. Routine jobs, operations, or campaigns in which any individual might receive as much as 300 mrem;	
3. Any job or operation in which the collective dose is expected to exceed the site-specific trigger level;	
4. Any job, operation, or campaign in which any individual might exceed an administrative dose level (e.g., 2,000 mrem /yr);	Show OT 109-4 Facility-specific values should be substituted, as applicable.
5. Any job, operation, or campaign in which the dose to an individual might cause the ALARA goal of the facility, the division, or the work group to be exceeded; and	
6. Any job, operation, or campaign in which airborne levels may potentially exceed 10 percent of the DAC.	

Lesson Plan	Instructor's Notes
7. Any job, operation, or campaign in which there is a potential for significant levels of contamination to be present.	
B. Operational Review Versus Radiological Work Permit (RWP) and Prejob Briefing The operational review is conducted in addition to the Radiological Work Permit (RWP) preparation (which may be required by procedure), or it can be part of it. A simplification of this process would be appropriate for small, uncomplicated operations; for example, the RWP preparation could satisfy this review if all areas required to be considered in both are covered, and appropriate operational reviewers are consulted. Also, the operational review could support RWP preparation or the reviews to be done by operating division personnel, as required by procedure. An operational review is not the same as the prejob briefing, since in the review, the planners are collecting and evaluating information on the final, agreed-upon plan for the work. At the end of the review, changes may remain to be made, while at the end of the briefing, everybody should understand what to do. However, for smaller jobs, the two could be combined provided that any concerns are fully evaluated and resolved before work begins.	Show OT 109-5

Lesson Plan	Instructor's Notes
3. PERFORMING AN OPERATIONAL REVIEW	
A. Conduct of the Review.	
The following method is suggested as a practical way of accomplishing and documenting the review. A simplification of this process is appropriate for small, uncomplicated projects. Usually representatives of the group managing the operation or job, worker groups, and the radiological control organization should participate.	
To serve as an aid in performing an ALARA Operational Review, an ALARA Operational Review Checklist is provided in Appendix E.	Show OT 109-6 Replace with facility-specific information, as applicable
B. Documentation of the Review. The review should be documented appropriately, usually by a written statement that a review was performed and by incorporation of the selected controls into the RWP and work documents. The documentation should be kept in either the appropriate job or operation file or in the radiological control organization's ALARA files, consistent with the requirement that records of ALARA decisions be retained (10 CFR 835).	Tell the students where the ALARA records are kept at your site.

Lesson Plan	Instructor's Notes
X. MODULE 110 **1. OPTIMIZATION ANALYSIS** **A. Objective.** During the presentation of Module 110, participants will demonstrate the application of optimization techniques by actively participating in the group exercises.	Note: Class exercises are optional depending on the audience.
B. Definition. "Optimization" may be defined as arriving at an optimal solution to a problem or selecting the best from among the available alternatives, in accordance with a given analytical method.	Show OT 110-1
C. Purpose of Optimization Analysis. The purpose of an optimization analysis is to show that the expense (in terms of money, person-hours, dose to install and maintain, etc.) of a project or feature of a project is justified in terms of the benefit received. This is in accordance with the idea of balancing ALARA considerations against technological, social, operational, and economic considerations.	
D. Regulations and Guidance for Optimization.	Show OT 110-2
1. 10 CFR 835.1002(a), Occupational Radiation Protection. "Optimization shall be used to assure that occupational exposure is maintained ALARA in developing and justifying facility design and physical controls."	

Lesson Plan	Instructor's Notes
2. DOE Order 5400.5, "Radiation Protection of the Public and the Environment." DOE 5400.5 requires that "Field Elements shall develop a program and shall require contractors to implement the ALARA Process for all DOE activities and facilities that cause public doses. Furthermore, DOE 5400.5 states that factors to be considered, at the minimum, shall include: a. The maximum dose to the public; b. The collective dose to the population; c. Alternative methods of processing, treating, controlling, and operating radioactive effluent systems; d. The dose associated with each alternative; e. The cost for each technological alternative; f. Examination of the changes in costs associated with the various alternatives; and g. Examinations of the changes in societal impact associated with the various alternative.	Show OT 110-3 Ref. DOE 1993

Lesson Plan	Instructor's Notes
3. ICRP 55, "Optimization and Decision-Making in Radiological Protection." ICRP 55 states that "...optimization provides a basic framework of thinking wherein it is proper to carry out some kind of balancing of the resources put into production, and the level of protection obtained against a background of other factors and constraints, so as to obtain the best that can be achieved in the circumstances."	Ref. ICRP 55
4. The RCS, Article 312, addresses major and minor activities.	Show OT 110-4 Ref. PNL-6577
5. PNL-6577, "Department of Energy, Health Physics Manual of Good Practices for Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)." PNL-6577 gives guidance on how to perform cost-benefit analyses.	Show OT 110-5
2. OPTIMIZATION METHODS	Show OT 110-6
A. Informal Analysis. There are various ways to determine whether a design or operation is optimized. One is a consensus recognition by the ALARA engineer and others on the design or operation team that a particular project or feature of a project justifies the cost in terms of dose, money, work-hours, and operational adjustments required to produce the project. Such a project or	Show OT 110-7

Lesson Plan	Instructor's Notes
feature can be termed "patently advantageous" as regards ALARA. This conclusion should be documented.	
B. Other Considerations. Often, however, the justification for the design, design feature, or operation is not so clear-cut. Then a more rigorous optimization must be done to demonstrate that the project is optimized by the design, the inclusion of the design feature, or the plan of the operation. This is particularly true if there are alternatives to the design, feature, or operation, and if "doing nothing" (*status quo*) is one of the alternatives.	
C. Formal (Analytical) Optimization Analysis. In formal (analytical) optimization analyses, one must express the value of all resources, including dose, in commensurate units, or rank them in some consistent way, or both. Usually the value expression is done by assuming a dollar value for each parameter, including dose.	Show OT 110-8 Show OT 110-9 Show OT 110-10 Show OT 110-11 Discuss your site's dollar value for a person-rem.
A formal optimization typically consists of a Cost-Benefit Analysis (CBA). In the CBA, all of the items to be considered must be expressed in the same units, usually dollars. Because of that reason, a dollar value must be given to the dose saved. DOE has specified that this value be determined on a site-by-site basis. The NRC uses a value of $2000 per person-rem. DOE evaluations to support ALARA analyses should apply monetary equivalents for a person-rem in the range from $1000 to $6000 with the nominal value of $2000.The net benefit of a feature, system, or method is then determined by subtracting the costs of production,	

Lesson Plan	Instructor's Notes
radiation protection, and dose from the gross benefit. Using this methodology, the net benefit can be determined for several alternatives and compared to determine the optimal choice.	
See Appendix F for further details regarding the CBA, including examples.	Discuss Appendix F to an appropriate level of detail.

(Part 3 of 5)

ALARA Training for Technical Support Personnel

Student's Guide

Coordinated and Conducted for Office of Safety, Health and Security U.S. Department of Energy

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Table of Contents

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I. MODULE 101

1. INTRODUCTION TO ALARA

A. Objectives.

Following self-study and classroom review, participants will be able to:

1. Define the acronym ALARA,
2. List the ALARA recommendations outlined in the DOE Radiological Control Standard (RadCon Standard), and
3. Identify which groups should participate in the ALARA design reviews.

2. DEFINITION AND PHILOSOPHY OF ALARA

A. ALARA.

ALARA stands for "As Low As Reasonably Achievable."

B. Definition.

ALARA is defined as an approach to radiation protection to manage and control doses (both individual and collective) to the work force and the general public such that doses are kept as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but a process, which has the objective of maintaining dose levels as far below applicable limits of 10 CFR 835 and DOE Order 5400.5, Ch. 2, as is reasonably achievable.

C. Discussion.

The current system of radiological protection reflected in the National Council on Radiation Protection and Measurements (NCRP) Publication 116, *Limitation on Exposure to Ionizing Radiation* (NCRP 1993), is based on three general criteria.

1. The need to justify any activity which involves radiation exposure on the basis that the expected net benefits to society exceed the overall societal cost.

2. The need to ensure that the total societal detriment from such justifiable activities or practices is maintained ALARA, economic and social factors being taken into account.

3. The need to apply individual dose limits to ensure that the procedures of justification and ALARA do not result in individuals or groups of individuals exceeding levels of acceptable risk.

Although DOE has not formally adopted the recommendations of NCRP 116, these criteria are reflected in the RadCon Standard and 10 CFR 835.

D. Linear Nonthreshold Hypothesis.

The linear nonthreshold hypothesis assumes the risk of detriment from radiation is directly proportional to the dose and no threshold exists below which there is no detriment (damage). This theory is controversial because it is derived from extrapolation of low dose and low dose rate effects from high dose and high dose rate data. To ensure adequate protection, national and international groups have recommended, and DOE has adopted, a system of regulatory limits and an emphasis on ALARA to keep exposures as far below the limits as is reasonable.

E. No Fixed Numerical Criteria.

The ICRP states that there is no one set of numerical criteria universally applicable in determining whether a measure or practice is ALARA. Instead, such criteria should be derived on a case-by-case basis. Sometimes the criteria are applicable to one site or facility, and sometimes to a single task. ALARA measures should not be implemented without careful consideration of associated costs and benefits. Failure to evaluate the costs and benefits of a protective measure can be a waste of resources, or even result in unjustifiably increased dose along with its associated risk. An example of such a case is presented in Appendix F.

F. Responsibility.

According to DOE Orders, the responsibility for controlling exposures lies at every organizational level, including management, supervision, engineering, the radiological control department, and individual employees. This includes occupational doses AND doses to the public and the environment from DOE operations.

3. POLICIES, REGULATIONS, AND OTHER GUIDANCE

The principal objective of the ALARA policy is to reduce the dose to facility personnel and the public, and to reduce the levels of radioactive materials released to the environment to the lowest levels in keeping with sound operating and economic practices. DOE directives and technical documents that require that ALARA measures be incorporated into nuclear facility design include:

A. 10 CFR 835, "Occupational Radiation Protection."

Section 835.1001 requires that:

"(a) Measures shall be taken to maintain radiation exposure in controlled areas as low as is reasonably achievable through engineered features and administrative control. The primary methods used shall be engineered features (e.g., confinement, ventilation, remote handling, and shielding). Administrative controls and procedural requirements shall be employed only as supplemental methods to control radiation exposure;

(b) For specific activities where use of engineered features is demonstrated to be impractical, administrative controls and procedural requirements shall be used to maintain radiation exposures ALARA."

Facility design and modification per 835.1002:

1. In areas of continuous occupational occupancy (2,000 hours per year) the design objective shall be to maintain dose rate levels below an average of 0.5 mrem (5 μSv) per hour and as far below this average as is reasonably achievable.

2. The design objectives for exposure to a radiological worker where occupancy differs from that above shall be ALARA and shall not exceed 20 percent of the applicable standards (10 CFR 835).

10 CFR 835.101(c) requires that the Radiological Protection Program shall include formal plans and processes for implementing ALARA. Also, DOE O 420.1, *Facility Safety,* sets ALARA design criteria.

B. DOE Radiological Control (RadCon) Standard.

1. The RadCon Standard recommends the following:

   a. Individual worker dose should be less than 500 mrem/yr;

   b. Discharges of radioactive liquid to the environment are covered by DOE 5400.5 and should not degrade the ground water;

   c. Control of contamination should be achieved by containment of radioactive material (Note: Ventilation is an alternative, if filtered, for control of particulates);

   d. Efficiency of maintenance, decontamination, operations, and decommissioning shall be maximized;

   e. Components should be selected to minimize the buildup of radioactivity;

   f. Support facilities shall be provided for donning and removal of protective clothing and for personnel contamination monitoring, when required; and

2. The RadCon Standard emphasizes engineered controls over administrative controls, especially to minimize the need for respiratory protection.

3. Operational planning and review of work is emphasized.

4. ALARA training for procedure writers, engineers, and planners is specifically recommended.

5. Records of ALARA planning are to be kept.

C. DOE Order 5400.5.

DOE Order 5400.5, Ch. 2, “Radiation Protection of the Public and the Environment,” gives specific dose limits for the general public, such as limits on the releases of radioactive materials in airborne and waterborne effluents from DOE nuclear facilities to the environment. This order also requires contractors to implement the ALARA process (i.e., cost-benefit/optimization analysis) for all DOE activities and facilities that cause public doses. The actual doses should be as far below the limits as is reasonably achievable.

D. PNL-6577.

PNL-6577, “Health Physics Manual of Good Practices for Reducing Radiation Exposures to Levels that are ALARA,” states that ALARA should be incorporated into the earliest stages of the design of a building or operation and that a radiological engineer or ALARA specialist should be on the design team from the beginning. The design or operation should be reviewed at each of the appropriate stages, and any team reviewing the design or operation should include representatives from:

1. Maintenance,
2. Operations,
3. Research,
4. Safety, and
5. Appropriate engineering disciplines.

PNL-6577 also states that design and operations engineers, as well as other groups, should be trained in the principles of ALARA.

Engineers must be aware of pitfalls or questionable practices to participate intelligently in ALARA reviews, and all disciplines should understand any radiological implications their equipment or operations may have.

Much design time can be saved if the engineer knows some of the good practices in advance, and the engineer trained in ALARA becomes more aware of what is contained in available references regarding good design or operation. Radiological engineers probably will not have the necessary expertise to make ALARA judgments in all engineering areas (e.g., HVAC, electrical, mechanical, architectural); this will most often be a consensus decision of a facility or operational project or a design team.

4. SITE SPECIFIC ALARA DESIGN REQUIREMENTS

Add materials here based on review of site procedures relating to safety reviews and design criteria.

II. MODULE 102

1. TYPES OF RADIATION

A. Objectives.

Following self-study and/or classroom review, participants will be able to define and identify the penetrating abilities in body tissue of:

1. Alpha,
2. Beta,
3. Gamma and X-rays, and
4. Neutron radiation.

2. RADIOACTIVITY AND RADIATION

A. Radioactivity.

Radioactivity may be defined as spontaneous nuclear transformations that result in the formation of new elements. It is this spontaneous decay or disintegration of an unstable nucleus that may result in the emission of ionizing radiation.

B. Radioactive Half-life.

Different radionuclides decay at different rates. The time required for any given radionuclide to decrease to one-half of its original quantity is a measure of the rate with which the radionuclide undergoes radioactive decay. This period of time is called the half-life, and is unique to the individual radionuclide.

C. Radioactive Material.

Radioactive material contains atoms whose nuclei have excess energy (unstable) and reduce their energy by decaying or transforming and releasing the excess energy in the form of ionizing radiation.

D. Ionizing Radiation.

Ionizing radiation is the actual particle or photon (packet of electromagnetic energy) emitted by the nucleus or atom during the process of radioactive decay. These radiations interact with and cause ionizations within the materials through which they pass. In the field of radiation protection, the primary concern is radiation interacting with the body, causing biological damage to living tissue. Engineers are also concerned with evaluating whether potential radiation damage to materials or equipment may compromise function.

E. Particles and Photon Radiations.

The two general categories of ionizing radiation are particulate (alpha, neutron, beta), which consists of subatomic particles ejected from the nucleus, and photons (X and gamma rays), which also have particle-like properties. Alphas and betas are electrically charged particles, while neutrons and photons have no charge.

3. TYPES OF RADIATION

A. Alpha Particles.

1. Alpha particles are highly energetic helium nuclei that are emitted from the nucleus of a heavy atom (e.g., Uranium-235).

2. They are made up of two protons and two neutrons, giving them a charge of +2 and a mass about four times that of a neutron or proton.

B. Beta Particles.

1. A beta particle is an energetic electron that is ejected from the unstable nucleus.

2. Beta particles carry an electric charge of -1 or +1 and have a mass much smaller than that of a neutron or proton.

C. Gammas and X-Rays.

1. Gammas and X-rays are chargeless and massless waves of electromagnetic energy. They both consist of discrete packets of energy called “photons.”

2. Gammas and X-rays radiation are identical except for where they originate.

   a. Gamma rays come from the nucleus of the atom, and

b. X-rays come from two sources. One is from the movement of an electron from one atomic orbital energy level to another, and the second is from the slowing down of a free electron when it passes close to a large nucleus. In the latter case, the X-rays are called “bremsstrahlung” (braking radiation); these are an important consideration in the shielding of beta particles.

D. Neutron.

1. Neutrons are uncharged particles that reside in the nucleus of the atom along with protons. A neutron has about the same mass as a proton.

2. Sources of neutron radiation include nuclear reactors, accelerators, natural neutron emitters (e.g., transuranic radionuclides) and mixtures of alpha emitters and radionuclides that absorb alpha particles and subsequently emit neutrons.

4. PENETRATING ABILITY IN TISSUE

A. Alphas.

1. Alpha particles will not penetrate the dead layer of skin and are not even considered from an external radiation standpoint. Alphas travel no more than a few inches in air.

2. Alphas are considered to be a hazard only when the radioactivity emitting them is inside the body, where the very localized deposition of the high alpha energy can be significantly damaging.

B. Betas and Electrons

1. A beta particle will travel several feet through the air and through several layers of skin depending on its energy.

2. Beta radiation, therefore, is considered to be both an external (predominantly the skin or eyes) and an internal exposure hazard.

C. Gammas and X-Rays.

1. Primarily because they have no charge, gamma and X- ray radiation are highly penetrating in tissue and are termed “penetrating radiation.”

2. They will pass deeply into or completely through the whole body, possibly causing biological damage to internal organs they interact with.

D. Neutrons.

1. Because they carry no charge, neutrons are very penetrating and may travel long distances in air.

2. Neutrons are more readily stopped by materials that contain hydrogen, such as tissue, and other materials with low atomic mass. Neutrons are generally considered an external hazard.

3. The low-energy neutrons eventually are absorbed by another nucleus, and the resulting nuclide may be radioactive. The latter process is called neutron activation. In the absorption process, excited nuclei are created which subsequently emit gamma radiation. This radiation may also result in added dose.

II. MODULE 103

1. SELECTED TOPICS IN RADIATION PROTECTION

A. Objectives.

Following self-study and/or classroom review, participants will be able to:

1. List four ways radioactive material enters the body.
2. Define the terms “crud” and activation products.
3. Discuss controls for airborne radioactive material.
4. Discuss methods to process radwaste.
5. Define the terms “Controlled Area” and “Radiological Area.” Discuss types of radiological areas.
6. Identify types of contamination control measures.
7. Define scattering and streaming.

2. RADIATION EXPOSURE MODES

A. Radiation Dose.

Radiation interacts with the body by depositing its energy in the cells of the tissue. Deposition of this energy causes chemical alterations which may cause biological damage.
This energy is delivered to the tissue from the decay of radioactive material deposited inside the body or from radiation emitted from external sources.

Appendix C discusses certain dosimetry calculations using the dosimetry quantities provided in 10 CFR 835.

B. External Dose.

All or part of the body can receive dose delivered by a source that is outside the body. Typical sources include radioactive materials in flasks, pipes, and sealed containers, and air or water containing radioactive materials.

C. Internal Dose.

Internal dose is delivered to the body tissue from radioactive material present inside the body. It may involve large or small portions of the whole body or specific organs to which the isotope is attracted. Radionuclides can enter the body in four ways:

1. <u>Inhalation</u>: worker breathes in air containing airborne radioactive materials.

2. Ingestion: worker swallows some radioactive material.

3. Absorption: a few radioactive materials can be absorbed through the skin.

4. Injection: radioactive materials may be carried into the body through wounds or punctures in the skin.

D. Whole-Body Dose.

Whole-body dose normally results from penetrating radiation such as gammas, X-rays, or neutrons. An exception is the whole-body dose delivered by some radioactive material, such as tritiated water, that is dispersed throughout the body. The gammas and X-rays may interact with the body in two ways:

1. They interact with body material and deposit all or part of their energy in local tissues, or

2. They pass through the body without interaction. With no deposition of energy, there is no dose.

E. Skin Dose.

In addition to the dose from penetrating radiation, skin dose may also be delivered by weakly penetrating radiation such as low-energy gamma rays, X- rays, and beta particles.

F. Extremity Dose.

Extremities include hands, arms below the elbow, feet, and legs below the knees. (The head is considered to be part of the whole body). High dose to an extremity without a correspondingly high dose to the body can result from work in nonuniform radiation fields or proximity to a small, strong radiation source. The extremities are not as sensitive to radiation damage as the rest of the whole body and can tolerate higher doses. Due to this fact, extremity dose limits have been established at levels higher than the whole-body limits.

3. CRUD AND OTHER RADIOACTIVE SOURCES

A. Crud.

Originally, crud was considered to be activated debris or fuel bits in the coolant piping of reactors. Because many people apply the term to any contamination in liquid systems that may deposit as solids in unfavorable spots, we will use it for convenience in this expanded sense as well. Crud deposition problems are thus potentially present for all facilities and equipment that have liquids containing radioactive material circulating in them. Such deposits can be a prime contributor to “hot spots” (small, localized areas with dose rates significantly higher than general area dose rates) in piping, valves, pumps, and tanks.

B. Radiation Levels from Crud.

The radiation from crud does not go away when the facility shuts down. The radiation levels usually decrease over time as a result of radioactive decay, with the rate depending on the half-lives of the radionuclides composing the crud. But, radiation levels may actually increase in cases when the radionuclide decays to a “daughter” nuclide that is also radioactive. The “parent” may be an alpha, beta, or weak gamma emitter, producing little or no dose rate outside the container, but the daughter(s) may emit strong gammas, neutrons, or even betas, producing significant bremsstrahlung.

C. Crud Production.

Crud can be produced in two ways:

1. Corrosion or erosion of equipment in or near a neutron-emitting source (e.g., a reactor core neutron-generating devices) may produce small free bits of steel or other metal that are near or can be carried near the source and activated by the neutron flux. These new radioactive bits (called activation products) can then be transported out of the vicinity of the neutron flux to plate out or be deposited on wet surfaces. Crud can be removed from the liquid by a filtration system.

2. The second method of crud production occurs at production, test, and research reactors. The fuel rods, fuel assemblies, or target materials contain the plutonium or uranium atoms to be fissioned and radioactive fission products. The fission products or activated target materials can leak, allowing some of the uranium and the fission products to escape into the reactor coolant. In nonreactor facilities, a leakage of radioactive materials into fluid transport systems can result in unwanted deposition of contamination.

D. Decontamination.

Advanced decontamination techniques are being studied. Decontamination of inner surfaces may reduce deposits, but they will usually build up again. Anti-deposition measures, such as metal passivation and electro-polishing treatments, inhibit crud from redepositing on surfaces.

E. Reducing Crud.

The best means to reduce the production of crud include:

1. Using low-activation materials.
2. Preventing corrosion and erosion of equipment, and
3. Avoiding crud traps such as low-flow areas,
4. Providing equipment with smooth internal surfaces, and
5. Preventing fuel or target leaks.

4. AIRBORNE RADIOACTIVE MATERIAL

A. Production.

Radioactive materials can become airborne in the following ways:

1. Normally Gaseous Forms: Some radionuclides, such as krypton, xenon, and argon, naturally exist in a gaseous form. Other radionuclides may be chemically combined with other elements to form a gas. Note that most gases mix readily with the air unless contained in some manner.

2. Volatile Liquids, Droplets, and Sprays: Some radionuclides are in the form of volatile liquids, either naturally or as part of a compound. If leaked or exposed to the air, these can also become airborne. Some liquids containing radionuclides, while not volatile, can become airborne in processes that produce droplets or sprays.

3 Airborne Particulates: Radioactive material in a particulate form can become suspended in air and be transported by air currents, sometimes after adhering to dust particles, until they eventually settle. Operations such as grinding, welding, etc., may create airborne particulates.

B. Radiological Protection Against Airborne Radioactivity.

Airborne radioactive materials can deliver both external and internal doses. External doses result from the worker being surrounded by a radioactive cloud; whereas internal dose results from the radioactive material entering the worker's body and organs. Protection measures against airborne radioactive materials include the following:

1. For external doses, a protective plastic suit can be worn as shielding against weakly penetrating radiation from airborne radioactive materials. This shielding will stop alphas and most betas and radioactive material, such as tritium, that can be also absorbed through the skin.

2. For internal doses, one can:
   - Wear a respirator, or
   - Wear a nonporous suit in atmospheres containing absorbable radionuclides.

3. Engineered features, which are the primary defenses against airborne radioactive materials, include:
   - ventilation cleanup systems,
   - liquid filtration and processing systems,
   - containment devices, and
   - airborne radioactive monitoring systems.

C. Derived Air Concentration (DAC).

DOE's limits on airborne radioactivity are expressed in terms of the Derived Air Concentrations (DACs) that are given in 10 CFR 835, Appendices A and C. Breathing 1 DAC for 2,000 working hours (1 year) would result in the annual limit on intake (ALI), corresponding to 5 rem committed effective dose (CED) or 50 rem committed equivalent dose (CED or organ dose), whichever is more limiting. An equivalent DAC for a mixture of radionuclides can also be calculated.

Areas with atmospheres containing a radionuclide or a mixture of radionuclides > the DAC or where an individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week must be posted as Airborne Radioactivity Areas.

D. Design Criteria.

The 10 CFR 835 design objective for airborne radiactive material states that “under normal conditions, to avoid releases to the workplace atmosphere, and in any situation, to control the inhalation of such materials to levels that are ALARA.”

If airborne radioactivity cannot be avoided, it is best to design an operation to try to stay below the 10 percent DAC level. At levels >10 percent DAC, more restrictive administrative and/or increased engineered controls may become necessary.

E. Respirator.

The primary method of controlling airborne contamination should be to use reasonable engineering design features. Good work practices and contamination control at the source should also be performed(e.g., flushing a pipeline to remove the radioactive source prior to maintenance).. Only when these features and controls are not feasible or effective (or while they are being evaluated) should respirators be prescribed.

To be ALARA, routine respirator use must be kept to a minimum. Design that requires the constant use of respirators in frequently or regularly occupied areas or during routine work is not acceptable.

F. Time Versus Respirator Usage.

In specific situations, the use of respiratory protection may not be suitable due to physical limitations or the potential for increased external exposure.

It is often generally perceived that personnel should not be allowed to work in an Airborne Radioactivity Area without a respirator. However, brief entries in airborne radioactivity areas may result in doses negligible compared to the risk of heat stress or the risk associated with not doing the job. Also, it has been shown that in Airborne Radioactivity Areas with elevated external dose rates, total doses (i.e., internal plus external) to workers without respirators may be lower than total doses to those workers with respirators. This is due to the extra length of time it takes the worker with respirators to perform tasks as a result of restricted movement, blurred vision, impaired breathing, and limited communication. In such cases, the radiological control staff and the operational supervisor may agree to waive respirator use.

5. DECONTAMINATION

A. Decontamination.

Decontamination is any process or method of removing contamination. Frequently, there is a need for decontamination to reduce the radioactive source, and thus avoid more significant exposures to workers or, if the radioactive material escapes from the facility, to the public. Unfortunately, the process of decontamination itself may involve some dose to workers, e.g. radioactive material may enter the body through broken skin.

B. Design Criteria.

10 CFR 835 has a design Objective that the design or modification of a facility and the selection of materials shall include features that facilitate operations, maintenance, decontamination, and decommissioning.

Provision for decontamination must be made in the design of any component, system, or area where the potential for leakage of radioactive materials exists. Facilities may be released for public use if contamination levels meet established limits (not zero).

C. Planning.

Planning for the likelihood of decontamination should be done for any operation which may involve the spread or generation of significant amounts of radioactive materials.

D. Methods.

Factors that affect the choice of decontamination method include type and quantity of radioactive leakage, item to be decontaminated, expense, practicality, etc.

E. Fixed and Removable Equipment.

Potential decontamination must be considered for fixed and removable equipment. Laundries and decontamination cells may be necessary for such items as respirators, clothing, or removable pumps. For equipment that must be decontaminated in place, provisions must be made for decontamination supplies (water, chemical, air) and electrical power.

6. RADIOACTIVE WASTE (RADWASTE)

A. Definition.

Radwaste is any radioactive material or substance that is not considered useful and must be disposed of. Useful materials that can be decontaminated and reused are not considered radwaste; however, the liquid and solid by-products of the decontamination process may be radwaste, such as rags, cleaning solutions, and filters.

B. Types of Radwaste.

1. Solid dry waste, also called “dry active waste” (DAW),
2. Liquid,
3. Gaseous,
4. Mixed waste,
5. High level radiactive waste, and
6. Transuranic waste.

C. Processing of Radwaste.

Radwaste can be processed in several ways:

1. Filtration: Mechanical removal of radioactive contamination from liquid or gaseous waste.

2. Ion Exchange Processes: Chemical removal of radioactive contamination with demineralizers or filter-demineralizers.

3. Volume Reduction: Methods that reduce the volume of waste that must be disposed of, such as incineration, compaction or evaporation.

4. Decay Tanks: Containers that allow contents to undergo radioactive decay to decrease radioactivity levels before further processing or disposal.

5. Dilution: Radioactive liquids or gases may be mixed with a large volume of air or water upon release (there are many restrictions on such releases).

D. Disposal.

Radwaste, either in its original form or after processing, is placed in tanks, drums, casks, or other appropriate sealed containers and disposed of through storage, burial, or release (when allowed).

E. Segregation.

Wastes containing oil, detergent, and many different chemicals must often be processed separately.

F. Mixed Waste.

Mixed waste is waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act.

Special considerations must be given to reducing generation of mixed waste because of the many restrictions on storage and disposal.

G. Methods of Collecting and Dealing with RadWaste.

(INSERT FACILITY-SPECIFIC INFORMATION)

7. CONTROLLED AREAS

A. Controlled Areas.

For the purposes of radiological access control, a facility can be divided into radiological areas according to the type and extent of the radiological hazard. When designing a new facility, anticipated dose rates are calculated or estimated; then, a radiological engineer or other radiological specialist divides the facility into radiological areas.

1. <u>Controlled Area</u>: Any area to which access is managed to protect individuals from exposure to radiation and/or radioactive material.

   (Insert facility-specific information concerning controlled and uncontrolled areas.)

2. <u>Radioactive Materials Area</u>: Any accessible area within a controlled area, accessible to individuals, in which radioactive material is used, handled, or stored shall be posted with the words "Caution, Radioactive Material." The posting shall meet the requirements of 10 CFR 835.601. The following areas are exempt from this posting requirement:

   (a) Areas may be excepted from the posting requirements of § 835.603 for periods of less than 8 continuous hours when placed under continuous observation and control of an individual knowledgeable of, and empowered to implement, required access and exposure control measures.

   (b) Areas may be excepted from the radioactive material area posting requirements of § 835.603(g) when:

(1) Posted in accordance with § 835.603(a) through (f); or

(2) Each item or container of radioactive material is labeled in accordance with this subpart such that individuals entering the area are made aware of the hazard; or

(3) The radioactive material of concern consists solely of structures or installed components which have been activated (i.e. such as by being exposed to neutron radiation or particles produced in an accelerator).

   (c) Areas containing only packages received from radioactive material transportation labeled and in non-degraded condition need not be posted in accordance with § 835.603 until the packages are monitored in accordance with § 835.405.

B. Area Designations.

The following area designations are defined in 10 CFR 835 and DOE directives:

1. Radiological Area: Any area within a Controlled Area that meets the definition of a Radiation Area, Contamination Area, High Contamination Area, Airborne Radioactivity Area, or High Radiation or Very High Radiation Areas.

   (Insert facility-specific information concerning radiological division of areas by type of hazard.)

2. Radiation Area: Any area accessible to personnel where an individual could receive to a major portion of the whole body an equivalent dose greater than 5 mrem (0.05 mSv) in 1 hour at 30 cm (30 cm is approximately 1 foot) from the radiation source or any surface through which the radiation penetrates.

   (Insert facility-specific information.)

3. High Radiation Area: Any area accessible to personnel where an individual could receive a dose equivalent greater than 0.1 rem (0.001 sievert) in 1 hour at 30 cm (approximately 1 foot) from the radiation source or from any surface through which the radiation penetrates.

4. Very High Radiation Area: Any area accessible to personnel where an individual could receive an absorbed dose in excess of 500 rad (5 grays) in 1 hour at 1 one meter from the radiation source or from any surface through which the radiation penetrates.

5. Radiological Buffer Area: An intermediate area established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure.

6. Contamination Area: Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in appendix D of 10 CFR 835, but do not exceed 100 times those values.

   (Insert facility-specific information concerning areas of potential surface and airborne contamination.)

7. High Contamination: Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in appendix D of 10 CFR 835.

8. Airborne Radioactivity Area: An area, accessible to individuals, where:
   (1) The concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in appendix A or appendix C of 10 CFR 835; or
   (2) An individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.

C. Entry Controls.

Some common entry control measures include signs, barricades, control devices on entrances, visible or audible alarms, locks, allowing entry to only necessary personnel, and administrative control procedures. 10 CFR 835 requires special access controls on High Radiation and Very High Radiation Areas.

(Insert facility-specific entry control method.)

D. Contamination Controls.

Some common types of contamination control measures include area posting; step-off pads; protective clothing; containments (such as gloveboxes and hot cells); and effective ventilation cleanup, filters, and flow rates.

(Insert facility-specific information concerning contamination controls.)

E. Potential or Intermittent Radiological Areas.

An area may remain posted as a Radiological Area even when conditions are potential or intermittent. Care must be taken in designing facilities and planning operations that such conditions are identified and appropriate controls (such as alarms, flashing lights, etc.) are specified to alert workers to changes.

8. SCATTER AND STREAMING

A. Scatter.

Scatter is the reflection of a neutron or photon resulting from the interaction of the radiation with matter. Basic concrete can reflect up to 1-3 percent of the gamma rays incident upon it. X-rays and neutrons, also, can be significantly reflected.

B. Skyshine.
Outside air can provide significant scatter, particularly for neutrons. This is referred to as “skyshine.”

C. Streaming.
Streaming results when radiation passes through an opening, void, or low-density region in shielding. Gaps in radiation shielding may exist because of doorways, penetrations, or air pockets. Most shielding installations will require at least some penetrations for electrical power, plumbing, personnel access, remote sensing, ventilation, and/or process fluid transfer.

D. Dose Rates.
Radiation scatter and streaming may create a significant dose rate outside the shield (non-source side). For example, a dose rate may be acceptable if the shield wall goes up to the ceiling, but may be unacceptable - due to scatter off the ceiling - if the wall stops short of the ceiling.

E. Exposure Control.
Scattering and streaming should be considered where applicable.

1. A labyrinth entrance can be a scatter path; so can a penetration.

2. Removable, overlapping block walls may be used to minimize streaming.

3. Shield slabs and plugs may be used to minimize exposure. Pass-through ports should be placed near the floor or ceiling.

4. Proper door or shield slab arrangement can reduce scatter.

(Insert facility-specific information concerning scattering and streaming exposure control.)

IV. MODULE 104

1. ALARA PRINCIPLES

A. Objectives.

Following self-study and classroom review, participants will be able to:

1. Identify the six fundamental principles used to reduce radiation doses and the release and spread of radioactive materials.

2. Identify applications of the fundamental principles.

3. Identify shielding materials used to reduce radiation exposures.

B. Six Fundamental Principles.

Six fundamental principles should be considered for every facet of the design or operation. The six principles are:

1. Eliminate or reduce the source of radiation,

2. Contain the source,

3. Minimize time in a radiation field,

4. Maximize distance from a radioactive source,

5. Use radiation shielding, and

6. Optimize manpower since using more workers to cut the time will increase the collective dose.

C. Hierarchy of Controls.

Emphasis should be placed on engineered controls instead of procedures, administration, or personal practices. The objective is to design an inherently safe facility.

(Insert facility-specific applications for the six fundamental ALARA principles, as appropriate.)

2. ELIMINATE OR REDUCE THE RADIOACTIVE SOURCE

The first ALARA design principle is to eliminate or reduce the source of radiation exposure.

A. Source Elimination.

Eliminate the use of the source by substitution of other appropriate technologies or materials. A good example of this is the use of an ultrasound exam (sonogram) in prenatal examinations rather than an X-ray exam or flushing a pipe to remove radioactive material.

B. Source Reduction.

A reduction in source means a reduction in dose rate. In planning a job or operation involving radiation exposure, consideration should be given to reduction of as much of the radioactive source(s) as possible. This may include:

1. Installing filtration and processing equipment to clean liquids;
2. Removal of nonessential radioactive material or equipment from the vicinity;
3. Selection of appropriate materials to minimize activation and deposition;
4. Draining and/or flushing of radioactive liquids from fluid systems; or
5. Ventilation of airborne radioactivity areas (with appropriate filtering of the air to reduce the concentration of airbornes and minimize deposition).
6. If practical, allow the radionuclide source(s) to decay for several half-lives to decrease the radiation field.

3. CONTAINMENT AND CONFINEMENT

The second ALARA design principle (which some view as a subset of the first principle) is to control and contain radioactivity by the use of containment, ventilation, and processing systems.

A. Methods to Control and Contain.

The methods one can use to control and contain radioactive sources are:

1. Containment: Leak-tight or controlled-opening enclosure to keep radioactive materials confined within (e.g., fuel cladding, piping, hot cells, and curbing around tanks that contain radioactive materials).

    a. Examples of temporary containments are tents and glove bags.

    b. Examples of structural containments for the control of radioactive materials are walls, windows, doors, floors, transfer ports, and ceilings, with appropriate gaskets, caulking, etc.

2. Ventilation: Provision of air and other gas flow direction and rate such that airborne material and radioactive gases are captured and directed to filters and an appropriate release point. Note that negative pressure is an important aspect of control for some contaminants.

3. Filtration: The capture of airborne material on a medium, thus confining them to a small and disposable volume.

B. Protective Designs.

Protective designs include such items as:

1. Ventilated fume hoods,
2. Gloveboxes for handling radioactive material,
3. Exhaust systems,
4. Water filtration and processing systems,
5. Conservatively sized ventilation cleanup systems, and
6. Double-walled pipes and tanks, canned pumps, and leak-tight valves.

4. MINIMIZING TIME

The third ALARA design principle is to eliminate or reduce the time a worker must spend in the vicinity of a radioactive source.

The amount of dose received is directly proportional to the amount of time spent in a given radiation field; therefore, dose is minimized if time is minimized.

A. Design Factors.

Appendix A discusses the application of ALARA in facility system design in greater detail.

Design factors to reduce time spent in radiation fields include:

1. Installing reliable equipment to reduce maintenance,

2. Choosing equipment that requires less frequent calibration,

3. Providing adequate clearance for maintenance and inspection around components,

4. Utilizing special tools to speed maintenance and access,

5. Using robots or remote equipment,

6. Removing components from the radiological area for repair or calibration, and

7. Installing permanent lighting and platforms.

8. Use mock-ups to allow practicing of tasks in nonradiological areas.

5. MAXIMIZING DISTANCE

The fourth ALARA design principle is to maximize the distance from the source.

A. Dose Rate Versus Source Size.

1. Point Source: For a point source (in which the size of the source is very small compared to the distance from it), radiation intensity varies inversely with the square of the distance from the source. This is called the inverse square law.

2. Large Source: Reduction in dose rates with distance from large sources such as pipes, tanks, floors, and walls is somewhat less dramatic, but the dose rate will still decrease with the distance from the source.

B. Design Factors.

Design factors to maximize the distance from radioactive sources include:

1. Remote operation (process, maintenance, surveillance, decontamination, sampling, remote tools and controls).

2. Locating all nonradioactivity-bearing instruments and readouts in low-dose areas;

3. Provision for removal of components to low-dose areas for maintenance;

4. Use of cameras, microphones, and other transmitters to perform remote surveillance and inspections; and

5. Layout of equipment so as to maximize the distance between workers and the radioactive source.

6. USE OF RADIATION SHIELDING

The fifth ALARA design principle is to provide shielding between the worker and the radiation source by providing permanent or temporary shielding between sources and the workers.

In general, any material through which ionizing radiation passes absorbs some or all of the radiation. This attenuation depends on the type and energy of the radiation, as well as the thickness and composition of the shielding material.

A. Design Factors.

Considerable thought should be given to incorporating adequate shielding structures during the design phase of a nuclear facility. This shielding can be quite elaborate in some cases and may even consist of several layers of different materials best suited for different types of radiation.

Considerations for shielding design include:

1. Anticipation of crud buildup and hot spots;

2. Use of labyrinths for shielding penetrations and cubicle entrances;

3. Installation of special shields such as hot spot covers, leaded windows, and shielded carts and forklifts;

4. Allow for adequate space and access for installing temporary shielding for anticipated hot spots or in frequent jobs; and

5. Use of appropriate shielding materials based on the type and level of radiation.

B. Shielding Materials.

The choice of shielding material depends on the type(s) of radiation to be shielded.

1. Alpha (can be stopped by a single sheet of paper): Due to the extremely low penetrating ability of alpha particles, shielding is not considered necessary.

2. Beta (can be stopped by 1/2-inch Plexiglas; 1/4-inch aluminum, wood, rubber): Due to the potential creation of bremsstrahlung when the beta particles are slowed or stopped, consideration must be given to shielding these X-rays whenever beta radiation is present.

This phenomenon is strongest when beta particles are stopped by materials with a high atomic number (such as steel or lead), making these materials inappropriate for shielding beta particles unless they are sufficiently thick to stop the bremsstrahlung also.

3. Gamma (lead, concrete, steel): The denser the material, the better it is suited for attenuation of gamma and X-rays.

4. Neutron (water, polyethylene, concrete, boron): Neutron-absorbing radionuclides (such as boron-10) and materials that contain large amounts of hydrogen make efficient neutron shields. The production of “capture gammas” in some materials must also be considered.

C. Fortuitous Shielding.

Fortuitous shielding should be used when possible. Fortuitous shielding is material placed in an area for reasons other than shielding but acting as a shield because of its location, composition and thickness. Steel cabinets, steel security doors, concrete columns, and similar objects can serve as fortuitous shielding. These objects should be permanently mounted if relied on as shielding, however.

D. Sequence of Shielding.

Shielding should be correctly layered for structural integrity and attenuation of different types of radiation. For example, with gammas and strong betas, a layer of plastic might precede a layer of lead, so that betas would be captured in the plastic and not produce bremsstrahlung in the lead.

E. Concrete.

The use of concrete can be considered for stopping any type of radiation when space, weight, and cost are not limiting, because it is the best all-purpose shield.

7. OPTIMIZATION

The sixth ALARA design principle is optimization.

ALARA design uses methods such as cost-benefit analysis to balance competing factors in dose reduction. It is important to maintain a separation between those concepts related to keeping radiation exposures below limits and those aimed at optimization or ALARA.

The purpose of an optimization analysis is to show that the expense (in terms of money, person hours, dose, etc.) of a project or feature of a project is justified in terms of the benefit received. This is in accordance with the idea of balancing ALARA considerations against technical, social, operational, and economic considerations.

Optimization is further addressed in Module 110. Both formal and informal methods of optimization analyses are addressed. In Appendix F, examples of analyses are performed.

8. SUMMARY

Following self-study and/or classroom review, participants will be able to:

A. Module 101 Objectives.

1. Define the acronym ALARA,
2. List the ALARA recommendations of the RadCon Standard, and
3. Identify which groups should participate in ALARA design reviews.

B. Module 102 Objectives.

1. Identify the penetrating abilities in tissue:
    a. alpha,
    b. beta,
    c. gamma and X-ray, and
    d. neutron radiation.

C. Module 103 Objectives.

1. List four ways radioactive material enters the body.
2. Define the terms "crud" and activation products.
3. Discuss controls for airborne radioactive material.
4. Discuss methods to process radwaste.
5. Define the terms "Controlled Area" and "Radiological Area." Discuss types of radiological areas.
6. Identify types of contamination control measures, and
7. Define scattering and streaming.

D. Module 104 Objectives.

1. Identify the six fundamental principles used to reduce radiation doses and the spread of radioactive materials,

2. Identify applications of the fundamental principles, and

3. Identify appropriate shielding material used to reduce radiation exposures.

V. MODULE 105

1. APPLICATIONS OF ALARA

A. Objectives.

During the presentation of Module 105, participants should demonstrate the application of ALARA principles of source term reduction and control by actively participating in the group exercises.

2. CRUD PRODUCTION AND RADIOACTIVE MATERIAL DEPOSITION REDUCTION IN LIQUID SYSTEMS

A. Reduce Crud Production.

Reduce crud production by avoiding the use of nickel, cobalt, and other readily activated materials in areas of high neutron radiation, such as:

1. On wetted surfaces that may come into contact with reactor coolant.

2. Near spontaneous or man-made neutron emitters.

3. In accelerators that produce neutrons as a result of beam interactions (including component cooling systems).

Where wear-resistant facings are essential, the use of stellite, inconel, and some stainless steels are undesirable from this standpoint.

Note that other radioactivity in liquid systems (i.e., not produced by neutron activation of loose particles) may stick to loose, eroded, or corroded particles and thus collect in places where such particles are deposited.

(Insert facility-specific information concerning crud buildup, including dose rates and locations.)

B. Reduce Erosion.

Reduce the loss of material by erosion:

1. Use good flow geometry.

2. Avoid sharp bends, reducers, and rough internal surfaces.

C. Reduce Corrosion Loss.
Reduce the loss of material by corrosion:

1. Use corrosion resistant material.

2. Pretreat or precoat surfaces.

3. Use pH and other chemistry controls.

4. Provide for wet layup during maintenance and shutdown periods.

D. Reduce Deposition.
Reduce the deposition of crud and/or other radioactive material circulating in a system:

1. Select a flow velocity appropriate for the stream to keep solids in suspension and to ensure representative sampling.

2. Provide strainers, if practical, upstream of a neutron source (in reactors, before the coolant reaches the core).

3. Ensure that all equipment and piping runs are drainable and flushable.

4. Minimize crevices, elbows, low points, sharp bends, and dead legs (low flow areas in which deposition may occur).

5. Generally use butt welds, consumable inserts, and freeze fits that usually produce smoother welds than socket welds and backing rings.

6. Generally use full-ported valves (plug, gate, or ball valves instead of globe valves).

7. Choose straight-tube, vertical heat exchangers rather than U-tube, horizontal ones.

8. Consider temperature or chemistry controls that can inhibit deposition (e.g., control of pH to inhibit a particular chemical deposition reaction).

3. CONTAMINATION CONTROL AND DECONTAMINATION

A. Contamination Control Measures.

Provide for proper contamination control measures.

Within radiological areas, contamination should be controlled as follows:

1. Contamination in one area should not result from minor or moderate incidents that occur in other radiological areas.

2. Outside radiological areas, radioactive surface contamination should not exceed the release values specified in 10 CFR 835 for Controlled Areas or DOE 5400.5 for uncontrolled areas.

3. Select equipment that can be readily, easily, and completely dismantled and allow sufficient space for dismantling the equipment and allow sufficient space for dismantling the equipment.

B. Equipment Decontamination.

Provide for equipment decontamination. There are many methods that can be used for decontamination, but not all methods will be suitable for a particular radionuclide or surface. Keep in mind that it is ALARA to select a method that reduces the dose to the worker (including both the external and the internal dose) while reducing the volume of radwaste produced and the cost of the decontamination, but there may be some tradeoffs that must be weighed.

VI. MODULE 106

1. APPLICATION OF ALARA TO FACILITY AND SYSTEM DESIGN

A. Objectives.

During presentation of Module 106, participants should demonstrate the application of
ALARA principles to system design by participating in group exercises.

A designer or operations planner must consider which systems or components are likely to produce worker doses and select types that minimize dose. He/she must also consider which components may require a great deal of maintenance or may prove unreliable. He/she must select types that are highly reliable, easy to maintain, and consistent with the necessary functions. Finally, he/she must keep in mind the types of jobs that are associated with the operation and maintenance of each system or component and consider which ones may account for the most individual and collective dose over the operation or the life of the equipment. This is important when there are tradeoffs between, for example, cost and maintenance time.

2. RELIABILITY AND EQUIPMENT QUALIFICATION

A. Choose Reliable Equipment.

1. Select equipment for ease and low frequency of maintenance.

2. Select equipment for length of service life under the expected conditions.

B. Choose Qualified Equipment.

1. Select materials that are qualified for the expected use (i.e., that will not degrade unduly under the expected combination of conditions of temperature, humidity, pressure, and especially radiation level).

2. Avoid using aluminum in High or Very High Radiation Areas where it may be in contact with fluids or concrete due to the potential for adverse chemical reactions to occur over time.

3. Avoid locating microelectronics, rubber, cork, and other radiation-sensitive items in radiation areas. If necessary, place them in low-field areas only.

3. AIRBORNE RADIOACTIVITY AND HVAC

Airborne sources should be reduced or eliminated as much as possible. Where airborne levels may still be significant, well- designed ventilation systems should be provided to limit the possibility of intake of airborne radioactive material.

Such systems should be designed considering both normal and abnormal conditions. Routinely requiring workers to wear respiratory protection generally is not an acceptable solution to reducing intakes of radioactive material.

A. Essential Features.

As noted before, ventilation systems are provided to direct airborne contamination away from personnel and over to filters or other collection points; to reduce airborne concentrations; and to prevent or limit the release of airborne materials through necessary openings.

To attain these objectives, ventilation systems usually incorporate the following features:

1. Airflow:
   a. A system of differential pressure should be used to direct flow. The flow rate should be sufficient to ensure that airborne particles or gases are adequately captured or diluted.

   b. Airflow should go from areas with no or less potential contamination to areas with greater potential for contamination.

   c. Air should be exhausted from areas with greatest potential for contamination.

   d. Room air may be recirculated if adequate filtration and monitoring are provided.

   e. When transporting potentially contaminated air, the exhaust duct should be routed away from frequently occupied areas.

2. Filtration:
   a. Filters should be selected to match the chemical and physical form of the radionuclide(s). For example, High Efficiency Particulate Filters (HEPAs) should generally be used for particulate forms and charcoal filters for iodines.

b. Prefilters, moisture removal devices, and the like should be provided as necessary to prevent overloading the filter with dust, degrading it with moisture, etc. These provisions can increase the life and effectiveness of the radionuclide filter.

c. Local filtration (e.g., for hoods) should be provided where appropriate to maximize capture of particles near where they are produced.

d. Filters should be located upstream of fans and most of the ductwork to minimize contamination of ventilation system internal surfaces.

B. Area-Specific Requirements.
Even apparently similar areas do not always require identical ventilation characteristics, especially differential pressure and filtration. Ventilation design criteria need to accommodate a measure of flexibility because conditions may change as work changes and local or portable ventilation may be effective in reducing local airborne levels sufficiently.

(Insert facility-specific information.)

C. Maintenance.
Design ventilation systems for ease of maintenance, inspections, testing, and operations.

D. Monitoring and Sampling.
Design of ventilation systems should address monitoring and sampling requirements, such as inclusion of sampling ports.

4. CONTAINMENT

A. Containment.
A containment is an area enclosed by a set of barriers. These can be passive barriers, like walls, or active barriers, like valves and ventilation flow.

1. Primary Containment: is the barrier or set of barriers most intimately in contact with the radioactivity.

2. Secondary Containment: encloses the primary and receives and handles any leakage from it. The room(s) or vault enclosing the tank and piping are the secondary

containment and should be so designed; the outer wall of a double-walled tank may be the secondary.

3. Tertiary Containment (may also need to be provided): The building, itself, may be the tertiary containment.

One constraint on defining these is that it usually must not be possible for a single failure to compromise two containments at once (e.g., a primary and its secondary).

B. Gloveboxes/Glovebags.

Gloveboxes and other handling enclosures are primary containments when radioactivity in them is not completely enclosed or is enclosed in containers that cannot be assumed to be well-sealed. Gloveboxes are secondary containments when the radioactivity is actually contained in a piping system, vessel, instrument, etc., inside the box. In the latter case, the room may be designed as the tertiary containment.

C. Primary Containment Penetrations.

Primary containment penetrations must be carefully laid out and minimized in number and size. They should be carefully sealed with regard to radiation streaming, air-flow control, fire protection, and flooding as applicable. Permeation of radioactivity through these seals should be considered. Transfer ports for passing items in and out should, in general, be airlocks or mini-airlocks, with purging capabilities.

D. Isolation Systems.

A principle of good confinement is good isolation: systems with widely differing levels of actual or potential radioactivity content should be isolated from one another by check valves or other reverse-flow control devices. Pressure-relief devices should be required, and leak detection devices should be provided as appropriate to the process.

5. MECHANICAL AND ELECTRICAL SYSTEMS

This section will discuss six areas: piping, valves, pumps, filters, tanks, and heat exchangers.

A. Piping

Piping is used for fluid flow, pressure boundaries, and heat transfer. Piping can trap radioactive crud which can result in dose to personnel and potential for spread of contamination.

B. Valves.

Since operation and maintenance of valves can be two of the major contributors to workers' dose, the design engineer should carefully select and locate valves. It is generally recommended to use full-ported valves such as plug, gate, or ball valves.

C. Pumps.

Many pumps circulate radioactive water and other types of fluids and can trap radioactive crud. Maintenance and operation can thus present problems in minimizing dose and the spread of contamination. For example, crud can be trapped in piping elbows. Consider whether flooding due to leakage or backup may cause contamination of equipment.

D. Filters, Strainers, Evaporators, and Ion Exchangers

Filters, strainers, evaporators, and ion exchangers provide cleanup of radioactive fluid systems. Since these systems concentrate radioactivity, it is important that maintenance be reduced. Also, remote handling and shielding should be considered.

E. Tanks, Sumps, and Drains

Tanks, sumps, and drains prevent plugging in transfer systems. This equipment must be chosen carefully, considering decontamination and eventual decommissioning.

F. Heat Exchangers.

Heat exchangers may cause radiation dose during their cleaning, repair, inspection, and replacement. Design, modification, or replacement of heat exchangers carrying radioactive fluids should address shielding and placement.

6. ELECTRICAL POWER SYSTEMS.

Even something as seemingly simple as the type of light bulbs used to illuminate areas can be an ALARA and waste consideration. The use of long-life bulbs can decrease maintenance time in elevated dose rate areas by requiring less frequent replacement; the number used up over the life of the facility will be fewer than for shorter-lived bulbs.

VII. MODULE 107

1. APPLICATION OF ALARA FOR VARIOUS ENGINEERING DISCIPLINES

A. Objective.

Participants should demonstrate the application of ALARA principles in design by actively participating in group exercise(s).

B. Introduction.

This module addresses radiation dose assessment and radiological design considerations of new facilities and the modification of existing facilities.

Once a facility is built, changes in shielding or facility layout are difficult to accomplish and often cannot bring about the desired dose rates without considerable added cost and loss of usable work space.

Thus, it is more cost effective to design for anticipated and possible future radiological conditions rather than designing for near-term limited functions.

In many cases, existing facilities must be modified. The resultant need to avoid impact on existing operations and activities may present a major challenge to the engineer.

C. Civil/Structural Design Considerations.

The support structures within a facility can act as shielding devices and reduce doses. On the other hand, support structures may make maintenance difficult because of inaccessibility and may consequently result in increased doses. Therefore, facility design and layout can make a big difference in occupational doses.

2. ASSESSING RADIOLOGICAL DOSES

Radiation designs should provide for anticipated dose by including analysis of the tasks and processes that occur in these areas, the anticipated dose rates for the area, and the proposed inventories of radioactive materials.

A. Worker and Time.

The numbers of workers and the amount of time they are expected to spend in the area should be taken into consideration.

1. For example, general (low-level) operations areas consist of those areas with small or moderate inventories of radioactive materials or low dose rates. Examples are general

radionuclide research labs, rooms containing shielded X-ray diffraction and spectroscopy units, and operation areas with low contamination and low dose-rate potential.

2. Work in higher-level operation areas, however, typically involves more radioactive material or higher dose rates than does work in general operation areas. Examples of higher-level operation areas are glovebox and hot cell operating areas, control areas for high-dose rooms, and selected areas of accelerator facilities where experiments with moderate dose or contamination potential cannot be remote-controlled.

B. Multiple Sources.

It is important in building layout to minimize simultaneous dose from multiple sources at locations where maintenance personnel may be required to work. Similarly, individual work stations should be shielded from one another if work by one individual may expose others in the same area to unnecessary dose. Multiple sources must be taken into account when assessing possible doses.

C. Isolation of Areas.

Areas with high dose rates or airborne contamination levels should be isolated. Unauthorized and unmonitored entry in these areas is forbidden, and design features shall prevent the unauthorized entry of personnel. All personnel are prohibited from entering when conditions in the area present an immediate hazard to human life. Physical controls are required to limit doses when these areas are occupied. The ability to isolate areas with high dose rates should be taken into account when assessing possible doses.

3. ACCESS CONTROL

Access to radiological areas can be prevented by active (personnel) or passive (e.g.locks) controls. Interlocks are recommended because the source is moved or shielded when the interlock is tripped.

Building layout is an important factor in controlling personnel dose by regulating the flow of personnel and material. Proper layout reduces casual or transient exposures to radiation fields by segregating heavily used corridors and the work areas of nonradiological workers from the areas of elevated dose rate and potential contamination. The layout should effectively limit occupational dose to areas where the performance of an assigned task requires some receipt of radiation dose.

Radiological areas should be made as small as possible to aid in access and contamination control. Eventual decontamination and decommissioning (D&D) activities should be considered.

Controlled areas defined in 10 CFR 835 or the RadCon Standard are addressed in Module 103.

A general discussion follows.

A. Sequential Areas.

An acceptable technique for achieving proper building layout is to establish a system of sequential areas. This means that Radiological Areas have been laid out in a way that will minimize dose and reduce the spread of contamination. This concept is frequently used because it is adaptable to the physical control of external and internal dose equivalents.

B. General Access and Controlled Areas.

Two major types of areas are included in any nuclear facility: general access areas and controlled areas.

1. General access: General access areas are normally places to which public access is restricted but where radiation exposure is not necessary for job performance, such as the work areas of administrative and nonradiological support personnel. These areas include conference rooms, file rooms, clerical and other support offices, lunch rooms, and rest rooms.

2. Controlled areas: Controlled areas are areas to which access is managed to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter only the controlled areas without entering radiological areas are not expected to receive a total effective dose of more than 100 mrem (0.001 Sv) in a year. Note that this is the same limit as that for a member of the public outside the facility.

   Controlled areas may include corridors that are adjacent to, or connected with, areas that contain radioactive materials, change rooms, or special offices for radiation workers.

C. Traffic and Access.

1. Traffic: Locate frequently used pathways in low-dose rate and noncontaminated areas, but use common sense and logic; if the pathway is through “clean areas” but in a long and illogical route, people will not use it and may take “short cuts” through hot areas. Place inspection, control and readout instrumentation in low dose areas.

2. Access: Ensure that doorways are wide enough and large enough and access areas are provided for readily removing and servicing equipment.

4. CONTAMINATION CONTROL DESIGN

Contamination control measures may consist of curbs, gutters, drains, catch tanks and other liquid controls. Special attention needs to be given to drains not only for collection of radioactive liquids but also as potential inadvertent release points. Glove boxes and use of proper ventilation are examples of contamination control devices/practices for non-liquids. Contamination control designs should address eventual decontamination/ decommissioning with focus on a specific endpoint (e.g., completely clean or elevated contamination to be re-used as contaminated).

5. RADIOACTIVE WASTE

Locations for the temporary storage of radioactive wastes must be designed into both the building plan and the plan for each area where radioactive materials are handled. To prevent accumulations of waste in operating areas if normal disposal methods are temporarily interrupted, the waste storage area should be large enough to accommodate more than the expected volume of waste.

Additional considerations include transportation, drainage of liquid systems, monitoring, and fire suppression.

6. SHIELDING, PENETRATIONS, AND ROUTING

A. Shielding.

Obtain information on shielding types, thicknesses, and layout from a radiological specialist (a radiological engineer, ALARA specialist, or health physicist, as appropriate for your project or operation).

B. Penetrations.

Have experts from all affected disciplines review a planned penetration before the hole is made.

C. Routing of Ducts, Pipes, Cables, and Conduit (DPCs).

Don't route DPCs containing radioactive materials through general access areas, and don’t route clean DPCs through potentially contaminated or high-dose-rate areas. Do not regard the X-Y-Z grid as sacred. Minimize runs of piping by routing diagonally, using bends other than 90 degrees, and sloping lines, where appropriate.

7. SEPARATION, SEGREGATION, PLACEMENT, AND ISOLATION OF EQUIPMENT

A. Separation.

Put shield walls between components sharing the same cubicle to reduce the dose to a worker maintaining one of them (the equipment should be placed so that the worker does not have to pass close to one to get to the other).

B. Segregation.

Segregate highly radioactive equipment from moderately radioactive equipment, and both from clean equipment. Similarly, segregate equipment with high airborne potential from equipment with less airborne potential, and both from clean equipment.

C. Placement.

Even with shielding, lay out equipment in an area or equipment cubicle so that from the point that the worker enters, he progresses from low-dose rate areas to moderate to high-dose-rate areas, and from active to passive equipment.

D. Isolation.

The interconnections between systems of different radioactivity potential must be carefully considered.

1. Properly place isolation valves so as to minimize dead legs.

2. Minimize pipe runs in valve aisles (consider reach rods and valve operators).

E. Redundancy.

Provide adequate redundancy and backup capability, especially in systems of high radioactivity content and safety systems. Provide appropriate cross-connections to achieve this.

8. ACCESSIBILITY, LAYDOWN, AND STORAGE

Allow adequate working space around major components, usually at least 3 feet. Do not allow this space to be filled by reach rods, shields, pipes, scaffolds, etc.

Provide laydown space in a low-dose-rate area (besides equipment, consider such items as tool boxes, carts, and hoses).

(Insert facility-specific information.)

9. SNUBBERS, STRUTS, HANGERS, AND ANCHORS

Holding devices should be designed and located to facilitate removal and not interfere with inspections and maintenance.

10. HUMAN FACTORS

Design should address human factors such as vision, hearing, and physical limitations. These factors should be considered when the use of protective equipment is evaluated. For instance, heat stress, restricted vision, impaired hearing and speech are all associated with full-face respirators.

Working in elevated dose rate areas requires special considerations for lifting devices and access to equipment.

See Appendix B for supplemental information concerning ALARA civil/structural design principles.

VIII. MODULE 108

1. ALARA DESIGN REVIEW

This lesson provides guidance to the design engineer to determine through a dose assessment if an ALARA design review should be performed, and to incorporate radiation and contamination reduction considerations into a design or modification.

A. Objective.

Participants should demonstrate the application of ALARA principles in design reviews.

B. Definitions.

An ALARA design review is a systematic review of the design, modification, or construction of equipment and facilities to ensure that ALARA considerations are evaluated, incorporated if reasonable, and documented.

C. Requirements for ALARA Designs.

Part 835.1001 requires that engineered features and administrative controls be used for facilities and equipment to keep radiation exposures in controlled areas ALARA.

D. Phases.

The ALARA design review is conducted in five discrete phases:

1. Dose assessment.

2. Determination of need to conduct or not to conduct.

3. Selection of reviewers or review team.

4. Selection of criteria and conduct of review.

5. Documentation of the ALARA process.

2. DOSE ASSESSMENT

A. Initial Dose Assessment.

The first step in the ALARA Design Review is to perform an initial dose assessment, if this has not already been done in the course of design.

B. Information for Determining Dose.

The information should be supplied to the radiological engineer (or another qualified person on the project) as early as possible in each design stage even though some of this information will be tentative or sketchy in the early stages of the project. Include such details as:

1. Layouts and location diagrams;
2. Number and types of workers in each known or possible radiological area associated with the facility or system;
3. Nature of each task workers are to do;
4. Time spent by each worker on each task;
5. Paths to and from the radiological area(s) and the transit time;
6. Physical features such as ladders, manholes, hoods, etc.; and
7. Any dose rates, radioactive source strengths, and shield thicknesses, and the like that are known or recommended by a vendor.

   The above information will allow the radiological engineer (or other qualified person), with the help of other radiation protection personnel, to estimate doses and dose rates associated with the project.

C. Detailed Dose Assessment.

During later stages of the project, when the details of the design are known, a more detailed dose estimate may be performed.

1. At this point, it may prove to be of value to perform a walkdown of the installation with construction and radiological personnel. This will aid in the estimation of the installation dose, as well as scoping and planning installation.

2. Detailed dose information is needed for selection of design alternatives or to determine if the cost to incorporate an ALARA consideration is cost-beneficial.

3. The detailed dose assessment involves identification and estimation of the dose for the work tasks that involve radiation exposure for operation, maintenance, inspection, and installation of the equipment, similar to the initial dose assessment.

3. IS AN ALARA DESIGN REVIEW REQUIRED?

Following the initial dose assessment, the cognizant engineer should determine if an ALARA design review should be conducted. This is a two-step process.

First, the engineer or planner must determine if the facility design or design change involves work on a radioactive or potentially radioactive system. If not, an ALARA Design Review need not be performed.

Then the engineer or planner should use the information from the dose assessment to answer questions such as these:

1. Will this design change create a new radiological area or increase the exposure from an existing source?

2. Will this design change create or increase routine maintenance, operations, or inspection requirements in an area?

3. Will this design change cause workers to receive a total of 1 rem per year or greater?

If any of these criteria are met, additional occupational dose will result from the design change, and a review of design features that can reduce dose and the spread of contamination should be initiated.

If the answer to all three questions is “no,” an ALARA design review need not be performed. However, this determination should be documented.

For those design changes where there is one-for-one replacement of equipment or if the design change does not present the practical opportunity to incorporate dose reduction improvements or ALARA considerations, the ALARA design review need not be performed.

4. ALARA DESIGN REVIEW TEAM

The material below is included as an example of the Team Member process and conduct of an ALARA Design Review. Site-specific information should be substituted where applicable.

A. Key Personnel.

For a review of a simple facility or process, a radiation protection or ALARA representative may provide the review. The radiation protection and/or ALARA representative(s) should be qualified to provide an overall review of the facility design and should evaluate and approve the completeness of the designed safeguards, including redundancy, fail-safe features, interlocks, and alarms. However, for an extensive and complex review, other disciplines must be involved. The scope of the review should be determined either by procedure or by the project manager in consultation with radiation protection personnel. Others who may participate include:

1. Design Team: the group of people providing input into the project. It is composed of members from all appropriate engineering and other technical disciplines and should include a radiological member with safety expertise such as a radiological engineer or ALARA engineer.

2. Contributor Group: other groups who may not provide formal design input to the project but whose comments and suggestions are considered relevant to the project, such as:

   - X Maintenance,
   - X Production, and
   - X Research groups.

   Both the members of the design team and representative members of the contributor group should participate in the ALARA Design Review, even if some of the latter may not be trained in the ALARA design review process.

3. ALARA Review Coordinator: ALARA engineer, radiological engineer, or even a qualified operations representative who with other project and safety personnel will provide radiological input to the project. The ALARA Review Coordinator, together with the project engineer, is responsible for seeing that the ALARA Review is performed, completed, and documented.

5. SELECTION OF CRITERIA AND CONDUCT OF ALARA DESIGN REVIEW

The following methods are suggested as a practical way of accomplishing and documenting the review. A simplification of this process is appropriate for small, uncomplicated projects and system modifications.

A. Stages Recommended for Review.

An ALARA Design Review should be performed at each important stage of design or modification of a facility, building, or system, unless there is no radiologically significant change between stages (see PNNL-6577).

B. Radiological Design Criteria.

In conjunction with production of the Functional Design Criteria, the radiological engineer may produce, at her/his discretion and depending on the size of the project, either a set of Radiological Design Criteria or a memorandum containing radiological design considerations. This will be used by the design team beginning at the Conceptual Design Stage, and it should be updated in subsequent stages.

C. Minimum Criteria.

During the review, the review team should assess the features of the design against the Radiological Design Criteria and other applicable criteria to determine whether provision of an ALARA working environment is ensured. The review team should review the facility operation plan and determine if the radiological engineer has done a complete assessment of potential dose.

In the following review processes, different alternatives should be identified, differential costs and dose should be estimated, and cost-benefit analyses conducted to evaluate the alternatives.

1. Show that the public and facility personnel are protected from hazards associated with the use of radioactive and other hazardous materials as a result of:

   – Normal operations,
   – Anticipated operational occurrences, and
   – Design basis accidents.

2. Protection should be provided for normal operation and for those accidents that can be anticipated as occurring during the facility lifetime, such as radioactive material spills and small fires involving radioactive materials.

3. Review the general facility layout, considering traffic patterns, radiation zoning, change room location and size, adequacy of personnel decontamination facilities, location of fixed survey equipment, and provision of adequate space for anticipated maintenance needs.

4. Verify that the ventilation system design provides the required level of protection from airborne contamination, with particular attention to air flow patterns and locations of air inlets and exhausts.

5. Evaluate and confirm the adequacy of specific radiological control devices for reducing occupational exposures, including hoods, gloveboxes, shielded cells, decontamination areas, and remote operations.

6. Verify that shielding is adequate to support ALARA operation of the facility, system, or component.

7. Assess the adequacy of planned radiation monitoring and nuclear criticality safety instrumentation, including whether the proposed instrumentation is appropriate for the radiation types and intensities, and whether it has suitable redundancy and capability for operation both under normal operating conditions and in emergency situations.

8. Radiological requirements and ALARA considerations should be balanced against the total risk, including industrial safety and industrial hygiene requirements. The requirements must also be balanced with operational productivity.

D. Design Basis.

Occupational exposure to radiation should be limited according to 10 CFR 835. This primarily addresses the way people operate and use existing facilities and sites. Designs for new facilities and major modifications to existing facilities should be based on the following additional radiological control design criteria:

1. Individual worker dose in frequently occupied areas should be ALARA and less than 500 mrem per year;

2. Discharges of radioactive liquid to the environment are covered by provisions in DOE Order 5400.5, and other regulatory documents, and should not degrade the ground water;

3. Control of contamination should be achieved by containment of radioactive material;

4. Efficiency of maintenance, operations, decontamination and decommissioning should be maximized;

5. Components should be selected to minimize the buildup of radioactivity; and

6. Support facilities should be provided for donning and removal of protective clothing and for personnel monitoring, where appropriate.

E. ALARA Design Review Checklist.

(Insert facility-specific checklist.)

To serve as an aid in performing the ALARA Design Review, a checklist such as the one in Appendix D may be used.

The first part is a list of preliminary questions called "First Level Screening Questions" which identify appropriate questions from the main checklist.

The second part is the main checklist, a series of questions grouped by subject.

The last part is a disposition sheet on which individual answers may be discussed and resolutions may be recorded.

F. Performing the Review.

(Substitute facility-specific information as applicable.)

Near the end of each stage, the ALARA Design Review for that stage will take place.

Each ALARA reviewer may obtain a copy of the ALARA Design Checklist and fill it out according to her/his knowledge of the project. If the reviewer recognizes any issues of potential radiological impact not covered by the checklist, these issues should be noted on an attached sheet.

G. Existing Features and Non-radiological Additions.
The review is to consider not only new or newly added features, but also existing features which might be affected. The impact of non-radiological additions on radiological items must be considered.

H. Optimization Analysis.
As part of the design or modification, an optimization analysis may have been performed. This should also be examined in case anything has changed in the course of the design. However, the ALARA Design Review may show the need for an optimization analysis as well, and this analysis may be done as part of the review. Optimization is covered in Module 110.

I. Completed Review.
(Substitute facility-specific information, as applicable.)

When each reviewer has filled out the checklist, it is sent to the ALARA Review Coordinator.

6. DOCUMENTATION AND APPROVAL

A. Review Documentation.
(Substitute facility-specific information, as applicable.)

When all comments are returned, the ALARA Review Coordinator makes a final resolution of all comments and issues a memorandum report.

The report lists all reviewers, describes the areas covered, summarizes the conclusions of the Design Review, highlights any conflicts, and gives any recommendations the ALARA Review Coordinator may have.

B. Review Approval.
(Insert facility-specific information.)

The report (with associated documentation) may then be reviewed and approved by the site Radiological Control Manager (RCM) or Radiological Engineering Manager (REM), if she/he elects to do so.

The written waiver of review and approval by the RCM/REM constitutes approval of the project ALARA design.

C. Copies of the Report.
(Insert facility-specific information.)

Copies of the report (with associated documentation) should also be sent by the ALARA Review Coordinator to relevant management and technical review committees, and to appropriate health and safety groups. The ALARA Committee(s), who may also need to review the design, should be sent copies.

IX. MODULE 109

1. ALARA OPERATIONAL REVIEWS

A. Objective.

Participants should demonstrate the application of ALARA principles in operations.

B. Definitions and Purpose of Review.

An ALARA operational review (sometimes referred to as an ALARA job/experiment review) is a systematic pre- and post-job review of activities within the potential for significant dose, contamination, or airborne concentrations to ensure that ALARA controls are planned, evaluated, implemented where reasonable, and documented. An ALARA operational review serves to document the use of ALARA and to show any compromises or adjustments made in balancing ALARA against operational, practical, and other considerations.

C. Requirements.

10 CFR 835.1003 requires that during operations, the combination of engineered controls and administrative controls shall ensure that the total effective dose equivalent does not exceed 5 rem in a year and that the ALARA process is used.

2. WHEN TO PERFORM A REVIEW

A. Operational Review.

An Operational Review can be done when required by procedure or requested by the operational group, facility manager, ALARA Committee, or other groups such as the Facility Review Committees. Reviews should also be performed if the site-specific trigger levels (as identified in articles 312.3 and 312.6 of the RadCon Standard) are exceeded.

In addition, an ALARA review should be performed for the following cases:

1. Non-routine jobs, operations, or campaigns in which any individual might receive a dose of 100 mrem or more, or where there is any uncertainty in the predicted dose;

2. Routine jobs, operations, or campaigns in which any individual might receive as much as 300 mrem;

3. Any job or operation in which the collective dose is expected to exceed the site-specific trigger level;

4. Any job, operation, or campaign in which any individual might exceed an administrative dose level (e.g., 2,000 mrem /yr);

5. Any job, operation, or campaign in which the dose to an individual might cause the ALARA goal of the facility, the division, or the work group to be exceeded; and

6. Any job, operation, or campaign in which airborne levels may potentially exceed 10 percent of the DAC.

7. Any job, operation, or campaign in which there is a potential for significant levels of contamination to be present.

B. Operational Review Versus Radiological Work Permit (RWP) and Prejob Briefing

The operational review is conducted in addition to the Radiological Work Permit (RWP) preparation (which may be required by procedure), or it can be part of it. A simplification of this process would be appropriate for small, uncomplicated operations; for example, the RWP preparation could satisfy this review if all areas required to be considered in both are covered, and appropriate operational reviewers are consulted.

Also, the operational review could support RWP preparation or the reviews to be done by operating division personnel, as required by procedure.

An operational review is not the same as the prejob briefing, since in the review, the planners are collecting and evaluating information on the final, agreed-upon plan for the work. At the end of the review, changes may remain to be made, while at the end of the briefing, everybody should understand what to do. However, for smaller jobs, the two could be combined provided that any concerns are fully evaluated and resolved before work begins.

3. PERFORMING AN OPERATIONAL REVIEW

A. Conduct of the Review.

The following method is suggested as a practical way of accomplishing and documenting the review. A simplification of this process is appropriate for small, uncomplicated projects. Usually representatives of the group managing the operation or job, worker groups, and the radiological control organization should participate.

To serve as an aid in performing an ALARA Operational Review, an ALARA Operational Review Checklist is provided in Appendix E.

B. Documentation of the Review.

The review should be documented appropriately, usually by a written statement that a review was performed and by incorporation of the selected controls into the RWP and work documents. The documentation should be kept in either the appropriate job or operation file or in the radiological control organization's ALARA files, consistent with the requirement that records of ALARA decisions be retained (10 CFR 835).

X. MODULE 110

1. OPTIMIZATION ANALYSIS

A. Objective.

During the presentation of Module 110, participants will demonstrate the application of optimization techniques by actively participating in the group exercises.

B. Definition.

"Optimization" may be defined as arriving at an optimal solution to a problem or selecting the best from among the available alternatives, in accordance with a given analytical method.

C. Purpose of Optimization Analysis.

The purpose of an optimization analysis is to show that the expense (in terms of money, person-hours, dose to install and maintain, etc.) of a project or feature of a project is justified in terms of the benefit received. This is in accordance with the idea of balancing ALARA considerations against technological, social, operational, and economic considerations.

D. Regulations and Guidance for Optimization.

1. 10 CFR 835.1002(a), Occupational Radiation Protection.

   "Optimization shall be used to assure that occupational exposure is maintained ALARA in developing and justifying facility design and physical controls."

2. DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

   DOE 5400.5 requires that "...contractors develop a program to implement the ALARA process for all activities that cause dose to the general public." Furthermore, DOE 5400.5 states that "...Factors to be considered, at the minimum, shall include:

   a. The maximum dose to the public;

   b. The collective dose to the population;

   c. Alternative methods of processing, treating, controlling, and operating radioactive effluent systems;

d. The dose associated with each alternative;

e. The cost for each technological alternative;

f. Examination of the changes in costs associated with the various alternatives; and

g. Examinations of the changes in societal impact associated with the various alternatives.

3. ICRP 55, "Optimization and Decision-Making in Radiological Protection."

   ICRP 55 states that "...optimization provides a basic framework of thinking wherein it is proper to carry out some kind of balancing of the resources put into production, and the level of protection obtained against a background of other factors and constraints, so as to obtain the best that can be achieved in the circumstances."

4. The RCS, Article 312, addresses major and minor activities.

5. PNL-6577, "Department of Energy, Health Physics Manual of Good Practices for Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)."

   PNL-6577 gives guidance on how to perform cost-benefit analyses.

2. OPTIMIZATION METHODS

A. Informal Analysis.

There are various ways to determine whether a design or operation is optimized. One is a consensus recognition by the ALARA engineer and others on the design or operation team that a particular project or feature of a project justifies the cost in terms of dose, money, work-hours, and operational adjustments required to produce the project. Such a project or feature can be termed "patently advantageous" as regards ALARA. This conclusion should be documented.

B. Other Considerations.

Often, however, the justification for the design, design feature, or operation is not so clear-cut. Then a more rigorous optimization must be done to demonstrate that the project is optimized by the design, the inclusion of the design feature, or the plan of the operation. This is particularly true if there are alternatives to the design, feature, or operation, and if “doing nothing” (status *quo*) is one of the alternatives.

C. Formal (Analytical) Optimization Analysis.

In formal (analytical) optimization analyses, one must express the value of all resources, including dose, in commensurate units, or rank them in some consistent way, or both. Usually the value expression is done by assuming a dollar value for each parameter, including dose.

A formal optimization typically consists of a Cost-Benefit Analysis (CBA). In the CBA, all of the items to be considered must be expressed in the same units, usually dollars. Because of that reason, a dollar value must be given to the dose saved. DOE has specified that this value be determined on a site-by-site basis. The NRC uses a value of $2000 per person-rem.

The net benefit of a feature, system, or method is then determined by subtracting the costs of production, radiation protection, and dose from the gross benefit. Using this methodology, the net benefit can be determined for several alternatives and compared to determine the optimal choice.

See Appendix F for further details regarding the CBA, including examples.

(Part 4 of 5)

ALARA Training for Technical Support Personnel

Appendices

Coordinated and Conducted
for
Office of Safety, Health and Security
U.S. Department of Energy

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APPENDIX A - APPLICATION OF ALARA TO FACILITY SYSTEM DESIGN

I. AIRBORNE RADIOACTIVITY AND HVAC SYSTEM CONSIDERATIONS

Ventilation systems deserve separate ALARA considerations because of the possibility of increased doses due to internal uptake of airborne and surface contamination. Routinely requiring workers to wear respiratory devices is not the preferred solution to reducing internal deposition of airborne radioactive materials.

The facility ventilation system(s) are a major means for controlling airborne radioactivity levels in occupied areas under both normal and abnormal conditions.

A. Essential Features.

Ventilation systems have two tasks: to direct airborne radioactivity away from personnel and to provide an adequate method to capture any airborne radioactive materials that are accidentally released. To attain these objectives, ventilation systems usually incorporate two essential features:

1. Appropriate differential pressure (DP) between ventilated areas and outside areas, and

2. High-Efficiency Particulate Air (HEPA) filtration.

B. Area-Specific Requirements.

Similar areas do not always require identical ventilation characteristics, especially differential pressure and filtration. Ventilation design criteria need a measure of flexibility since conditions may change as work changes and since local or portable ventilation may be effective at reducing local airborne radioactivity levels significantly.

C. Eliminate/Reduce Airborne Sources.

To ensure control of airborne radioactivity, design for the following as appropriate:

1. Properly seal and pressurize equipment and ducts with continuously welded seams and flange gaskets.

2. Leak-test HVAC equipment after installation and repair.

3. Select filters appropriate to the operation and radionuclides present (e.g., charcoal filters are good for iodine, but they don't last as long if they get loaded with non-radioactive particulates and dust; you may also need a prefilter for dust and/or a HEPA filter for particulates).

4. Provide differential pressure detectors across filters to monitor dust loading.

5. Avoid open-topped tanks or tanks with vent lines lower than tank overflow lines.

6. Generally avoid hard-piping tank vents directly to ducts if the tank may become pressurized.

7. Use good contamination control practice in designing for such tasks as filter change-out, wet layup of equipment, and machining contaminated parts.

8. Use water for back flushing and unplugging in preference to compressed gases.

9. Properly place and seal penetrations, gratings, openings, etc., which are open to areas of potential airborne radioactive materials.

10. Specify sealed bearing motors with the motor mounted external to the exhaust.

11. Provide intake air filters to minimize exhaust filter loading and dust accumulation in radiological areas.

12. Provide drains and/or dryers and/or moisture separators upstream of filters and charcoal beds.

13. Provide auxiliary or temporary ventilation systems for sampling stations used to sample highly radioactive fluids (e.g., reactor primary coolant) and for repair of equipment that when opened, has a potential for airborne releases. (Consider both temporary ductwork attached to existing systems and independent, portable HEPA-filtered ventilation systems.)

D. Air Flow.

A system of differential pressure should be used to direct the flow of any airborne radioactive material that escapes containment.

1. Room air may be recirculated if adequate filtration and monitoring are provided.

2. Direct air flow from areas with no or less potential contamination to areas with greater potential for contamination.

3. Primary confinement shall always have the least pressure in a facility (relative to the outside atmosphere).

4. A gradient should be established, on a facility and room basis, so that the lowest pressure and exhaust collection points are located in areas with potentially dispersible material.

5. Ducts carrying potentially contaminated air should be at a negative pressure when passing through a clean area.

6. Locate ventilation supply points above the worker or work area and away from the sources of contamination, or otherwise place as appropriate for the work activity (e.g., for work tables, gloveboxes, and hoods).

7. Avoid drawing contaminated air across walkways, doorways, entrances, work areas, and, especially, breathing zones.

8. Locate ventilation exhausts near the floor and away from entrances or openings to clean areas.

9. Locate ventilation fans as close as possible to the discharge, downstream of filters so as to avoid contaminating the fans and pressurizing the filters.

10. Exhaust through a filtration system from areas with greatest potential for contamination.

11. Minimize the number of elbows in ventilation ducts to reduce the plateout of radioactivity and to reduce flow losses. Alternatively, consider flow straighteners.

12. Size ducts and fans to have high enough flow rates to reduce plateout.

13. Select smooth materials or consider coating inner surfaces to reduce plateout.

14. Ensure that the opening of doors and removal of shield plugs does not disrupt proper air flow.

15. Provide connections to attach temporary ventilation systems where additional ventilation flow may be needed.

16. Design ventilation so as to minimize the use of respirators.

17. Use airlocks where appropriate.

E. Filtration Systems.

1. Select proper type, size, and quantity of air filtration devices.

2. Locate filters as close to the source as possible and upstream of any fans to reduce contamination buildup in ductwork and fans.

3. Provide roughing filters upstream of HEPAs, and HEPAs upstream of charcoal filters.

4. Provide flushing ports and drains for decontamination of filter housings and ventilation ducts.

5. Place filters for highly contaminated ventilation systems in shielded housings and locate filter banks in low-occupancy areas.

6. Design filter housings and filters so that filters can be removed remotely or quickly in the event of an incident.

F. Maintenance.

1. Design ventilation systems for ease of maintenance, inspections, testing, and operations.

2. Locate ventilation motors in low-dose-rate areas whenever possible.

3. The proper design of the ventilation system permits filters to be changed easily and with a minimum potential for the release of radioactivity and worker exposure.

4. The design shall provide the capability for in-place testing of the filtration system.

G. Monitoring.

1. All airborne and potentially airborne radioactivity areas shall be vented to a monitored release point.

2. The design should allow for continuous particulate sampling before the first testable stage and after the last stage, to provide direct evidence of filter performance.

3. Areas with a high potential for airborne radioactivity may require sampling between intermediate stages to verify the performance of each stage.

H. Emergencies.

1. Key ventilation systems in a radiological facility must be provided with emergency power to assure continued operation if normal power is lost.

2. Ensure adequate air flow throughout the area to provide quick cleanup of air during spills or leaks.

II. CONTAINMENT CONSIDERATIONS

A. Containment.

A containment is an area enclosed by a set of barriers. These can be passive barriers, like walls, or active barriers, like valves and ventilation flow.

1. The primary containment is the barrier or set of barriers most intimately in contact with the radioactivity.

2. The secondary containment encloses the primary and receives and handles any leakage from it.

3. A tertiary containment may also need to be provided.

One constraint on defining these is that it usually must not be possible for a single failure to compromise two containments at once (e.g., a primary and its secondary).

B. Primary Containment.

Containment is a way of thinking about a system configuration at a given time or in a given mode of operation, as well as having a physical meaning. For example, for a tank containing radioactive liquid, the tank itself is the primary containment, together with its intake and outlet piping up to the nearest isolation valves. When these valves are open, the primary containment extends to the next valve and so on. Also, a tank farther along may be a separate primary containment but can be considered, while the valves between it and the first tank are open, to be an extension of the first tank and, therefore, part of a single primary containment.

C. Secondary Containment.

The room(s) or vault enclosing the tank and piping are the secondary containment and should be so designed; the outer wall of a double-walled tank may be the secondary. The building itself may be the tertiary containment.

D. Gloveboxes.

Gloveboxes and other handling enclosures are primary containments when radioactivity in them is not completely enclosed or is enclosed in containers that cannot be assumed to be well sealed. Gloveboxes are secondary containments when the radioactivity is actually contained in a piping system, vessel, instrument, etc., inside the box. In the latter case, the room may be designed as the tertiary containment.

E. Primary Containment Penetrations.

Primary containment penetrations must be carefully laid out and minimized in number and size. They should be carefully sealed with regard to radiation streaming, air-flow control, fire protection, and flooding as applicable. Permeation of these seals should be considered. Transfer ports for passing items in and out should, in general, be airlocks or mini-airlocks, with purging capabilities.

F. Isolation Systems.

A principle of good confinement is good isolation; systems with widely differing levels of actual or potential radioactivity content should be isolated from one another by check valves or other reverse-flow control devices. Pressure relief devices should be required, and leak detection devices should be provided as appropriate to the process.

G. Check Valves.

Check valves on tritium systems leak when closed and don't provide good confinement.

Because check valves have problems, they are often used in pairs. Their good points cause them to be extensively used, but they must be used wisely.

III. MECHANICAL SYSTEMS CONSIDERATIONS

This section discusses six areas: piping, valves, pumps, filtration, tanks, and heat exchanger systems.

A. Piping and Tubing.

The following guidance should be applied in piping and tubing design.

1. Eliminate/Reduce Radiation Sources

   a. Route piping to minimize the length and number of pipe fittings and bends.

   b. Tee branch piping above the main flow piping or slope the teed branch upwards.

   c. Design piping to avoid dead legs and minimize tees.

   d. Provide a continuous slope on the piping to prevent backflow and settling of crud.

   e. Provide smooth surfaces to avoid crud traps and facilitate decontamination and flushing.

   f. Use materials with low nickel and cobalt content for reactor facilities or other facilities where neutron activation may occur.

   g. Route piping carrying highly radioactive fluids away from equipment requiring frequent maintenance.

2. Eliminate/Reduce Contamination Sources

    a. Segregate radioactive and non-radioactive piping.

    b. Provide adequate controls to prevent and/or detect cross-contamination of clean non-radioactive systems.

    c. Plumb pipe and leakage to floor drains and vents to ventilation ducting, where possible. But beware of pressurization that may send liquid or solid materials out of vents.

    d. Select piping and components that will maintain containment over the environmental qualification range to prevent release of radioactivity to the offsite environment.

    e. Avoid the field routing of piping that transports radioactive materials.

3. Maintenance

    a. Select low-dose-rate areas for installation whenever possible.

    b. Provide adequate vents and drains to allow for system testing, maintenance, and operation.

    c. Use consumable inserts for welding in lieu of backing rings for pipes carrying radioactive materials.

    d. Use butt welds rather than socket welds for pipes >1.5 inches. If a choice of welds is given in the welding specifications and if it is for a highly radioactive system, use a butt weld.

    e. Specify pipe bends of at least five pipe diameters in radius for the transfer of resin and sludge.

    f. Provide remote methods to unclog drain lines.

    g. Specify removable pipe insulation in areas where welds require in-service inspection.

h. Provide connections on piping and components to allow flushing, hydrolazing, or chemical decontamination on piping that contains resins, sludge, or highly radioactive fluids.

B. Valves.

Since operation and maintenance of valves are two of the major contributors to workers' dose, the design engineer should apply the following guidance:

1. Eliminate/Reduce Radiation Sources

a. Install valves with stems in the upright position to minimize crud buildup.

b. Select valves with internal surfaces and configurations that minimize crud buildup.

c. Use materials with low nickel and cobalt content for reactor facilities or other facilities where neutron activation may occur.

d. Provide steps in installation procedures to control stellite filings that are in valve internals (e.g., dams and/or vacuuming after grinding for reactor facilities or other facilities in which neutron activation may occur).

2. Eliminate/Reduce Contamination Sources

a. Provide packing and seals that result in minimal contamination leakage and maximum reliability.

b. Consider packless valves or those using live-loaded packing; valves above 2.5 inches should generally have double packing and a lantern ring.

c. Locate valves away from low points in piping.

d. Provide check valves to prevent radioactive fluid backup.

e. Provide catch pans, floor and equipment drains, or curbing under valves that have a significant potential for leakage.

f. Separate valves carrying highly radioactive fluids from associated equipment and components.

g. Consider future decontamination when providing isolation valves for fluid systems.

3. Maintenance

a. Select valve materials that are compatible with contact materials.

b. Locate valves in low-dose-rate areas whenever possible.

c. Provide remote operators or reach rods for valves located in areas of elevated dose rates.

d. Locate valves in an area with adequate work space to provide easy maintenance, inspection, and operation.

e. Consider maintenance requirements on valves, operators, and reach rods (e.g., select those that are easily removed).

f. Generally provide flanged connections on valves that may require removal from the radiation areas (e.g., pressure relief or isolation valves) however, welded connections may be preferable in some cases.

g. Provide rigging and lifting points for heavy valves requiring removal for repair or inspection.

C. Pumps.

Pump design should include the following considerations:

1. Eliminate/Reduce Radiation and Contamination Sources

a. Provide a mechanism to flush seals on pumps carrying highly radioactive fluids.

b. Install catch pans or curbing around pumps that transport radioactive fluids and have a significant potential for leakage.

c. Provide drain connections on pump casings as well as smooth surfaces on impellers.

2. Maintenance
   a. Consider maintenance requirements on pumps, such as access and pull space for the motor shaft.

   b. Provide rigging and lifting points for heavy pump parts requiring removal for repair or inspection.

   c. Provide flange connections to facilitate removal of pumps located in areas of elevated dose rates to facilitate removal.

   d. Select pumps with mechanical rather than packing seals (canned-rotor pumps or magnetic-driven pumps).

D. Filtration.

Maintenance, inspection, and operational requirements for filtration/cleanup systems as well as shielding and isolation of highly radioactive systems must be considered.

1. Eliminate/Reduce Radiation Sources

   a. Provide filters upstream of deep-bed demineralizers to extend resin life and thus reduce radioactive waste volume.

   b. Provide strainers downstream of filters and demineralizers to entrain stray fines.

   c. Lay out demineralizers and resin storage components to assist resin flow and minimize piping (straight runs of piping with a minimal number of elbows).

   d. Provide filters and strainers that are back-flushable.

   e. Provide back-flushing capabilities sufficient to relieve plugged lines in resin slurry piping.

2. Eliminate/Reduce Contamination Sources

   a. Provide containment or ventilation to prevent spread of contamination during filter, strainer, and resin changes.

b. Provide screens, filters, or other catch devices over resin or sludge overflows and vents.

3. Dose Rate

a. Isolate or shield filtration systems that contain high radioactivity.

b. Locate filtration systems in low-occupancy and low-traffic areas.

4. Maintenance

a. Ensure that filters, strainers, evaporators, ion exchangers and routinely serviced items are compatible with existing equipment.

b. Ensure that filters, strainers, and evaporator tubes are easily removable and adequate space is provided.

c. Provide space for pallets to support temporary decontamination equipment that chemically cleans the system.

d. Provide remote methods for draining filter housings on systems processing offgas and radioactive water.

e. Provide remote and/or shielded methods for replacement of hot filters, strainers, and resins.

f. Provide flush connections that will facilitate high-velocity chemical flushes.

E. Tanks, Sumps, and Floor and Equipment Drains

1. Radioactive Material Handling Equipment

Choose radioactive material handling equipment carefully. Consider decontamination and eventual decommissioning. Apply the following design guidance.

a. Never undersize a tank used for holding radioactive material.

b. Select tanks with sloped or dished bottoms to facilitate flow/draining and to eliminate corners as potential low-flow areas where crud may accumulate.

c. Install top mixers, spargers, or spray systems as appropriate to mix the contents for transfer and representative sampling, and for decontamination prior to inspection or maintenance.

d. Ensure overflow lines are lower than the tank's vent.

e. Provide screens or strainers on tank vents and overflow for tanks containing resin or sludges.

f. Provide a slope from tank, drain, and sump bottom to outlet.

g. Provide curbing or other containment to restrict spread of leakage.

h. Locate radioactive material tanks and sumps in low-occupancy and low-traffic areas or shield to reduce personnel dose.

i. Locate tanks containing high radioactivity in shielded tank farms or cubicles.

2. <u>Transfer Systems.</u>

Prevent plugging in transfer systems:

a. Avoid long vertical runs ending in a turn to the horizontal, which may lead to plugging.

b. Reduce crud deposition by using pipes with at least 1-1/2 inch diameter, long bend radii, no right-angle bends, and sloping runs.

c. Choose full-ported valves, especially when the stream has a high-solids content.

d. Provide turbulent flow to maintain homogeneity and keep solids in suspension.

e. Choose full-ported valves when the fluid has a high solids content.

f. Consider automation of valve operation so that flow does not stop after a backwash or pre-coat.

g. Provide a "recirc" line to ensure good mixing before transfer.

h. Interior surfaces should be smooth and free of pockets to facilitate transfer and decontamination.

i. When transporting liquid radioactive waste by pipes, the pipe route should be isolated from uncontrolled areas.

j. Locate transfer lines in low-occupancy and low-traffic areas.

3. Maintenance/Decontamination

a. Provide adequate space for maintenance and repair of tank support equipment (e.g., pumps, agitators, gear boxes, etc.).

b. Select preferred cleaning methods. Hydrolazing is preferred to air blowout, which is preferred to rodding out. Screens or filters should be provided when using air blowout. Stringent contamination control measures should be used during rodding out.

c. Avoid lap joints and backing rings on welds.

F. Heat Exchangers, Moisture Separators, and Heaters.
Modifications or replacement of heat exchangers carrying radioactive fluids should consider the following:

1. Eliminate/Reduce Radiation and Contamination Sources

a. Provide drains at low points to facilitate flushing and cleaning.

b. Design vessels to reduce crud traps in those areas that require access during inspection and cleaning.

c. Select the proper material for the operating environment to minimize corrosion (e.g., titanium tubes for brackish water).

d. Orient heat exchangers in the vertical position, where feasible, to reduce deposition along the length of it.

e. Maintain radioactive fluids at lower pressures to ensure that leakage would be from the non-radioactive side into the radioactive side.

f. Provide curbing and drains to contain radioactive fluids during repair and cleaning.

2. Dose Rate

a. Pump fluids with the higher concentration of radioactivity inside the tubes to utilize the water in the shell as shielding.

b. Place heat exchangers that are expected to be highly radioactive inside shielded cubicles.

c. Provide adequate space to allow for removal and cleaning of the tubes and shell.

IV. ELECTRICAL POWER SYSTEM CONSIDERATION

The ALARA design considerations that follow are geared toward the power systems engineering discipline:

A. Routing/Location

1. Perform walk downs or utilize photographs in low-dose-rate and low-interference areas to aid in locating conduit runs.

2. Route cable and conduit in low-dose areas.

3. Evaluate routing of electrical cabling through potentially contaminated areas in light of installation doses and accessibility requirements.

4. Locate breaker boxes, power control centers, and electrical cabinets in low-dose rate areas.

5. Physically separate local control and alarm stations from associated electrical equipment located in areas of elevated-dose rates.

B. Maintenance

1. Select long-life bulbs to decrease maintenance time in radiation and contamination areas.

2. Select electrical equipment with features that minimize inspection, calibration, testing, and preventative maintenance (e.g., quick disconnects).

3. Select high-quality electrical equipment with proven reliability records and low maintenance requirements.

4. Provide external access for fault location determination capability for those electrical systems that are difficult to inspect or troubleshoot.

5. Prefabricate conduit, supports, brackets, cable trays, junction boxes, and other electrical components to be installed in areas of elevated-dose rates.

6. Provide sufficient electrical outlets for air-sampling devices as well as for electrically operated maintenance tools, welding machines, and temporary power distribution boxes.

7. Provide adequate lighting as well as provisions for supplemental temporary lighting.

8. Ensure that the conduit and electrical equipment do not interfere with the maintenance or operations of nearby equipment.

V. SAMPLING, MONITORING, AND INSTRUMENTATION

A. Sampling.

It is important that the sample is representative of the material sampled with respect to location, physical state, and chemical composition.

Therefore, avoid having the sample deposit inside sample lines and equipment because it and subsequent samples might then be unrepresentative. The design engineer should apply the following guidelines to ensure representative sampling.

1. Follow the guidelines for reduction of crud deposition, especially considering the reactivity of the line material with the sample. For example, plastic piping may be best in many

cases because of low-chemical reactivity but may not be suitable for airborne particulates due to static charge buildup.

2. Provide sample lines that have few bends. Any necessary bends should have a large radius and be able to be isolated and flushed.

3. Provide a strong and continuous purge of sample lines in high-radioactivity systems.

4. Consider very carefully the proper flow velocity in the system, given the physical and chemical characteristics of the stream.

5. In gaseous systems, ensure continuous flow or well-tracked flow (consider flow meters, totalizers, constant-flow regulators, and recorders).

B. Sampling Station

The following design criteria is applicable to radioactive material handling areas.

1. Make sure any ventilation hoods have a face velocity of 100-150 linear feet per minute with the hood window in its full open position.

2. Direct ventilation hood exhaust to the facility vent upstream of the filters.

3. Route any sink drains in sampling or radioactive material handling areas to radioactive waste or retention tanks. Sinks should be free of any potential crud traps.

4. Construct or coat sinks and surfaces of sampling areas with materials that are easily decontaminated.

5. Separate or shield sampling stations from other radioactive components.

6. Provide adequate shielding or separation for high dose rate activities.

7. Minimize potential for cross-contamination of non-radioactive systems.

C. Monitoring.

Sufficient and carefully chosen radiation and air monitors should be provided to cover all areas where there is a potential for dose rates or airborne concentrations to exceed the limits of the respective areas. The design engineer should apply the following guidelines for selection and location of monitors.

1. Make sure that there are no obstructions or blocking of any monitor.

2. Provide methods to perform remote sampling and monitoring for airborne radioactivity, where appropriate.

3. Locate process and effluent monitors to provide enough detection lead time so as to divert or isolate a process stream, if that is their function.

4. Provide manual friskers, portal monitors, and half-body contamination monitors in suitable locations. Be sure to provide services for them; for example, a gas-flow proportional counter needs room for its gas bottle and, perhaps, storage for another nearby.

5. Make sure that all airborne monitors are able to detect 8 DAC-hours (under laboratory conditions) as recommended by the Radiological Control Standard.

6. Make sure that all monitors have circuitry that automatically can detect monitor failure and indicate whether the dose rate is off-scale.

7. Provide readouts and alarms that are local, remote, or both, as appropriate (make sure the alarms are both visible and audible where required).

D. Instrumentation.

The ALARA design considerations that follow apply to the instrumentation and control systems disciplines.

1. Select instruments that contain minimal quantities of contaminated working fluid and isolate whenever possible by choosing pressure transducers over bellows-type instruments.

2. Follow good practices for crud deposition reduction.

3. Locate instrument tubing taps on the top half of instrument lines carrying radioactive fluids.

4. Locate all instrumentation, except for primary sensing elements, in low-dose-rate areas and provide for in-place calibration from low-dose-rate areas.

5. Locate pagers, telephones, and other communication systems in a low-dose-rate area.

6. Ensure instruments that must be located in areas of elevated-dose-rates are easily removable for remote repair and calibration in a low-dose-rate area.

7. Provide remote viewing of local readout instruments.

8. Select instruments with features that minimize inspection, calibration, and testing functions.

9. Select high-quality sensors with proven reliability records and low-maintenance requirements for monitoring systems.

10. Provide for logical groupings of readout instruments to decrease time needed for surveillance and logging.

11. Consider using computers for automatic logging.

12. Consider using computers for sensor reliability checks or calibration checks (e.g., smart transmitters).

13. Provide adequate warning systems via flashing light, speakers, or siren for high-radiation sources that can change with time.

ALARA Protective Measures Used for D&D

The decontamination, deactivation, decommissioning and demolition of radiological work facilities presents new challenges to personnel who manage, plan, and accomplish work on these facilities. Decisions need to be made early on, what is to be done with each facility. The choice might be to decontaminate a facility, release it from radiological controls and then return it to the public. Another choice might be to remove everything from a facility, apply fixatives to contain contamination and other hazardous products, and then demolish the facility. A cultural change is necessary as everyone learns to make risk-based decisions and how to use new techniques to accomplish the different phases of D&D work.

Personnel who plan and accomplish D&D work are required to implement ALARA protective measures to ensure the workers and the environment remains safe. In the past, most people thought about ALARA as finding ways to reduce dose. In D&D work, most of the emphasis has changed to controlling contamination spread and, instead of minimizing waste, how to deal with the large amounts of waste that can be created. The following information should help personnel understand the new challenges of D&D work.

The use of new and different technology requires different skills for managers and workers. Managers need to look at different options on accomplishing the work and select the best choice. Often times the choice is based on "How much risk are you willing to accept? Managers have to ensure the work can be accomplished without spreading contamination outside posted boundaries.

Characterization of the facility is the first step in identifying the hazards so that planning can proceed using the ISMS process. The characterization establishes a baseline concerning the physical, chemical, and radiological conditions. This provides a technical basis for work and project decisions on cost, risk, and waste estimates.

The D&D of old facilities presents several challenges. Most of the older buildings were not built with D&D in mind. Many are constructed of concrete and some walls may be several feet thick. High levels of fixed and removable contamination may be found throughout facilities. Thousands of feet of piping and ventilation ducting may be encapsulated in concrete or underground. The piping and ventilation may contain residual acids. Some materials may be pyrophoric or be fissile materials. Insulation in older facilities is usually asbestos and other products like lead and beryllium may be present. Existing cranes and other equipment may not be operational. Large equipment may not fit through existing doors, and that means that it has to be size-reduced or the openings enlarged.

Personnel who plan the work and want to implement ALARA protective measures have to become familiar with new processes, tools, equipment and work practices used in D&D work. New skills for workers include:

- Use of new equipment to characterize a facility,
- Use of new decontamination products to decontaminate floors, walls, gloveboxes and other surfaces,
- Use of hand-tools to size-reduce materials so they will fit into waste containers,
- How to apply fixatives to keep contamination from spreading,
- Use of misting to reduce airborne contamination,
- Use of robots, manipulative arms and remote tools to accomplish work in high radiation areas or areas containing high levels of contamination and other hazardous materials,
- Use of video equipment and closed circuit television
- Use of specialized tools such as hydrolasing equipment, thermal cutting techniques, scabbling and expandable foam,
- New methods to package and ship waste, and
- Use of point-source ventilation and containments to reduce contamination spread.

The work practices used to accomplish D&D work can result in the creation of large amounts of Low Level, Mixed, Transuranic and chemical waste. Often, the waste stream dictates how the D&D work has to be accomplished. Waste planning usually starts early and personnel are encouraged to look for "opportunities" to streamline the process or reduce the amount of waste created.

The work practices, tools, and ALARA Protective measures used in D&D work have to ensure that no contamination is spread outside posted boundaries. Workers may need specialized training using the new tools and work practices. New types of protective clothing and respiratory equipment may be required to enter some areas. More attention has to be directed at ensuring workers do not harm themselves during component or building demolition. Often time's workers will be required to wear cut and puncture resistant clothing or clothing that is designed for "hot" work.

Understanding the lessons learned from past D&D projects can help personnel who are trying to implement ALARA protective measures on new projects. See the list below:

- Need detailed review of facility history and locations of past spills, where hazardous materials were stored and actual work was accomplished. Older workers can be consulted to help identify how the facility was operated and the locations of past problems.
- During characterization, it is important that planning personnel understand what isotopes are present and if they behave differently. For example; Tritium contamination may pass through concrete.
- If the work operations generate airborne contamination, the work is normally shutdown until contamination controls are in place to fix the contamination or remote technology used to accomplish the work.
- Decontaminating a facility so that it can be released from radiological controls is time consuming and may require thousands of surveys and samples. It may be

better to "fix" the contamination and demolish the facility using multiple engineered controls.

- The location of a facility affects what measures are taken to accomplish D&D. If the facility is located near a public road, river, or town, less aggressive measures are used to D&D the facility. In addition, if other buildings surround the facility, the number of Project Design choices of measures that can be used, are reduced.
- Facilities undergoing D&D normally have a posted barrier around the facility to isolate the potentially contaminated area from areas with lesser controls. If contamination is detected outside these barriers, it is typically understood that the D&D project is "out of control". During preplanning, a study needs to be done to determine where these barriers need to be placed.
- Base planning on what is "probably" going to happen rather than "worst case". Have contingency plans available though in case the "worst case" happens.
- Whatever options are chosen, they need to be flexible and adapt to changing work conditions. Consider each activity a new and potentially different opportunity.
- Weather conditions will affect the choice of controls used during D&D and can make counting surveys difficult. For example; damp smears and air sample filters are difficult to measure if they are wet.
- More difficult phases of the work should be done by subcontractors who are specialists. The subcontractor workers may need training on radiological work practices.
- Taking "shortcuts" can lead to increased costs due to delays, events, or shutdowns.
- Base planning on current surveys, whenever possible. If current conditions are unknown, be conservative until current surveys are taken and evaluated.
- Facilities that do a through job of characterizing before work starts have less job stoppages and increase their chance they will complete the work on schedule.
- During demolition, contamination control and monitoring is difficult. Removing walls creates lack of containment and changes the work environment. Radiological conditions can change rapidly when contamination is disturbed. Pu contamination seems to migrate quickly even when there is no apparent cause.
- Training workers in mockups is effective in teaching new skills and the donning and doffing of protective clothing. Full-scale mockup training needs to be as realistic as practical.
- Thorough pre-job briefings are important to make workers understand what has been done, is the procedure correct, are the tools available, what is expected from them and the work practices they will use to accomplish the job.
- Use of videotape and digital photos is an effective way to brief workers on changing conditions and to create an historical record.
- Expect to find lead-based paint, asbestos gaskets, asbestos tile, PCBs, and other hazardous materials in old facilities.
- Contaminated vent ducting may contain several inches of dust or chemical residues. Spills have occurred when sections of ducting were removed.
- HEPA filters may have leaked and spread contamination into areas that should be uncontaminated.

- Piping systems may contain liquids and be pressurized.
- Have full-time safety, industrial hygiene, and Radcon personnel assigned to the project.
- Work will likely extend over many months. Consider debriefing the work periodically to capture lessons learned and get recommendations on improvements. Maintain open lines of communication between managers, planners, workers, RCTs, IH, and Safety professionals.
- There are more stringent regulations for shipping hazardous or radioactive wastes than disposing it.
- Need to constantly consider Criticality Safety issues regarding the geometry of waste containing fissile material.
- The use of large amounts of misting or spraying dust suppressants during demolition prevents airborne contamination.
- It is difficult to predict where concrete will fracture during demolition due to its thickness and rebar.
- Expandable foam can be used to reduce contamination during piping and ventilation removal. Other fixatives can be effective in coating the inside of long runs of piping prior to removal.
- Soil contamination may be present near radiological work facilities where storm run-off occurs, storage pads, asphalt parking and liquid waste treatment areas.
- Complex equipment can be wrapped in plastic wrap and sprayed with a product like polyurea to provide a “strong-tight” container for shipping.
- Decontaminate or fix high levels of removable contamination before securing building HEPA filtered ventilation. On one project the ventilation was secured before high levels of surface contamination decontaminated and this resulted in airborne contamination.
- The protective clothing requirements for D&D may include plastic suits, bubble suits, and supplied air respiratory equipment. Planners need to understand the impact of adding layers of PPE and its affect on the workers. For example; It may be better to pad a worker’s knees instead of adding another suit.
- During D&D, workers may be required to handle materials with sharp edges that could puncture or cut the worker. This wound could be contaminated and require flushing, surgery, or other actions to reduce the worker’s exposure. Cut and puncture resistant gloves, arm sleeves or aprons may be needed to protect the workers.
- Throughout the project, good housekeeping, eliminating safety hazards and combustible materials are priorities.
- There has been many examples of the benefits of planning carefully, listening to the workers, and looking for opportunities. Expect the Unexpected.

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APPENDIX B - ALARA ENGINEERING DESIGN PRINCIPLES

I. ASSESSING RADIATION DOSES

Radiation designs should provide for anticipated dose by including analysis of the tasks and processes that occur in these areas, the anticipated dose rates for the area, and the proposed inventories of radioactive materials.

A. Workers and Time.

Moreover, the numbers of workers and the amount of time they are expected to spend in the area should be taken into consideration.

1. For example, general (low-level) operations areas consist of those areas with small or moderate inventories of radioactive materials. Examples are general radionuclide research labs, rooms containing properly shielded X-ray diffraction and spectroscopy units, and operation areas with low contamination and low dose-rate potential.

2. Work in higher-level operation areas, however, typically involves more radioactive material than does work in general operation areas. Examples of process operation areas are glovebox and hot-cell operating areas, control areas for high-dose rooms, and selected areas of accelerator facilities where experiments with moderate dose or contamination potential cannot be remote-controlled.

B. Multiple Sources.

It is important in building layout to minimize simultaneous dose from multiple sources at locations where maintenance personnel may be required to work. Similarly, individual work stations should be shielded from one another if work by one individual may expose others in the same area to unnecessary dose.

C. Remote Operations.

Functions in remote operation areas are usually remotely or automatically controlled. Occupancy in these areas is predominately for process monitoring or the adjustment of operations occurring in areas of high hazard and restricted access. Examples of this type of area are hot-cell service and maintenance areas and transfer areas where highly dispersible materials of high-dose rate are introduced into the process system or hot cell.

D. Isolation Areas.

Isolation areas include areas with high-dose rates or airborne contamination levels. Unauthorized and unmonitored entry in these areas is forbidden, and design features shall prevent the unauthorized entry of personnel. All personnel are prohibited from entering when conditions in the area present an immediate hazard to human life. Physical controls are required to limit doses when these areas are occupied.

II. ACCESS CONTROL CONSIDERATIONS

Building layout is an important factor in controlling personnel dose by regulating the flow of personnel and material. Proper layout reduces casual or transient exposures to radiation fields by segregating heavily used corridors and the work areas of nonradiological workers from the areas of high radiation and contamination. The layout should effectively limit occupational dose to areas where the performance of an assigned task requires some degree of radiation dose. Controlled areas defined in 10 CFR 835 are addressed in Module 103. A general discussion follows.

A. Sequential Areas.

An acceptable technique for achieving proper building layout is to establish a system of sequential areas. This concept is frequently used because it is adaptable to the physical control of external and internal dose equivalents. In addition, the design is an excellent precursor to planning and establishing operational radiological control areas.

B. General Access and Controlled Areas.

Two major types of areas are included in any nuclear facility: uncontrolled areas and controlled-access areas.

1. General access: General access areas are normally places to which public access is restricted but where direct radiation exposure is not necessary for job performance, such as the work areas of administrative and nonradiological support personnel. These areas include conference rooms, file rooms, clerical and other support offices, lunch rooms, and rest rooms.

2. Controlled areas: Controlled areas are areas to which access is managed to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter

only the controlled areas without entering radiological areas are not expected to receive a total effective dose equivalent of more than 100 mrem (0.001 sievert) in a year.

Controlled areas may include corridors that are adjacent to, or connected with, areas that contain radioactive materials, change rooms, or special offices for radiation workers.

3. Radiological Area: Any area within a Controlled Area that meets the definition of a Radiation Area, Contamination Area, High Contamination Area, Airborne Radioactivity Area, or High Radiation or Very High Radiation Areas. For the purpose of access control, we can divide Radiological Areas into buffer areas (also called contingent areas) and areas of contamination or elevated dose rates.

4. Buffer/contingent areas: Buffer areas should contain offices only if the facility design criteria specify that the offices must be near radiological areas. The primary functions of buffer areas are to control contamination and to isolate radiological areas from general access areas.

C. Traffic.

Locate frequently used pathways in low-radiation areas and non-contaminated areas. (Note: Use common sense and logic. If the pathway is in "clean areas" but in a long and illogical route, people will not use it and may take "short cuts" through hot areas.)

1. Plan transport routes inside and between buildings so that non-radioactive material does not have to pass through radiological areas and *vice versa*.

2. Plan personnel traffic routes so that clean or general access areas are not isolated and do not have to be reached by passing through a radiological area.

3. Plan personnel traffic routes so that access paths between contaminated areas do not pass through clean areas.

4. Consider the sizes and locations of monorails, cranes, doorways, corridors, and hatches in relation to the radiological or non-radiological areas they will serve.

5. Be sure to consider the paths that firefighters will take in entering a radiological area. Try to provide paths that will keep them farthest away from areas of high-dose rate while providing adequate access to the most likely area for a fire.

D. Access.

1. Provide adequate space around components for inspections and maintenance activities.

2. Locate supports so as not to interfere with inspections and maintenance, and facilitate removal of equipment.

3. Provide space and rigging path so that equipment can easily be removed from areas of elevated dose rates for maintenance.

4. Ensure that wide and large enough doorways and access areas are provided so that components can be easily removed for maintenance or inspection.

5. Provide permanent platforms, rigging devices, etc., for easy access to components in hard-to-reach places.

6. Provide laydown space to allow equipment and components to be disassembled.

7. Minimize the number of personnel access control points, and size and equip them for the expected number of workers who will use them.

8. Areas with significant concentration of airborne radioactive materials should be provided with physical barriers to prevent the entry of unauthorized individuals.

9. Provide one of the following features for each entrance or access point to High Radiation Areas:

   a. A control device that prohibits entry when high radiation levels exist, or upon entry causes radiation levels to be reduced below High Radiation Area levels;

   b. A device that prevents operation of the radiation source;

   c. A control device that energizes a conspicuous visible or audible alarm;

d. A locked entry-way; or

e. Continuous surveillance capable of preventing entry.

Additionally, Very High Radiation Areas must prohibit entry when dose rates are greater than posting requirements.

10. Provide panic exit bars on the insides of locked doors as well as locks, alarms, and interlocks as appropriate for areas requiring them.

11. Provide space for temporary access control points where it is anticipated they will be needed from time to time.

12. Provide space, support, and electrical hookups for personnel contamination monitors as needed at each access control point.

E. Radiological Areas.

1. Make contamination and radiation areas as small as possible.

2. Provide for posting of radiological areas and anticipated hot spots.

III. CONTAMINATION CONTROL DESIGN CONSIDERATIONS

A. Contamination Control.

1. Slope floors toward sumps or floor drains and use curbs, dikes, berms, and trenches as appropriate to remove leakage promptly.

2. Hard-pipe drains, tank overflow, valve stem leakage, etc., to sumps.

3. Route drains directly to proper radwaste sumps or tanks.

4. Provide stainless steel collection pans as needed and direct leakage to drains via tubing or piping (stainless steel resists corrosion and facilitates decontamination).

5. Always consider whether flooding (due to leakage, backup of a sump, etc.) may cause the contamination of equipment, and elevate such equipment above flood levels.

6. Use raised sleeves in floor penetrations; consider sealing the penetrations or providing a hood.

7. Avoid using open gratings for stairs or platforms in potentially contaminated areas.

8. Provide space and support for the use of glove bags and other containments over the space created when the head of a heat exchanger is removed, or where a pipe is opened, and in similar cases.

9. Allow room inside and/or near contaminated or potentially contaminated areas for friskers, step-off pads, and used protective clothing bins.

B. Decontamination.

Plan for eventual decontamination. If decontamination is done in place, the worker may experience a high-dose rate from other equipment in the area; he may not have much room to work in; and the decontamination fluids, cloths, and removed parts will have to be collected. If the equipment is removed for decontamination at another location, it may have to be bagged up, lifted, loaded, and moved along a path, possibly passing through general access areas or areas of narrow clearance.

There are several ways to facilitate decontamination during the design phase:

1. Provide smooth, nonporous, and nonreactive surfaces on equipment (inside and out), floors, insulation, walls, trenches, doors, plugs, and tools.

2. Make generous provisions for services to be used for anticipated decontamination: water, air, electricity, and other connections.

3. Provide cleanout openings, taps for hydrolasing or chemical "decon," hatches, collection pans, and means for flushing and draining (be aware that the cleanouts are themselves a crud trap).

4. Consider a central decontamination station for a large facility or operation; size, equip, and locate it for the types, sizes, number, and locations of the equipment it is to handle.

IV. RADIOACTIVE WASTE CONSIDERATIONS

A. Temporary Radwaste Storage.

1. Location for the temporary storage of radioactive wastes must be designed into both the building plan and the plan for each area where radioactive materials are handled.

2. Radioactive material handling areas should be designed with a special area for waste accumulation. This area should be removed from the generally occupied areas of the facility.

3. Special attention should be paid to fire prevention, spill control, and (if necessary) vapor or odor control.

B. Bulk Radwaste Storage.

1. Operating areas should not be the principal areas for interim bulk waste storage. Instead, all major facilities should be designed with a special bulk storage area.

   This area should be located so that wastes being removed from the building will not have to be transported along major personnel traffic routes or through uncontrolled-access areas.

2. To prevent accumulations of waste in operating areas if normal disposal methods are temporarily interrupted, the waste storage area should be large enough to accommodate more than the expected volume of waste.

C. Transport.

1. Plan routes over which solid and liquid wastes in containers must be transported to avoid general access areas as much as possible.

2. Minimize distances over which moderately and highly radioactive wastes are transported from operating areas to disposal points.

D. Drainage of Liquid Systems.

Design drain basins, curbs, and catch or retention tanks for efficient and complete drainage.

E . Monitoring.
Install monitoring systems to detect any leaks or spills in areas where drainage or retention is unattended or is remote-controlled.

F. Fire Suppression.
Install fire-suppression systems in areas where combustible radioactive material may accumulate or be stored. Consider the effects of fires not only in the Radiological Areas, but also in the non-Radiological Areas.

V. SHIELDING, PENETRATIONS, AND ROUTING CONSIDERATIONS

A. Shielding.

1. Obtain information on shielding types, thicknesses, and layout from a radiological specialist (a radiological engineer, ALARA specialist, or health physicist, as appropriate for your project or operation).

2. Don't be reluctant to ask if another type of shielding will do, or if there is a way to accomplish what you want without so much shielding.

3. Labyrinth entrances should be considered for some Radiation Areas, and for all High Radiation and Very High Radiation Areas.

4. Take into account the buildup of the source or other source accumulation over the years (install more shielding than is immediately necessary, or provide space and support for shielding to be added later as the source builds up).

5. Consider removable shielding, such as block walls and ceiling hatches for large equipment, but remember that the removal and re-emplacement will cost some dose. Use proper overlapping and stepping in the design and emplacement of such shielding.

6. Consider temporary shielding when it would be needed only briefly or infrequently (allow for space, support, and transport requirements).

7. Consider special shielding such as shield doors, leaded glass windows, covers for hot spots, transport casks, and shielded carts or forklifts.

8. Add permanent hooks, latches, fasteners, and structural supports to secure temporary shielding.

9. Design shielding to separate components used for processing or storage of radioactive materials to allow for routine operations and maintenance.

B. Penetrations.

1. Have experts from all affected disciplines review a planned penetration before the hole is made.

2. Minimize the size and number of penetrations (several small penetrations are usually better than one big one).

3. Place penetrations in the thinnest shield wall, near a corner, as high up as possible, and not in a line of sight with a source.

4. Place penetrations so they do not line up with accessible areas, including stairways, doorways, and elevators.

5. Place penetrations so they do not line up with any radiation-sensitive equipment, such as electronics, attached to a wall or ceiling on the low-dose-rate side of the penetration.

6. Consider offset penetrations.

7. Provide labyrinths or shadow shields behind penetrations to reduce streaming or scattering through the penetration.

8. Seal penetrations, where justified, for dose-rate reduction, air-flow control, and leakage control.

C. Routing of Ducts, Pipes, Cables, and Conduit (DPCs).

1. Have DPCs enter through a labyrinth or door, if possible.

2. Don't route DPCs containing contaminated fluids through general access areas, or clean DPCs through potentially contaminated or high-dose-rate areas.

3. Locate connections, pull spaces, junction boxes, panels, valve operators, and taps in low-dose-rate areas or at least on the low-dose-rate side of the wall.

4. Provide as short a run of sample and other potentially contaminated lines as possible into the accessible areas.

5. Do not regard the X-Y-Z grid as sacred. Minimize runs of piping by routing diagonally, using bends other then 90 degrees, and sloping lines.

6. Route clean and radioactivity-containing pipes in separate areas, especially pipe tunnels. A worker servicing clean systems should generally not receive significant dose.

7. Route to provide adequate clearance for maintenance, inspection, and insulation.

8. Do not field-route radioactivity-containing DPCs (if it is necessary, guidance should be given to the routers as to the path and areas in which the pipe may go).

9. Make as-built drawings of field-routed piping to ensure that lines containing radioactivity are known and identified.

VI. EQUIPMENT SEPARATION, SEGREGATION, PLACEMENT, AND ISOLATION CONSIDERATIONS

A. Separation.

1. Put shield walls between components sharing the same cubicle to reduce the dose to a worker maintaining one of them (the equipment should be placed so that the worker does not have to pass close to one to get to the other).

2. Separate passive equipment, such as tanks, from active or frequently maintained equipment with shielding.

3. Consider multi-skid designs for appropriate pieces of equipment to allow interstitial shielding (e.g., place shielding between pumps and their motors in highly radioactive streams because the pumps get "hot" while the motors do not).

B. Segregation.

1. Segregate highly radioactive equipment from moderately radioactive equipment, and both from clean equipment. Similarly, segregate equipment with high airborne potential from equipment with less airborne potential, and both from clean equipment.

2. Segregate radioactive equipment of different systems so that both systems will not have to be flushed, drained, or decontaminated to reduce the dose when only one needs maintenance.

C. Placement.

1. Even with shielding, lay out equipment in an area or equipment cubicle so that the worker enters, progresses from low-dose-rate areas to moderate to high-dose-rate areas, and from active to passive equipment.

2. Place inspection, control, and readout devices and panels in low-dose-rate areas.

3. Place services (demineralized water, electricity, etc.) near entrances or at least in the lowest-dose-rate areas.

D. Isolation.

1. Properly place isolation valves to minimize dead legs.

2. Minimize pipe runs in valve aisles (consider reach rods and valve operators).

3. Thoroughly review any proposed interconnection between systems of different radioactivity potential (consider having only temporary connections between radioactive and clean systems, such as the demineralized water supply).

E. Redundancy.

Provide adequate redundancy and backup capability, especially in systems of high radioactivity content and safety systems. Provide appropriate cross-connections to achieve this.

VII. ACCESSIBILITY, LAYDOWN, AND STORAGE CONSIDERATIONS

A. Accessibility.

1. Allow adequate working space around major components, usually at least 3 feet. Do not allow this space to be filled by reach rods, shields, pipes, scaffolds, etc.

2. Provide more space if many workers or large tools are necessary for maintenance, and consider the space taken by protective clothing and respirators.

3. Size labyrinths and doorways to allow the passage of workers, carts, forklifts, and tools.

4. Provide cranes or monorails for large pieces of equipment, pad eyes or anchor points for smaller ones, and lifting lugs on all components of significant weight.

5. Consider permanent galleries or scaffolding where maintenance is frequent or prolonged; provide space and attachments for temporary structures where it is not.

6. Select tanks that have manways sized for a worker wearing a full set of protective clothing, including respirator (preferably at least 24 inches).

7. Supply adequate access around welds by providing prescribed separation between welds and between welds and penetrations.

8. Minimize the number of stops, hangers, supports, and snubbers, and orient them to maximize access space in the area.

9. Consider sectional or modular design (e.g., snap-on segments of insulation on heat-traced lines that require frequent maintenance).

10. Provide space for removal of filters into plastic bags or shielded containers.

B. Laydown and Storage.

1. Provide laydown space in a low-dose-rate area (besides equipment, consider such items as tool boxes, carts, and hoses).

2. Store hot tools (fixed contamination) and tools waiting for decontamination in appropriately posted, locked, shielded, and ventilated areas.

3. Properly store nonradioactive items to be used in radiological areas, such as dosimeters, filters, insulation, and so forth, so that they will not be degraded by radiation, light, moisture, etc.

VIII. SNUBBER, STRUT, HANGER, AND ANCHOR CONSIDERATIONS

1. Locate and design snubbers, struts, hanger, and anchors so as to facilitate removal and replacement.

2. Locate snubbers, struts, hangers, and anchors so as not to interfere with inspections and maintenance.

3. Replace snubbers with struts or energy absorbers whenever possible.

4. Paint and tag snubbers, struts, hangers, and anchors to facilitate location for repair and inspection.

IX. HUMAN FACTORS

A. Consider Visual Factors.

1. Make sure that signs, indicators, readouts, etc., are clearly legible from a reasonable distance away.

2. Avoid the use of nonstandard lettering.

3. Provide adequate lighting and consider auxiliary lighting where equipment is located in a corner or behind other equipment, or where remotely operated cameras are used (provide automatic emergency lighting in areas where the dose rate may be elevated).

B. Consider Auditory Factors.

1. Provide alarms numerous and loud enough to be heard everywhere in the subject area. Also minimize background noise.

2. Provide adequate communications measures, especially in areas where maintenance and inspection workers or health physics technicians may need to communicate with their supervisor or health physicist during a job.

C. Consider Human Physical Characteristics.

1. Familiarize yourself with an appropriate reference on human sizes and physical capacities, and apply this guidance to all design and operations work.

2. Consider the use of lifting devices and special tools so that fewer workers can accomplish a job.

3. Consider the effects of heat stress, particularly with protective equipment such as respirators and/or non-porous protective equipment.

4. Consider provisions for lifelines to pull accidentally injured or unconscious workers from tanks, pools, or other areas of high dose rates or high airborne activity.

D. Help Prevent Human Error.

1. Make permanent alignment marks on the equipment or floor.

2. Color-code tools, conduit, bolts, and pipes.

3. Place identification on insulation to show what is underneath it.

4. Clearly mark system lineup indication of valve position, breaker settings, etc., near controls or equipment.

5. Locate valves, valve operators, controls, etc., in a logical manner.

6. Consider automation of operational sequences, or use interlocks and warning lights for dangerous choices in manual sequences (also use interlocks as an aid to memory, such as automatically starting sample hood HVAC when the sample draw starts).

7. Make it cheap in terms of dose for operations to be accomplished safely (e.g., in areas where the “buddy system” is used for safety, provide a low-dose-rate area where the watcher can observe, perhaps in the labyrinth entrance with a mirror).

8. Consider providing mockups and simulators on which operators can practice for long or complex jobs.

9. Special tools or equipment specific to one area should be provided and kept near that area.

X. OPERATION, MAINTENANCE, AND INSPECTION CONSIDERATIONS

A. Operations.

1. Provide adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., for operation of equipment.

2. Locate remote operators or reach rods on high-dose-rate valves outside contaminated areas.

3. Locate instrument readouts in low-dose-rate areas and away from contaminated areas whenever possible.

4. Provide for operations and surveillance from outside a High Radiation Area through the use of remote readout devices, viewing ports, radiation detector ports, or TV cameras.

5. Provide access to equipment or instruments requiring frequent manual operation or surveillance via areas with the lowest possible dose rates.

B. Maintenance.

1. Provide adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., for maintenance.

2. Select the components or systems with long service life, ease of maintenance, reliability, and operating record of low maintenance frequency.

3. Ensure components requiring frequent maintenance (e.g., small pumps and valves) are designed to permit prompt removal (e.g., flanged connections) to facilitate repairs in lowdose- rate areas.

4. Eliminate or minimize periodic maintenance items (e.g., O-rings, gaskets, packing, protective coatings, lighting components).

5. Consider using lubricating systems or self-lubricating units.

6. Provide a mechanism to allow rigging of the component (e.g., pad eyes).

7. Provide access to equipment and components requiring frequent maintenance via areas with lowest dose rates practicable.

8. Ensure that the valve maintenance procedure controls stellite filings to reduce cobalt where neutron activation of the stellite is possible.

9. Design and orient components to minimize crud buildup.

C. Inspection.

1. Provide adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc.

2. Ensure that insulation design allows for rapid removal and replacement (e.g., match marks, fiberglass blankets).

3. Locate equipment with consideration given to facilitating inspections required by Section XI of the ASME Code, Appendix J, Appendix R, and other inspection requirements of the ISI leak rate and fire protection programs.

4. Provide there visible tags and levels to identify equipment, snubbers, welds, penetrations, valves, and other items requiring inspection.

5. Locate access to equipment or components requiring frequent inspections via areas with lowest possible dose.

APPENDIX C - CALCULATIONS INVOLVING THE QUANTITIES USED IN 10 CFR PART 835

Perhaps the best way to understand the dosimetric methodology of 10 CFR 835 (which is based on ICRP Publication 68) is to learn the way the calculations are performed. Anyone who has mastered simple arithmetic and is willing to give some thought to the subject can perform these computations.

I. DEFINITIONS AND BASIC RELATIONSHIPS

Definitions

In 10 CFR 835, the rem is used as the unit of measurement for the physical quantities listed below. Remember that just as the *meter* is the unit for the quantity *distance*, and the *liter* is the unit for the quantity *volume*, so too is the *rem* (or *sievert, Sv*) the unit for the quantity *equivalent dose*.

A. **Equivalent Dose (H_T)**: The product of average absorbed dose ($D_{T,R}$) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (W_R). For external dose, the equivalent dose to the whole body is assessed at a depth of 1cm in tissue; the equivalent dose to the lens of the eye is assessed at a depth of 0.3 cm in tissue, and the equivalent dose to the extremity and skin is assessed at a depth of 0.007 cm in tissue. Equivalent dose is expressed in units of rem (or Sv).

B. **Deep Equivalent Dose (DED)**: The equivalent dose derived from external radiation at a depth of 1 cm in tissue.

C. **Lens of the Eye Equivalent Dose (LED)**: The external exposure of the lens of the eye; it is taken as the dose equivalent at a tissue depth of 0.3 cm.

D. **Shallow Equivalent Dose (SED):** The dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

E. **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. It does not include contributions from radiation sources external to the body. Committed equivalent dose is expressed in units of rem (orSv).

[1]Tissues and organs include: gonads, breasts, red bone marrow, lungs, thyroid, bone surfaces, and remainder organs.

F. **Effective Dose (E)**: The summation of the products of the equivalent dose received by specified tissues or organs of the body (H_T) and the appropriate tissue weighting factor for that tissue or organ (w_T)[2] - that is $E=\Sigma w_T H_T$.

G. **Committed Effective Dose (E_{50})**: The sum of the committed equivalent doses to various tissues and organs in the body ($H_{T,50}$), each multiplied by the appropriate weighting factor (w_T) - that is $E_{50}= \Sigma w_T H_{T,50} + w_{remainder} H_{remainder,50}$.

H. **Total Effective Dose (TED)**: The sum of the effective dose (E) for external exposures and the committed effective dose (E_{50}) for internal exposures.

Other important definitions listed in 10 CFR 835 that are important in dosimetry calculations include:

I. **Annual Limit on Intake (ALI)**: The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the Reference Man (ICRP Publication 23) that would result in a Committed Effective Dose of 5 rem or a Committed Equivalent Dose of 50 rem to any individual organ or tissue. Since the ALI is a radioactivity quantity, its units are *curies (Ci)*.

J. **Derived Air Concentration (DAC)**: The airborne concentration of radionuclides that equals the ALI for an individual radionuclide divided by the volume of air breathed by an average worker for a working year of 2,000 hours assuming a breathing volume of 2400 m^3. The DAC is a concentration quantity with typical units of *microcurie per milliliter (μCi/ml)*.

A useful quantity that is not defined in 10 CFR 835, but is very useful in the application of these dosimetry concepts is the DAC-hour:

K. **DAC-hour (DAC-hr)**: The time spent by a worker in an airborne radioactivity concentration multiplied by the ratio of that concentration to the appropriate DAC. For example, a worker

[2] Weighting factors, W, are listed in 10 CFR 835 for specific organs and tissues.

who works for 8 hours in an area with an airborne radioactivity concentration of 1 DAC would have spent 8 DAC-hrs in the area. If the worker worked for 8 hours in an area with an airborne radioactivity concentration of 10 DAC, he would have spent 80 DAC hours in the area. A total of 2,000 DAC-hrs would result in a Committed Effective Dose of 5 rem or a Committed Equivalent Dose of 50 rem to any individual organ or tissue.

II. CALCULATIONS INVOLVING THE DOSIMETRY QUANTITIES

A. 10 CFR 835 Limits.

10 CFR 835 sets the following annual limits with regards to occupational exposure of general employees:

1. Total Effective Dose

   TED $\leq$ 5 rem

2. Deep Equivalent Dose and Committed Equivalent Dose to any organ or tissue.

   DED + $H_{T,50} \leq$ 50 rem (T other than lens of eye)

3. Lens of Eye Equivalent Dose

   LED $\leq$ 15 rem

4. Shallow Equivalent Dose

   SED $\leq$ 50 rem (to the skin or any extremity)

B. Combining Internal and External Exposures.

The TED during a year shall be determined by summing Effective Dose from external exposures and the Committed Effective Dose from intakes during the year. For purposes of compliance, the Deep Equivalent Dose to the whole body may be used as Effective Dose for external exposures.

$$\text{TED} = E + E_{50}$$

or

$$\text{TED} = \text{DED} + E_{50}$$

C. Calculating Internal Exposure Using ALIs and DACs.

Internal exposures are typically determined by evaluation of bioassay results. For the purposes of ALARA planning, it is beneficial to be able to calculate or estimate what an individual's internal exposure would be based on air concentrations.

Begin by understanding the relationship between the DAC and the ALI:

$$\text{DAC } (\mu\text{Ci/ml}) = \frac{\text{ALI (Ci)}}{2400 \text{ m}^3}$$

The average worker breathes approximately 2400 m^3 of air during a 2,000-hour working year.

If C is the actual radioactivity concentration in which a worker is breathing, the Committed Effective Dose (E_{50}) may be calculated directly from air concentration measurements and using the DAC value found in 10 CFR 835 for the radionuclide being inhaled and the time that was spent in the area.

For example: Where the limiting ALI is based on 5 rem CEDE:

$$E_{50} \text{ (rem)} = \frac{C\ (\mu Ci\text{/ml})}{\text{DAC } (\mu\text{Ci/ml})} \times \frac{\text{time (hrs)}}{2000 \text{ hrs}} \times 5 \text{ rem}$$

Individuals may enter areas with airborne radioactivity concentrations greater than the DAC for specific radionuclides; however, their time spent in such an area must be limited so that TED $\leq$ 5 rem and CED $\leq$ 50 rem. In this case, it is easier to use the DAC-hour quantity to calculate E_{50}.

For example: Where the limiting ALI is based on 5 rem CED:

$$E_{50}(\text{rem}) = \frac{\text{DAC-hrs}}{2000 \text{ hrs}} \times 5 \text{ rem}$$

or

$$E_{50}(\text{mrem}) = \text{DAC-hrs} \times 2.5 \text{ mrem/hr}$$

If a worker spent 8 hours in an area in which the airborne radioactivity concentration was 3 DAC, based on the limiting ALI of 5 rem CED, his Committed Effective Dose (E_{50}) would be calculated as follows:

$$\text{DAC-hrs} = 3 \text{ DAC} \times 8 \text{ hrs} = 24 \text{ DAC-hrs}$$

$$E_{50}(\text{mrem}) = 24 \text{ DAC-hrs} \times 2.5 \text{ mrem/hr} = 60 \text{ mrem}$$

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APPENDIX D - ALARA DESIGN REVIEW CHECKLIST

(Insert facility-specific checklist or documents or substitute facility-specific information, as applicable.)

A. Overview.

As an aid in performing an ALARA Design Review, series checklists have been provided here.

The first part (Sections I) is a list of preliminary questions called “First Level Screening Questions” that serves to sort out which groups of questions in the main checklist will need to be answered. The second part (Section II-XXI) is the main checklist, a series of questions grouped by subject. These checklists include space where individual answers may be discussed and resolutions may be recorded.

B. Filling Out the Checklist.

1. If there is any doubt regarding the applicability of an issue or an ALARA principle being neglected, the reviewer should answer conservatively (i.e., answer to indicate an issue IS involved or that ALARA IS being neglected).

2. Where a question is not applicable, the reviewer should answer “N/A.”

3. The reviewer can call the ALARA Review Coordinator for guidance in responding to questions.

4. The questions are to be answered considering not only new or newly added features, but also existing features that might be affected. The impact of nonradiological additions on radiological items also must be considered.

I. ALARA PRELIMINARY SCREENING QUESTIONS

A.	Does the facility, system or subject include:	YES	NO
1.	Entry into or activity in or near a radiological Area?		
	Resolution:		
	Response:		
2.	Shielding; penetrations; equipment separation or segregation; or routing of pipes, conduit or ducts?		
	Resolution:		
	Response		
3.	Location of sensors, readouts, or like manual-access or visual-access components in a Radiological Area?		
	Resolution:		
	Response:		
4.	Activities which may affect ventilation equipment (such as selection and maintenance), produce airborne contamination, or other local ventilation or airborne controls?		
	Resolution:		
	Response:		
5.	Construction or assembly techniques, materials, shapes, flow patterns, or choices of equipment which potentially contribute to crud or other radioactivity production or accumulation?		
	Resolution:		
	Response:		

A.	Does the facility, system or subject include:	YES	NO
6.	Flow paths or contact surfaces which might require isolation or decontamination, or measures to facilitate decontamination?		
	Resolution:		
	Response:		
7.	Radiation monitoring or sampling systems, or modifications which may result in the need to alter or add such systems?		
	Resolution:		
	Response		
8.	Radwaste collecting or processing systems, or modifications which will result in additional radwaste or different forms of radwaste being sent to these systems?		
	Resolution:		
	Response:		
9.	Access, laydown, or storage space for installation, removal, maintenance, inspection, or calibration?		
	Resolution:		
	Response:		
10.	Lighting, access sizing, noise levels, communications, signaling, labeling, or other human factor considerations?		
	Resolution:		
	Response:		

A.	Does the facility, system or subject include:	YES	NO
11.	Component or design features that may cause significant radiation exposures during installation, removal, maintenance, or operation, or measures to reduce such exposures?		
	Resolution:		
	Response:		
12.	Component or design features that may cause a significant change in the dose to the public, whether by direct radiation or by releases to the environment?		
	Resolution:		
	Response		

II. GENERAL ALARA CHECKLISTS

A.	Materials of Construction	YES	NO
1.	Are material specifications established to decrease the formation of activated materials (e.g., by specifying materials low in cobalt and nickel content where applicable?		
	Resolution:		
	Response:		
2.	Are surfaces smooth and/or painted for easy decontamination?		
	Resolution:		
	Response		
3.	Are rough surface finishes such as crevices, holes, notches, recesses, socket-head cap screws, and knurled finishes avoided?		
	Resolution:		
	Response:		

B.	Shielding	YES	NO
1.	Is shielding placed between serviceable components and any substantial radiation source in the area?		
	Resolution:		
	Response:		
2.	If permanent shielding is not feasible, are provisions incorporated for rapid installation of temporary shielding (i.e., shield racks or supports)?		
	Resolution:		
	Response		
3.	Are shields employed to prevent streaming of radiation through doors, pipes, and duct penetrations (e.g., labyrinths or shadow shields)?		
4.	Is an adequate safety margin applied to seismic load analysis to accommodate the additional load from temporary shielding?		

C.	Access Control	YES	NO
1.	Are traffic pathways and areas that will be frequently used located in low radiation zones?		
	Resolution:		
	Response:		
2.	Are areas of the facility that exhibit high occupancy, or are presently uncontrolled, adequately protected from new or increased radiation sources?		
	Resolution:		
	Response		

C.	Access Control	YES	NO
3.	Is maximum distance provided between serviceable components and any substantial radiation sources in the area?		
	Resolution:		
	Response:		

D.	Contamination Control	YES	NO
1.	Can containment be established to reduce the spread of contamination (i.e., glovebags, cribs, catch pans, drip pans, or cofferdams)?		
	Resolution:		
	Response:		
2.	Are HEPA filters and/or charcoal used on the exhaust in areas that have the potential for airborne radioactivity?		
	Resolution:		
	Response		
3.	Are the pressure gradient and airflow such that air flows from areas of low potential for airborne radioactivity to areas of higher potential for airborne radioactivity?		
	Resolution:		
	Response:		
4.	Does the design incorporate features that will reduce the likelihood of cross-contamination of clean systems and unmonitored release pathways?		
	Resolution		
	Response:		

E.	Service Readiness	YES	NO
1.	Is the equipment ready for service as received?		
	Resolution:		
	Response:		
2.	Does the equipment require modification prior to installation? If so, is the modification reflected in applicable documents, and can the modification be performed in a nonradiologically controlled area?		
	Resolution:		
	Response		
F.	Documentation	YES	NO
1.	Are all changes, revisions, modifications, and configurations clearly reflected in applicable documents?		
	Resolution:		
	Response:		

III. ALARA INSTALLATION REVIEW QUESTIONAIRE

A.	Engineering Techniques	YES	NO
1.	Have special equipment, tools, convenience features (e.g., lighting, communications, staging, laydown areas, etc.), and engineering techniques that may minimize exposures been considered?		
	Resolution:		
	Response:		

A.	Engineering Techniques	YES	NO
1.	Have other engineered controls (such as prefabrication of work outside radiation area, robotic equipment, snap-tight connectors, etc.) Been considered to reduce exposure?		
	Resolution:		
	Response:		
B.	Installation Procedures	YES	NO
1.	Have installation procedures been prepared or modified to minimize exposures?		
	Resolution:		
	Response:		
2.	Have radiation protection hold points, radiological requirements for the job, listing of tools used on the job, and a step-by-step installation process been included in installation procedures?		
	Resolution:		
	Response		
C.	Shielding	YES	NO
1.	Have components/areas where shielding (including shadow and portable) might be effectively used to reduce exposures been considered?		
	Resolution:		
	Response:		
2.	For installations or modifications in high-dose-rate areas, have special or customized shields been designed and fabricated to reduce the dose to workers, where appropriate?		
	Resolution:		
	Response		

D.	Decontamination and Contamination Control.	YES	NO
1.	Have components, systems, and areas been considered for decontamination to reduce exposures and the spread of contamination (e.g., hydrolyzing, chemical decontamination, flushing, etc.)?		
	Resolution:		
	Response:		
2.	Have any special local ventilation, containment, or spray systems been considered that can reduce the spread of radioactivity (e.g., tents, gloveboxes, filtered blowers, etc.)?		
	Resolution:		
	Response		
E.	Planning	YES	NO
1.	Have installation and construction plans been developed to optimize the efficiency of the work?		
	Resolution:		
	Response:		
2.	Have installation and construction plans taken advantage of facility system (not specific enough) configuration and operating conditions (e.g., resin transfer, fuel out of vessel, etc.)?		
	Resolution:		
	Response		
3.	Have installation and construction plans included measures to minimize radwaste generation by unpacking equipment outside of radiological areas, pre-treating wood, etc.?		
	Resolution:		
	Response:		

F.	Scheduling.	YES	NO
1.	Have radiological hold points and ALARA controls been factored into the installation and construction schedule (e.g., surveys, decon, shielding, containment, ventilation systems, etc.)?		
	Resolution:		
	Response:		
2.	Has work been scheduled so as not to interfere with concurrent work in the same area?		
	Resolution:		
	Response		

IV. HEATING, VENTILATION, AND AIR CONDITIONING CHECKLISTS

		YES	NO
1.	Are welded seams employed in ductwork carrying contaminated air?		
	Resolution:		
	Response:		
2.	Has HVAC equipment been leak tested after installation and repair?		
	Resolution:		
	Response		
3.	Are filters appropriate to the operation and radionuclides present?		
	Resolution:		
	Response:		

4.	Are differential pressure detectors provided across filters to monitor dust loading?		
	Resolution:		
	Response:		
5.	Have open-topped tanks or tanks with vent lines lower than overflow lines been avoided?		
	Resolution:		
	Response		
6.	Has hard-piping to HVAC of relief valves and vents been avoided, where appropriate, except with proper additional provisions?		
	Resolution:		
	Response:		
7.	Have filters on highly radioactive systems been designed to minimize dose from the spread of contamination during changeout (e.g., filter bagout, located for each access, etc.)?		
	Resolution:		
	Response:		
8.	Is water used for back-flushing and unplugging, rather than compressed gas?		
	Resolution:		
	Response:		
9.	Have penetrations, gratings, construction openings, etc., been evaluated for proper placement and sealing when open to areas of potential airborne activity?		
	Resolution:		
	Response:		

10.	Are sealed-bearing motors with the motor mounted external to the exhaust duct provided? Are the motors located in a low-dose-rate area?		
	Resolution:		
	Response:		
11.	Is intake air filtered to minimize dust accumulation in radiological areas and exhaust filter loading?		
	Resolution:		
	Response		
12.	Have auxiliary or temporary ventilation systems been provided for sampling stations for highly radioactive fluids (e.g., primary coolant) and for repair of equipment that, when opened, has a potential for airborne releases? (Consider both temporary ductwork attached to existing systems and independent, portable HEPA-filtered ventilation systems.)		
	Resolution:		
	Response:		
13.	Does ventilation from areas of lower potential airborne radioactivity flow to areas of higher potential activity?		
	Resolution:		
	Response:		
14.	Are all ducts carrying potentially contaminated air operated at negative pressure when they pass through clean areas?		
	Resolution:		
	Response:		

15.	Are ventilation supply points located above the worker or work area and away from the sources of contamination, or otherwise placed as appropriate for the work activity (e.g., for work tables, gloveboxes, and hoods)?		
	Resolution:		
	Response:		
16.	Has the drawing or exhausting of potentially contaminated air across walkways and work areas been avoided?		
	Resolution:		
	Response		
17.	Are ventilation exhausts located near the floor and away from entrances of openings to clean areas, or otherwise placed as appropriate for the work activity (e.g., for work tables, gloveboxes, and hoods)?		
	Resolution:		
	Response:		
18.	Are ventilation fans located as close as possible to the discharge point and downstream of the filters?		
	Resolution:		
	Response:		
19.	Has the number of elbows in the ventilation ducts been minimized to reduce plateout?		
	Resolution:		
	Response:		

20.	Are the direction changes in ductwork gradual and minimized?		
	Resolution:		
	Response:		
21.	Are ducts and fans sized so that flow rates are high enough to reduce plateout?		
	Resolution:		
	Response		
22.	Has special materials or coating of inner surfaces been considered to reduce plateout?		
	Resolution:		
	Response:		
23.	In flow balancing, have effects such as opening and closing of large doors, which may occur during normal operation or shutdown, been considered, and are the capacity and flexibility of the ventilation system(s) capable of overcoming these effects?		
	Resolution:		
	Response:		
24.	Is ventilation flow sufficient to keep airborne radioactivity concentrations below prescribed levels?		
	Resolution:		
	Response:		

25.	Have connections been provided to attach temporary ventilation systems where additional ventilation flow may be needed?		
	Resolution:		
	Response:		
26.	Is the ventilation system designed to minimize the use of respirators?		
	Resolution:		
	Response		
27.	Have HEPAs, charcoal filters, electrostatic precipitators, molecular sieves, or other aircleaning devices been provided as appropriate?		
	Resolution:		
	Response:		
28.	Are filters located as close to the source as practicable, and upstream of any fans, to reduce contamination buildup in the ductwork and fans?		
	Resolution:		
	Response:		
29.	Are roughing filters provided upstream of HEPA filters, and are HEPA filters provided upstream of charcoal filters?		
	Resolution:		
	Response:		

30.	Are there drains/dryer/moisture separators upstream of filters and charcoal?		
	Resolution:		
	Response:		
31.	Are there provisions for decontamination of filter housing and ventilation ducts?		
	Resolution:		
	Response		
32.	Are filters for highly contaminated ventilation systems located in shielded housing or in low occupancy and low-traffic areas?		
	Resolution:		
	Response:		
33.	Can airborne activity and filter radiation levels be monitored or sampled without physically entering the area? Are differential pressure gauges provided across filters to monitor the need for filter change?		
	Resolution:		
	Response:		
34.	Are ventilation motors located in low-dose areas?		
	Resolution:		
	Response:		

35.	Does the ventilation system permit filters to be changed easily and with a minimum potential for release of radioactivity and worker exposure?		
	Resolution:		
	Response:		
36.	Is there the capability for in-place testing of the filtration system?		
	Resolution:		
	Response		
37.	Are all airborne and potentially airborne radioactivity areas vented to a monitored release point?		
	Resolution:		
	Response:		
38.	Are connections provided for sampling probes in isokinetic locations, where required?		
	Resolution:		
	Response:		
39.	Can filter housing and filters be removed remotely or quickly in the event of an accident?		
	Resolution:		
	Response:		
40.	Are key ventilation systems provided with emergency power?		
	Resolution:		
	Response:		

41.	Have adequate capacity and volume of HEPA and charcoal filters been provided to handle conditions during abnormal operations?		
	Resolution:		
	Response:		

V. PIPING AND TUBING CHECKLIST

		YES	NO
1.	Are piping run lengths, tees, elbow joints, and horizontal runs minimized?		
	Resolution:		
	Response:		
2.	Has tee-branched piping been routed above the main flow piping or sloped upwards?		
	Resolution:		
	Response		
3.	Are sharp constrictions, sharp bends crud traps, and stagnant legs avoided?		
	Resolution:		
	Response:		
4.	Are surfaces smooth and continuously sloped?		
	Resolution:		
	Response:		

5.	Has piping carrying resin or sludge been designed to reduce the chance of plugging?		
	Resolution:		
	Response:		
6.	Are materials selected to minimize activation products?		
	Resolution:		
	Response		
7.	Has piping carrying highly radioactive fluids been routed away from equipment and components requiring frequent maintenance or repairs?		
	Resolution:		
	Response:		
8.	Has piping carrying highly radioactive fluids been routed in shielded chases or inside shielded cubicles that have restricted access?		
	Resolution:		
	Response:		
9.	Has piping carrying radioactive fluids been segregated from piping not carrying radioactive fluids?		
	Resolution:		
	Response:		

10.	Have adequate controls been established to prevent cross-contamination of clean, nonradioactive systems?		
	Resolution:		
	Response:		
11.	Are pipes and leakage plumbed to drains; and vents to ventilation ducting? Has pressurization of the system been considered?		
	Resolution:		
	Response		
12.	Have piping and components been selected that will maintain containment over the environment qualification range to prevent release of radioactivity to the offsite environment?		
	Resolution:		
	Response:		
13.	Has field routing of piping carrying radioactive fluids been avoided?		
	Resolution:		
	Response:		
14.	Have piping and components requiring maintenance been located in low-dose-rate areas?		
	Resolution:		
	Response:		

15.	Has an adequate number of vents and drains been required to allow system testing, maintenance, and operations?		
	Resolution:		
	Response:		
16.	Have consumable inserts for welding been specified for pipes carrying radioactive materials?		
	Resolution:		
	Response		
17.	Have butt welds rather than socket welds been used for pipes greater than 1.5 inches?		
	Resolution:		
	Response:		
18.	Are pipe bends at least five pipe diameters in radius for the transfer of resin and sludge?		
	Resolution:		
	Response:		
19.	Is instrument tubing that taps into pipes carrying primary coolant located on the top half of the pipe?		
	Resolution:		
	Response:		
20.	Are remote techniques available to unclog plugged drain lines or instrumentation tubing?		
	Resolution:		
	Response:		

21.	Has removable pipe insulation been specified in areas requiring in-service inspection?		
	Resolution:		
	Response:		
22.	Are techniques available to periodically flush, hydrolase, or chemically decontaminate piping? Is the flush connection equipped with quick disconnect fittings?		
	Resolution:		
	Response:		

VI FILTER, STRAINER, EVAPORATOR, AND ION EXCHANGER CHECKLIST

		YES	NO
1.	Are filters provided upstream of deep-bed demineralizers to extend resin life and reduce radioactive waste volume?		
	Resolution:		
	Response:		
2.	Are strainers provided downstream of filters and demineralizers to entrain stray fines?		
	Resolution:		
	Response		
3.	Have demineralizers and resin storage tanks been located so as to facilitate resin flow and reduce the length of pipe needed?		
	Resolution:		
	Response:		

4.	Are filters or strainers backflushable?		
	Resolution:		
	Response:		
5.	Does resin slurry piping have backflushing capabilities with sufficient velocity to relieve plugged lines?		
	Resolution:		
	Response		
6.	Can containment or ventilation be established to reduce the spread of contamination during filter, strainer, or evaporator tube cleaning resin changes?		
	Resolution:		
	Response:		
7.	Are screens filters, or other catch devices placed in the vent and overflow lines? Is pressurization of the system considered?		
	Resolution:		
	Response:		
8.	Is concentrate and distillate piping on evaporators kept separated and segregated?		
	Resolution:		
	Response:		

9.	Are filters, strainers, evaporators, and ion exchangers that contain high radioactivity isolated or shielded?		
	Resolution:		
	Response:		
10.	Are filters, strainers, evaporators, and ion exchangers located in low-occupancy and low-traffic areas?		
	Resolution:		
	Response		
11.	Have filters, strainers, evaporators, ion exchangers, and other related routinely serviced items been selected to be compatible with existing equipment?		
	Resolution:		
	Response:		
12.	Are filter and strainer easily removable?		
	Resolution:		
	Response:		
13.	Has adequate space been provided for removal of filters, strainers, and heating tube bundles?		
	Resolution:		
	Response:		
14.	Have quick disconnects been provided for quick flush connection?		
	Resolution:		
	Response:		

15.	Do filters that process high radioactivity containing water or off gas have remote methods to isolate and drain filter housing?		
	Resolution:		
	Response:		
16.	Have remote or shielded methods for replacement of hot filters, strainers, and resins been considered?		
	Resolution:		
	Response:		
17.	Are systems supplied with flush connections that will facilitate high-velocity decontamination/chemical flushes?		
	Resolution:		
	Response:		

VII. TANK, SUMP, AND FLOOR AND EQUIPMENT DRAIN CHECKLIST

1.	Are tanks generously sized?		
	Resolution:		
	Response:		
2.	Is the tank, drain, or sump bottom sloped to the outlet?		
	Resolution:		
	Response:		

3.	Are corners in tanks eliminated or minimized?		
	Resolution:		
	Response:		
4.	Is adequate tank mixing provided to prevent crud from settling on the bottom?		
	Resolution:		
	Response		
5.	On tanks containing resins or sludge, are screens or strainers provided on tank vents and overflows? Is the overflow line lower than the tank's vent?		
	Resolution:		
	Response:		
6.	Is the tank vent outlet located near a plant ventilation system inlet?		
	Resolution:		
	Response:		
7.	Has curbing or other containment been considered to restrict the spread of leakage? Is curbing or other containment required to prevent an unmonitored release?		
	Resolution:		
	Response:		
8.	Are radioactive tanks or sumps located or shielded so as to minimize personnel exposure?		
	Resolution:		
	Response:		

9.	Are piping run lengths, tees, elbow joints, and horizontal runs minimized?		
	Resolution:		
	Response:		
10.	Are pipes sized to reduce crud deposition?		
	Resolution:		
	Response		
11.	Is the flow adequate to maintain homogeneity and keep solids in suspension?		
	Resolution:		
	Response:		
12.	Are full-ported valves used in radioactive fluid streams with high-solids contents?		
	Resolution:		
	Response:		
13.	Are automated valves used to ensure continued flow after a backwash or precoat?		
	Resolution:		
	Response:		
14.	Is a “recirc” line provided to ensure good mixing before tank transfer?		
	Resolution:		
	Response:		

15.	Are the interior surfaces smooth and free of pockets to facilitate decontamination?		
	Resolution:		
	Response:		
16.	Are pipes containing radioactive material isolated from uncontrolled areas?		
	Resolution:		
	Response		
17.	Are transfer lines located in low-occupancy and low-traffic areas?		
	Resolution:		
	Response:		
18.	Does adequate space exist for maintenance and repair of tank support equipment (e.g., pumps, agitators, gear boxes)?		
	Resolution:		
	Response:		
19.	Have decontamination methods been considered?		
	Resolution:		
	Response:		
20.	Are lap joints and backing rings avoided on welds?		
	Resolution:		
	Response:		

21.	Is a built-in spray system, manway with adequate laydown space, drain or flush system included for cleanout?		
	Resolution:		
	Response:		

VIII. HEAT EXCHANGER, MOISTURE SEPARATOR, AND HEATER CHECKLIST

		YES	NO
1.	Are drains provided at the low point so as to drain out radioactive crud and facilitate cleaning?		
	Resolution:		
	Response:		
2.	Are vessels designed such that crud traps are minimized in those areas where access is needed for inspection and cleaning?		
	Resolution:		
	Response		
3.	Have materials been selected to minimize corrosion?		
	Resolution:		
	Response:		
4.	Are heat exchangers oriented in the vertical position?		
	Resolution:		
	Response:		

5.	Is the pressure higher on the side with the lower concentration of radioactivity so that leakage would result in nonradioactive water leaking into the radioactive system rather than the reverse?		
	Resolution:		
	Response:		
6.	Have curbing and drains been provided to contain radioactivity during repair and cleaning?		
	Resolution:		
	Response		
7.	Is the fluid with the high concentration of radioactivity inside the tube so that the water on the shell side provides shielding?		
	Resolution:		
	Response:		
8.	Are heat exchangers that are expected to become highly radioactive placed inside shielded cubicles and provided with a flushing or decontamination capability?		
	Resolution:		
	Response:		
9.	Has adequate space and component design been provided to facilitate removal and cleaning of tube bundles and/or shell?		
	Resolution:		
	Response:		

IX. ELECTRICAL CABLE AND CONDUIT CHECKLIST

		YES	NO
1.	Has a walkdown or photographs that may aid in locating conduit runs in low-dose-rate and low-interference areas been considered?		
	Resolution:		
	Response:		
2.	Have cable and conduit been routed in low-dose-rate areas?		
	Resolution:		
	Response		
3.	Have breaker boxes, power control centers, and electrical cabinets been located in low-dose rate areas?		
	Resolution:		
	Response:		
4.	Are long-life bulbs used in radiation and contamination areas?		
	Resolution:		
	Response:		
5.	Has electrical equipment been selected that minimizes inspection, calibration, testing, and preventative maintenance?		
	Resolution:		
	Response:		

		YES	NO
6.	Do electrical connectors to equipment have quick-disconnect features, where appropriate?		
	Resolution:		
	Response:		
7.	For electrical systems that are difficult to inspect or troubleshoot, has external analysis capability been considered for fault location determination?		
	Resolution:		
	Response		
8.	Can busses, conduit, supports, trays, and electrical cabinets be prefabricated in a low-dose-rate area?		
	Resolution:		
	Response:		
9.	Are sufficient electrical outlets provided for air-sampling devices, electrical tools, welding machines, and temporary distribution boxes?		
	Resolution:		
	Response:		
10.	Have adequate lighting and electrical outlets, as well as provisions for supplementary and emergency lighting, been provided?		
	Resolution:		
	Response:		

11.	Does conduit or other electrical equipment interfere with the maintenance or operation of other equipment?		
	Resolution:		
	Response:		

X. INSTRUMENTATION AND CONTROLS CHECKLIST

		YES	NO
1.	Are bends in sample lines minimized?		
	Resolution:		
	Response:		
2.	Are sample lines in high radioactivity systems provided with a strong and continuous purge?		
	Resolution:		
	Response		
3.	Does the ventilation hood have a face velocity of 100-150 linear feet per minute with the hood window in its full open position?		
	Resolution:		
	Response:		
4.	Is the ventilation hood exhaust directed to the facility vent upstream of the filters?		
	Resolution:		
	Response:		

5.	Are sampling sink drains for radioactive samples routed to radwaste and free of potential crud traps?		
	Resolution:		
	Response:		
6.	Are the sampling sinks for radioactive materials constructed of a material or coated such that they will be easy to decontaminate?		
	Resolution:		
	Response		
7.	Are routine sampling stations for radioactive materials separated or shielded from other radioactive components?		
	Resolution:		
	Response:		
8.	Are the sample stations adequately shielded?		
	Resolution:		
	Response:		
9.	Is cross contamination of nonradioactive systems minimized and/or monitored?		
	Resolution:		
	Response:		

10.	Are monitors visible?		
	Resolution:		
	Response:		
11.	Have methods been provided to perform remote sampling and monitoring for airborne radioactivity?		
	Resolution:		
	Response		
12.	Are process and effluent monitors located as to provide enough detection leak time to divert or isolate a process stream?		
	Resolution:		
	Response:		
13.	Are personnel monitors provided?		
	Resolution:		
	Response:		
14.	Are airborne radioactivity monitors capable of detecting 8 DAC-hours?		
	Resolution:		
	Response:		
15.	Do all monitors automatically detect monitor failure and indicate if the dose rate is off-scale?		
	Resolution:		
	Response:		

16.	Are monitors visible?		
	Resolution:		
	Response:		
17.	Are flush connections provided for instrumentation lines carrying radioactive fluid in which crud traps cannot be avoided?		
	Resolution:		
	Response		
18.	Do instruments contain minimal quantities of contaminated working fluids?		
	Resolution:		
	Response:		
19.	Are instrument tubing taps located on the top half of instrument lines carrying radioactive fluids?		
	Resolution:		
	Response:		
20.	When access is necessary, is instrumentation located in what will be a low background area? Have remote readouts (or closed circuit TV monitoring) and calibrations been considered?		
	Resolution:		
	Response:		

21.	Have communication devices such as pagers and telephones been located in low-dose-rate areas and low-noise areas?		
	Resolution:		
	Response:		
22.	Are instruments located in High Radiation Areas easily removable for repair and calibration?		
	Resolution:		
	Response		
23.	Are instruments grouped functionally to minimize time for surveillance and calibration?		
	Resolution:		
	Response:		
24.	Does the instrument selected take into account frequency of maintenance, repair, testing, and calibration?		
	Resolution:		
	Response:		
25.	Have instruments been selected with features of computerized or automated data loggings (applicable)?		
	Resolution:		
	Response:		

26.	Are warning systems such as lights, alarms, and sirens provided in areas where high radiation levels can change with time?		
	Resolution:		
	Response:		
27.	Have instruments been chosen that are radiation qualified for the areas they are to function in?		
	Resolution:		
	Response:		

XI. PUMP CHECKLIST

		YES	NO
1.	Is there a capability to flush seals and cooling lines that carry radioactive fluids?		
	Resolution:		
	Response:		
2.	Have catch pans or floor and equipment drains or curbing berms been installed around radioactive pumps that have a potential for leakage?		
	Resolution:		
	Response		
3.	Do pump casings have drain connections, and are impellers fabricated with smooth surface finishes?		
	Resolution:		
	Response:		

4.	Have pump maintenance requirements been considered?		
	Resolution:		
	Response:		
5.	Have canned pumps or mechanical seals been considered instead of standard packing glands?		
	Resolution:		
	Response		
6.	Are pump seals easily accessible and replaceable?		
	Resolution:		
	Response:		
7.	Can the pump be removed without affecting the surrounding components?		
	Resolution:		
	Response:		
8.	Is there adequate pull space for motor shafts?		
	Resolution:		
	Response:		
9.	Are pumps that are located in High Radiation Areas and require periodic repair or maintenance been provided with flanged connections to make them easy to remove?		
	Resolution:		
	Response:		

10.	Have rigging and lifting points been provided to life heavy pump parts during repair?		
	Resolution:		
	Response:		
11.	Are pumps oriented to permit easy access?		
	Resolution:		
	Response:		

XII. VALVE CHECKLIST

		YES	NO
1.	Are valves full-ported (e.g., ball valves), without bonnet cavities, installed stem up, and located away from low points in piping?		
	Resolution:		
	Response:		
2.	Are valves selected with internal surfaces and configurations that will minimize crud buildup?		
	Resolution:		
	Response		
3.	Are materials selected to minimize activation products and are stellite filings controlled?		
	Resolution:		
	Response:		

4.	Do specified valve packing and seals result in minimal contaminated coolant leakage and maximum reliability (e.g., live-loaded packing)?		
	Resolution:		
	Response:		
5.	Are check valves included with appropriate caution to prevent radioactive fluid backup?		
	Resolution:		
	Response		
6.	Are catch pans, floor and equipment drains, and drip pans or curbing installed under valves that have a significant potential for leakage of radioactive liquids?		
	Resolution:		
	Response:		
7.	Are valves carrying primary coolant separated from associated equipment and components operated and maintained from the floor or a platform?		
	Resolution:		
	Response:		
8.	Are valves located in low-dose areas?		
	Resolution:		
	Response:		

9.	Do highly radioactive valves that are manually-operated have remote operating reach rods and/or are located in shielded cubicle or shielded valve galleries?		
	Resolution:		
	Response:		
10.	Are any modifications required that can be performed in a low-dose-rate area prior to installation (e.g., removal and plugging of gland seal leakoff lines)?		
	Resolution:		
	Response		
11.	Are valves located so as to be easily operated and maintained from the floor or a platform?		
	Resolution:		
	Response:		
12.	Is quick access to packings provided?		
	Resolution:		
	Response:		
13.	Can the valve operator be quickly removed?		
	Resolution:		
	Response:		
14.	Are pressure relief or isolation valves provided with flanged connections to facilitate testing?		
	Resolution:		
	Response:		

15.	Are rigging and lifting points provided for heavy valve removal?		
	Resolution:		
	Response:		
16.	Has future decommissioning been considered (e.g., isolation valves for fluid systems)?		
	Resolution:		
	Response:		

XII. ACCESS CONTROL CHECKLIST

		YES	NO
1.	Have frequently used pathways been located in low-dose rate and noncontaminated areas?		
	Resolution:		
	Response:		
2.	Are routes laid out so nonradioactive material does not have to pass through radiological areas and vice versa?		
	Resolution:		
	Response		
3.	Are traffic routes such that individuals do not have to pass through radiological areas when traveling between two clean or general access areas?		
	Resolution:		
	Response:		

4.	Is the path for emergency personnel planned and clearly delineated?		
	Resolution:		
	Response:		
5.	Have frequently used pathways been located in low-dose rate and noncontaminated areas?		
	Resolution:		
	Response		
6.	Is entry prohibited to areas where conditions are an immediate hazard to human life?		
	Resolution:		
	Response:		
7.	Is there a control device to prevent entry to areas when high radiation levels exist or upon entry causes the radiation level to be reduced below that level defining a high radiation area?		
	Resolution:		
	Response:		
8.	Is access prohibited to very high radiation areas?		
	Resolution:		
	Response:		

9.	Are there physical barriers to prevent the entry of unauthorized individuals into areas with significant concentrations of airborne radioactive materials?		
	Resolution:		
	Response:		
10.	Are panic exit bars provided on insides of locked doors?		
	Resolution:		
	Response		
11.	Is the number of personnel access control points minimized?		
	Resolution:		
	Response:		
12.	Are personnel access control points adequate in size and associated equipment (e.g., personnel monitoring, card readers)?		
	Resolution:		
	Response:		
13.	Are temporary access control points available where it is anticipated they will be needed?		
	Resolution:		
	Response:		
14.	Is there adequate space (including maintenance and inspection), support, electrical hookups for personnel contamination monitors?		
	Resolution:		
	Response:		

15.	Are supports located so as not to interfere with inspections, maintenance and removal of equipment?		
	Resolution:		
	Response:		
16.	Are permanent platforms, rigging devices, etc., for easy access to components in hard-to-reach places?		
	Resolution:		
	Response:		
17.	Are sequential areas (e.g., general access to controlled to radiological) utilized?		
	Resolution:		
	Response:		

XIV. CONTAMINATION CONTROL DESIGN CHECKLIST

		YES	NO
1.	Have surfaces that are likely to become contaminated been painted or prepared so as to facilitate decontamination?		
	Resolution:		
	Response:		
2.	Have walls or curbing and floor or equipment drains been installed around equipment that has a high potential for leakage?		
	Resolution:		
	Response		

3.	Are contaminated drains directed to the proper sump or tank?		
	Resolution:		
	Response:		
4.	Has space and support for glove bags and other containment devices been provided maintenance of heat exchangers, piping, valves, etc.?		
	Resolution:		
	Response		
5.	Is hard piping to sumps used for tank overflows, valve stem leakage, etc.?		
	Resolution:		
	Response:		
6.	Are floors sloped to direct leakage to floor drains or sumps?		
	Resolution:		
	Response:		
7.	Are raised sleeves used for floor penetrations?		
	Resolution:		
	Response:		
8.	Are open gratings for stairs or platforms avoided in potentially contaminated areas?		
	Resolution:		
	Response:		

9.	Are contaminated drains directed to the proper sump or tank?		
	Resolution:		
	Response:		
10.	Has space and support for glove bags and other containment devices been provided maintenance of heat exchangers, piping, valves, etc.?		
	Resolution:		
	Response		
11.	Is hard piping to sumps used for tank overflows, valve stem leakage, etc.?		
	Resolution:		
	Response:		

XV. RADIOACTIVE WASTE CHECKLIST

		YES	NO
1.	Is there a designated area for storage of radioactive waste, with proper containment, shielding, monitoring, etc.?		
	Resolution:		
	Response:		
2.	Is the waste storage area large enough to accommodate twice the expected volume of waste?		
	Resolution:		
	Response		

3.	Are distances minimized over which moderately and highly radioactive material is transported?		
	Resolution:		
	Response:		
4.	Are there monitoring systems to detect any leaks or spills where drainage or retention is unattended or is remote-controlled?		
	Resolution:		
	Response		
5.	Are fire-suppression systems installed in all areas where combustible material may accumulate or be stored?		
	Resolution:		
	Response:		

XVI. SHIELDING, PENETRATIONS, AND ROUTING CHECKLIST

		YES	NO
1.	Are labyrinth entrances used for High Radiation and Very High Radiation Areas?		
	Resolution:		
	Response:		
2.	Is shielding adequate for potential buildup of crud?		
	Resolution:		
	Response		

3.	Have provisions been made for overlapping and stepping for removable shielding?		
	Resolution:		
	Response:		
4.	Have permanent hooks, latches, fasteners, and structural supports been added to secure temporary shielding?		
	Resolution:		
	Response		
5.	Are penetrations minimized in number and size?		
	Resolution:		
	Response:		
6.	Are penetrations placed in the thinnest shield wall, near a corner, as high up as possible, and not in a line of sight with a source?		
	Resolution:		
	Response:		
7.	Have offset penetrations been considered?		
	Resolution:		
	Response:		
8.	Are primary containment penetrations sealed with respect to streaming, air-flow control, fire protection and flooding as applicable?		
	Resolution:		
	Response:		

9.	Are labyrinths or shadow shields used?		
	Resolution:		
	Response:		
10.	Have provisions been made so that no direct or reflected radiation escapes a shielded cubicle without passing through a suitable shield?		
	Resolution:		
	Response		
11.	Are all serviced components (e.g., connections, junction boxes, panels) located in low-dose rate areas or at least on the low-dose side of the wall)?		
	Resolution:		
	Response:		
12.	Are run lengths of potentially contaminated pipes minimized?		
	Resolution:		
	Response:		
13.	Is there adequate clearance for maintenance, inspection, and insulation?		
	Resolution:		
	Response:		

XVII. SEPARATION, SEGREGATION, PLACEMENT AND ISOLATION OF EQUIPMENT CHECKLIST

		YES	NO
1.	Are labyrinth entrances used for High Radiation and Very High Radiation Areas?		
	Resolution:		
	Response:		
2.	Is shielding adequate for potential buildup of crud?		
	Resolution:		
	Response		
3.	Is highly radioactive equipment segregated from moderately radioactive equipment, and both from clean equipment?		
	Resolution:		
	Response:		
4.	Are different systems segregated so that both systems do not have to be flushed, drained or decontaminated to reduce the dose when only one needs maintenance?		
	Resolution:		
	Response		
5.	Are equipment areas laid out so that workers enter and progress from low-dose rate areas to moderate to high dose rate areas, and from active to passive equipment?		
	Resolution:		
	Response		

		YES	NO
6.	Are inspection, control and readout devices and panels located in low-dose rate areas?		
	Resolution:		
	Response:		
7.	Are services (e.g., demineralized water, electricity) located near entrances or at least in the lowest-dose rate areas?		
	Resolution:		
	Response		
8.	Are isolation valves located as to minimize dead legs?		
	Resolution:		
	Response:		
9.	Are pipe runs minimized?		
	Resolution:		
	Response		
10.	Are temporary interconnections used between systems of difference radioactivity potential?		
	Resolution:		
	Response		
11.	Are redundancy and backup capabilities employed in system of high radioactivity content and safety systems?		
	Resolution:		
	Response		

XVIII. ACCESSIBILITY, LAYDOWN AND STORAGE CHECKLIST

		YES	NO
1.	Have wide and large enough doorways and access areas been provided so that components can be easily removed for maintenance and inspection?		
	Resolution:		
	Response:		
2.	Has adequate laydown space been provided to accommodate equipment and component disassembly?		
	Resolution:		
	Response		
3.	Is highly radioactive equipment segregated from moderately radioactive equipment, and both from clean equipment?		
	Resolution:		
	Response:		
4.	Is adequate working space provided around major components?		
	Resolution:		
	Response		
5.	Are lifting devices provided for equipment?		
	Resolution:		
	Response		

		YES	NO
6.	Are permanent galleries or scaffolding provided where maintenance is frequent or prolonged?		
	Resolution:		
	Response:		
7.	Is there adequate access around welds?		
	Resolution:		
	Response		
8.	Has the number of stops, hangers, supports and snubbers been minimized and are they orientated to maximize access space?		
	Resolution:		
	Response:		
9.	Have sectional or modular designs been considered (e.g., snap-on segments of insulation on heat-traced lines that require frequent maintenance)?		
	Resolution:		
	Response		
10.	Are laydown spaces in low-dose rate areas?		
	Resolution:		
	Response		
11.	Has storage been provided for hot tool and is it appropriate posted, locked, shielded and vented?		
	Resolution:		
	Response		

12.	Has proper storage been provided for nonradioactive items?		
	Resolution:		
	Response		

XIX. SNUBBERS, STRUT HANGERS, AND ANCHORING CHECKLIST

		YES	NO
1.	Are snubbers, struts, hanger and anchors designed and located so as to facilitate removal and replacements?		
	Resolution:		
	Response:		
2.	Have snubbers, struts, hangers, and anchors been located so as not to interfere with inspections and maintenance?		
	Resolution:		
	Response		
3.	Have snubbers been replaced with struts or energy absorbers whenever possible?		
	Resolution:		
	Response:		
4.	Have snubbers, struts, hangers, and anchors been painted and tagged to facilitate location for repair and inspection?		
	Resolution:		
	Response		

XX. HUMAN FACTORS CHECKLIST

		YES	NO
1.	Are signs, indicators, readouts, etc., clearly legible from a reasonable distance away?		
	Resolution:		
	Response:		
2.	Has nonstandard lettering been avoided?		
	Resolution:		
	Response		
3.	Is lighting adequate?		
	Resolution:		
	Response:		
4.	Is background noise minimized around audible alarms?		
	Resolution:		
	Response		
5.	Are audible alarms of sufficient decibels and placed to include all potentially occupied areas?		
	Resolution:		
	Response		

		YES	NO
6.	Has equipment that reduces number of workers (e.g., lifting devices, special tools) been considered?		
	Resolution:		
	Response:		
7.	Is there a provision for lifelines for tanks, pools or other areas with high dose rates or high airborne radioactivity?		
	Resolution:		
	Response		
8.	Are permanent alignment marks on the equipment or floor?		
	Resolution:		
	Response:		
9.	Are tools, conduit, bolts, and pipes color coded?		
	Resolution:		
	Response		
10.	Is insulation identified as to what is under it?		
	Resolution:		
	Response		
11.	Are valve position, breaker settings, etc., clearly marked as to system lineup?		
	Resolution:		
	Response		

12.	Are valves, valve operators, controls, etc., in a logical manner?		
	Resolution:		
	Response		
13.	Has automation or use of interlocks and warning been considered for manual sequences of high consequence?		
	Resolution:		
	Response		
14.	Are mockups and simulators available?		
	Resolution:		
	Response		

XXI. OPERATION, MAINTENANCE AND INSPECTION CHECKLIST

		YES	NO
1.	Has adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., been considered for operation of equipment?		
	Resolution:		
	Response:		
2.	Have remote operators or reach rods on high-dose rate valves been located outside contaminated areas?		
	Resolution:		
	Response		

		YES	NO
3.	Have instrument readouts been located in low-dose rate areas and away from contaminated areas whenever possible?		
	Resolution:		
	Response:		
4.	Can operations and surveillance be performed from outside a High Radiation Area through the use of remote readout devices, viewing ports, radiation detector ports or TV cameras?		
	Resolution:		
	Response		
5.	Is access to equipment or instruments requiring frequent manual operation or surveillance via areas with the lowest possible dose rate?		
	Resolution:		
	Response:		
6.	Has adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., been considered for maintenance of equipment?		
	Resolution:		
	Response		
7.	Has the component or system been selected based on long-service life?		
	Resolution:		
	Response		

		YES	NO
8.	Are components requiring frequent maintenance (e.g., small pumps and valves) designed to permit prompt removal (e.g., flanged connections) to facilitate repairs in low-dose rate areas?		
	Resolution:		
	Response:		
9.	Have periodic maintenance items been eliminated whenever possible (e.g., O-rings, gaskets, packing protective coatings, lighting components)?		
	Resolution:		
	Response		
10.	Have lubricating systems of self-lubricating units been considered?		
	Resolution:		
	Response:		
11.	Are provisions incorporated to allow rigging of the component? (E.g., pad eyes)?		
	Resolution:		
	Response		
12.	Is access to equipment and components requiring frequent maintenance via areas with lowest dose rates practicable?		
	Resolution:		
	Response		

		YES	NO
13.	Does the valve maintenance procedure control stellite filings to reduce cobalt where neutron activation of the stellite possible?		
	Resolution:		
	Response:		
14.	Are components designed and oriented to minimize crud buildup?		
	Resolution:		
	Response		
15.	Has adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., been considered for inspections?		
	Resolution:		
	Response:		
16.	Does insulation design allow for rapid removal and replacement (e.g., match marks, fiberglass blankets)?		
	Resolution:		
	Response		
17.	Has equipment been laid out with consideration given to facilitating inspections required by Section XI of the ASME Code, Appendix J, Appendix R, and other inspection requirements of the ISI leak rate and fire protection program?		
	Resolution:		
	Response		

18.	Are there visible tags and levels to identify equipment, snubbers, welds, penetrations, valves and other items requiring inspection?		
	Resolution:		
	Response		
19.	Is access to equipment or components requiring frequent inspections via areas with lowest possible dose?		
	Resolution:		
	Response		

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APPENDIX E - METHODS OF PERFORMING AN ALARA OPERATIONAL REVIEW

I. METHODS OF PERFORMING AN ALARA OPERATIONAL REVIEW

The following method is suggested as a practical way of accomplishing and documenting the review of a new or revised operation or job campaign, the "Operation" or the "Project."

A. Operations Team.

1. Consists of people who are providing input into the project, whether continuously or intermittently.

2. The Operations Team may include a member with radiological work experience, such as a radiological engineer, ALARA engineer, and a health physicist.

B. Contributor Group.

1. Consists of representatives of other groups who may not provide formal input to the operation, but whose comments and suggestions are considered relevant.

2. These may include maintenance, process, and research groups. Members of the Operations Team and representative members of the Contributor Group may both participate in the ALARA Operational Review.

C. ALARA Review Coordinator.

There may also be an ALARA Review Coordinator appointed by the Radiological Control Manager or the Operations Manager. This individual may be an ALARA specialist, radiological engineer, or health physicist; for small or routine jobs, the individual may be a job supervisor trained in ALARA.

The ALARA Review Coordinator, with input from the Operations Manager, is responsible for seeing that the ALARA Review is performed, completed, and documented.

D. Information Gathering.

The beginning of the process is information gathering by the ALARA Coordinator.

1. The Coordinator should be knowledgeable about the functions, layout, equipment, and limiting factors associated with the operation, particularly:

a. Layout and location of the area;

b. Number and types of workers in each known or possible radiological area associated with each step of the operation;

c. Nature of each task workers are to do;

d. Time spent by each worker on each task;

e. Paths to and from the radiological area(s) and the transit time;

f. Physical features such as ladders, manholes, or hoods; and

g. Work-area-dose rates and wall thicknesses (in case shielding is needed).

2. Such information may come from systems descriptions, drawings, and other descriptive design documents, but could also come from walkdowns of the subject area, interviews with the manager of the operation and members of the Operations Team as appropriate, and discussions with vendors or contractors.

3. In particular, the Radiological Control Organization should be asked to provide historical dose and dose rate information, or to perform an appropriate radiological study of the area.

4. Based on this information, the ALARA Review Coordinator or designee (e.g., the local HP) should estimate doses and dose rates associated with the operation, taking credit for any engineered controls to be used.

5. The ALARA Review Coordinator should then describe the radiological features and implications in writing.

6. Small or Routine Jobs
For small or routine jobs only, if a review such as this is done, the Radiological Control Organization may provide simple dose and dose rate information to the Coordinator, and the write-up of the job can be omitted if it is covered by routine job procedures, standard practice, or information on an RWP prepared for this job.

E. Preoperational Review (Planning Checklist).

1. The ALARA Review Coordinator sends or presents to the Operations Team and representative members of the Contributor Group the written information regarding the operation, proposed engineering and administrative controls, and the estimated doses.

2. The team and the representative Contributor Group members may use the Prejob (planning) section of the ALARA Operations Review Checklist as a tool to review and comment on this information.

3. The checklists they complete are sent to the Coordinator, who records the information in a report, as amended by the review, including all comments, their resolutions, and a listing of hold points.

   A hold point is a step in the operation where work is stopped for evaluation of progress of analysis of data or for radiological surveys and evaluations, pending a decision by named groups or individuals as to how or whether or not to proceed. "Named" means that their title or job classification is given in a procedure (e.g., "Do not proceed until HP has taken an air sample" or "If any individual dose exceeds 200 mrem at this point, do not proceed until the Facility Manager has approved a further dose increment").

4. The Coordinator combines the checklists from the various reviewers into a single-draft version of the ALARA Checklist, noting any discrepancies and resolutions of reviewer comments. (Note that only the Planning section is completed at this point.)

5. This checklist and other associated written information serves as documentation of the Prejob Review. As a report, it should be sent to:
   a. Members of the Operations Team,

   b. Members of the Contributor Group,

   c. Radiological Control section (including the area/facility safety representative if not on the Operations Team),

d. ALARA Program group, and

e. Other interested parties.

6. In the case of required ALARA reviews (e.g., by procedure), this can be written up as an ALARA plan for the operation. (For small or routine jobs, of course, no plan is required.)

7. Further revisions can be made to the Checklist write-up as necessary.

8. The Report eventually should be attached to the official copy of the RWP for future reference.

II. PREJOB REVIEWS

A. Preparation and Review of the Radiological Work Permit (RWP).

1. The RWP is prepared by the appropriate person(s) according to procedure, and necessary approvals are secured.

2. A further review of the RWP may be required in accordance with the RWP procedure.

3. After the RWP is written, the ALARA Review Coordinator, in consultation with the Operations Manager and the area/facility safety representative, establishes the dose and other applicable ALARA goals for the operation. These should be circulated to the same parties who received a copy of the Review Report and should eventually be attached to the official copy of the RWP.

4. The ALARA Review Report, the RWP, and the goals write-up together are referred to here as the “RWP Package.”

B. Prejob Briefing.

1. The briefing is for supervisors, workers, an area/facility safety representative, and Radiological Control personnel.

2. It could range from a simple rundown of the radiological conditions to a more complete presentation that covers RWP requirements and the work procedure to be followed.

3. It could be a complete series of training sessions, including practice on mockups.

4. The radiological controls, which should be in place before the operation is started, should also be covered so that those people who are briefed will understand them before the operation is started.

5. Other operations conducted simultaneously, which could affect this operation, should also be described.

6. The ALARA Review Coordinator and the Operations Manager should determine the scope of the briefing based on advice from the Radiological Control Section or the ALARA Program group, or both, and information contained on the RWP Package.

C. Prejob Check (Start of Job Checklist).

1. This ensures that radiological controls are in place before an operation starts.

2. The Prejob Check should be performed by the Operations Manager or other designated person(s).

3. The work supervisor and area/facility safety representative in charge should also verify that radiological controls are in place.

4. The performance of these checks and verifications should be recorded in writing and signed by the individuals who performed them (there may be operating procedures for documenting this).

5. The Operations Manager should report to the ALARA Review Coordinator that the check has been done.

6. The ALARA Review Coordinator then completes the Start of Job section of the ALARA Operational Review Checklist.

III. OPERATIONAL REVIEWS

During the Operation (substitute site-specific titles as appropriate).

1. Tracking of dose and man-hours during the operation will normally be done by radiological control personnel.

2. The radiological control personnel may recommend or order that the work be stopped due to unexpected circumstances that may result in excessively high doses:

   a. Dose rates higher than anticipated.

   b. Airborne radioactivity levels higher than anticipated.

   c. Slow work completion rates.

   d. Unsafe working conditions.

3. The radiological control personnel may require simple alterations to the RWP if the circumstances are not likely to result in significant increases above the expected doses, or may request a revisitation of the ALARA review in view of the actual situation.

4. The scope of such a review should be decided by the Radiological Control Manager, the Operation Manager, and the ALARA Program Manager.

5. Facility operational management should cooperate in this review, whatever its scope.

IV. POST OPERATIONAL REVIEW

Substitute site-specific information as applicable.

1. Finally, when complete, the operation should be reviewed against the RWP Package by management, the Radiological Control personnel, and the ALARA program group.

2. The last section of the ALARA Operational Review Checklist (Postjob Review) should be filled out by the Operation Manager, the area/facility safety representative, and other parties, as appropriate.

3. These should be collated by the ALARA Review Coordinator into a final version of this section that should be circulated for final review and comment to appropriate parties, including the area/facility safety representative.

4. The ALARA Review Coordinator then produces the final version of the Postjob Review section of the ALARA Operational Review Checklist, adds it to the other sections, and sends it to appropriate parties. It is attached to the RWP to form the RWP Package or Work Package of record. Copies are retained as part of the required documentation.

5. Note that a formal job review even beyond the scope of this one may be procedurally required for some jobs.

6. If any ALARA goals, administrative levels, or regulatory limits were exceeded, the Radiological Control Organization and ALARA Review Coordinator should be informed, even if they were not involved up to this point (e.g., on a small job). The following should then be determined by the Operation Manager, area/facility safety representative, and ALARA Review Coordinator in consultation with these groups:

   a. Which ALARA goals were exceeded and why.

   b. Which administrative limits were exceeded and why.

   c. Which regulatory limits were exceeded and why.

   d. The effectiveness of dose reduction measures employed.

   e. Recommendations for future performances of this or similar operations.

7. The ALARA Review Coordinator should pool the findings in a memorandum or report to be presented to the Operation Division management, the appropriate committees, and other interested parties.

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APPENDIX F - COST-BENEFIT ANALYSIS

I. COST-BENEFIT ANALYSIS

Cost-Benefit Analysis (CBA) involves estimating the costs and benefits associated with a design change or modification to choose among alternatives or to select the optional value of a parameter. These costs and benefits must be estimated over the life of the new measure, feature, or practice. In addition, if adjustment is needed to correct for inflation, the techniques of engineering economics, such as the use of future value adjustment and annualization, can be used.

II. COST-BENEFIT ANALYSIS METHODOLOGY (CBA WORKSHEET)

A. (Dollar) Value of a Person-Rem.

In a CBA, all of the items to be considered must be expressed in the same units, usually dollars. Thus, to convert doses in a CBA to dollars, we must have a conversion factor. Such a conversion factor is called the (dollar) value of a person-rem. There may be actually several different values for different purposes. DOE has specified that this value(s) is to be set on a site-by-site basis; at (your site), this value(s) is $ per person-rem.

For comparison, note that NUREG-1530 states that the NRC now uses a value of $2,000 per person-rem, makes future value adjustments, and restricts the basis of this figure to health effects only.

B. Formal Methodology.

The point of optimization is to maximize the net benefit of an activity or design or of a feature of an activity or design. Thus, we have the following general equation:

$$B = V - P - X - Y$$

where B is the net benefit, V is the gross benefit, P is the costs of production not including radiation protection costs, X is the radiation protection costs, and Y is the dose cost. As can be seen, we can maximize B by maximizing V and minimizing P, X, and Y.

In practice, it is sometimes difficult to place a value on benefits and costs; for example, what is the value of a research activity that does not produce a marketable “product” but does produce useful information? For this reason, we try to look at only those components of B (i.e., V, P, X, and Y) that change and compare those. For example, if the only question is “one foot or two” of shielding and we can rule out effects on efficiency of operation, pipe routing, etc., as insignificant, then we could look at only X and Y. This is true because with more shielding the cost goes up but the dose goes down, and vice versa. In this case, V and P would not depend on the value of the thickness, and we could write

$$dB/dt = d/dt\,(V - P - X - Y) = - d/dt\,(X+Y)$$

We can set this equal to zero so as to solve for the value of t that makes B a maximum and the sum of X + Y a minimum. Note that neither X nor Y is necessarily a minimum, but rather the sum must be a minimum. This approach works where X and Y (and possibly V and P as well) are functions of a continuous variable.

If we are comparing separate alternatives, we can again start from the B equation. For two alternatives, we have

$$B_1 \geq V_1 - P_1 - X_1 - Y_1$$

$$B_2 \geq V_2 - P_2 - X_2 - Y_2$$

For $B_2 \geq B_1$, we must have $(V_2 - P_2 - X_2 - Y_2) \geq (V_1 - P_1 - X_1 - Y_1)$, or

$$(V_2 - V_1) \geq (P_2 + X_2 + Y_2) - (P_1 + X_1 + Y_1)$$

That is, the net benefits of choosing Alternative 2 over Alternative 1 must exceed the net costs.

Note that where V and P are essentially the same in the two alternatives, this boils down to a shorter cost expression:

$$X_1 + Y_1 \geq X_2 + Y_2$$

Finally, note that if there is one new feature to be considered, we really have two alternatives: adopting the new feature or measure and not adopting the new feature (i.e., keeping the status quo). However, given a value of a man-rem, one can look at the “marginal” value of the alternative as follows. First,

$$B_1 - (V_1 - P_1 - X_1) = Y_1$$

$$B_2 - (V_2 - P_2 - X_2) = Y_2$$

Then,

$$B_2 - (V_2 - P_2 - X_2) - \{B_1 - (V_1 - P_1 - X_1)\} = Y_2 - Y_1$$

We see that the expression to the left of the equals sign boils down to the net savings or net costs, depending on whether the value is positive or negative. Similarly, the expression on the right is the net dose savings or net dose cost. Let us call the expressions the net cost and the net dose cost, with the understanding that these might actually be savings if the value is negative. We could proceed directly to this point by writing this ratio:

□ Costs/□ Dose = ?

If the ratio is positive, then the cheaper option also has the lowest dose. If the ratio is negative and its absolute value exceeds the site's ALARA criteria (in units of dollar/man-rem), then the measure is not cost-effective and should be not adopted. If the value is less, then it is cost-effective to adopt it. Many people prefer this "ratio of differences" method to the X + Y comparison method, but the former does not always give unique results and can be more difficult to interpret if there are more than two options or if optimization is to be done on a continuous variable.

C. Implementation of the Methodology.

There are four main steps in performing a CBA, as given below.

1. Describe each feature or measure, including the status quo where applicable. This should include the radiological implications of its adoption.

2. Estimate or calculate the applicable costs, benefits, and doses for each feature or measure. If any dose exceeds a regulatory limit or a contract provision, or there is any other such absolute barrier, then the feature or measure can be ruled out at once and the analysis need not be completed.

3. Determine the net benefit or a shorter cost expression of each feature or measure and then compare them. Or, where applicable, form the cost-dose difference ratio and compare it to the value of a person-rem.

4. Where the results are close or where there are uncertainties, perform a subjective factors analysis or a sensitivity analysis or both.

D. Description of a Feature, Measure, or Practice.

In describing a feature, measure, or practice, only information that has a bearing on the analysis should be provided. This would include the area or facility at which or for which the feature, measure, or practice would be adopted; the effects on radiological protection, such as increased need for shielding, reduction of respirator use, etc.; the applicable lifetime or period of use of the feature, etc.; and known costs, doses, and dose rates associated with the adoption of the feature or measure. The same should be done for each alternative to the feature, etc., including the status quo.

Note that sometimes constraints will limit alternatives. For example, since a dose of greater than 5 rem to 1 person would exceed the (annual) regulatory limit, it would not be acceptable to consider that as an option.

E. Production of Costs and Doses.

Once the known costs and doses have been produced, then the unknown costs and doses can be estimated or calculated from other information. For example, the known capital cost now may have to be annualized to compare it to operating costs in other years. Or the doses may have to be estimated from projected stay times and dose rates.

F. Comparison of Results and Use of Subjective Factors Analysis.

Once all of the costs and doses have been produced, they can be combined appropriately to produce the net benefit, a shorter cost expression, or the cost-dose differences ratio for each feature or measure. The results should be compared among alternatives or with the value of a man-rem, as applicable. The alternative with the highest net benefit or lowest cost expression should be chosen or, where the cost-dose difference ratio is used, features or measures with a ratio less than the cost of a person-rem may be chosen.

Where the results are close or where an analysis of more subjective factors is desirable, a sensitivity analysis might be performed in which the most important or most uncertain cost(s) or dose(s) is varied slightly to see how much difference variability or uncertainty makes. In addition or instead, a subjective factors analysis may be done. This is a ranking of the feature or alternative according to factors that are difficult to quantify but which are nevertheless important, such as schedule flexibility, reduction of the potential for a reportable occurrence, and good public relations.

G. Example.

Workers were doing an important job in a hot but uncontaminated area. A nearby valve suddenly started leaking radioactive water. This produced airborne radioactivity, so now the workers should probably wear respirators in the area while completing the hot job. Or should they? The leak has stabilized at a low but steady rate, and since it is an essential system, the valve system can't be turned off.

Consider an example with the following paramters:

> Without the respirators, the job would take 2 workers 2 more hours to complete, with a resulting external dose of 100 mrem and 20 mrem internal (CEDE) to each.
>
> With respirators, the time and the external dose for the job would also increase by 50 percent. Assume there would be no internal exposure.
>
> The cost of an hour for a worker or HP is $75, and the cost of a person-rem is $2,000.

Here, doing the job right now is not presented as an option, but as a must. This may be because the job is the principal function of the facility, or the job may be required for safety or another important reason. So we start this example by assuming that we must do the job and that we are then trying to make the optimal choice regarding ways of doing the job. We are not given any information regarding contributions to P or V, so we will simply find the value of U = X + Y.

Option 1: Without Respirators

> Without respirators, the cost of the job is calculated by

X_1 = (2 workers) (2 hrs) ($75 hr) = $300

The dose cost is

Y_1 = (2 workers)(0.100 rem+0.020 rem)($2000/person-rem)=$480

Thus, the sum is

$U_1 = X_1 + Y_1$ = $780

Option 2: With Respirators

With respirators, the cost of the job is

X_2 = (2 workers) (2 hrs * 1.5) ($75/hr) = $450

The dose cost is

Y_2 = (2 workers) (0.100 rem * 1.5) ($2000/person-rem) = $600

Thus, the sum is

$U_2 = X_2 + Y_2$ = $450 + $600 = $1050

Since U_1 gives the minimum value of U (i.e., the lowest total cost), this is the option that should be chosen. For this option, both the total dose and total cost is lower. Note that we ignored the cost of the respirators themselves (e.g., cleaning after use), but in a more complete analysis, this should be included.

Let's try this using the cost-dose difference ratio and the difference between (1) not using and (2) using respirators.

Δ Costs = X_2 - X_1 = $450 - $300 = $150
Δ Dose = D_2 - D_1 = 0.300 rem - 0.240 rem = 0.060 rem
Δ Costs/Δ Dose = $150/0.060 rem = $2,500/(person-)rem

Since this is a greater than $2,000/person-rem, the first option, not using respirators, is the one to choose. Since the ratio is positive, the lowest dose option and the lowest cost option are the same. There is no trade-off, and <u>not</u> using respirators is the correct choice to make.

If the above example had a higher internal dose component, the cost for not wearing a respirator would have been greater. For example, using option 1 (without respirators), an internal dose component of 100 mrem to each of the two workers would result in a total cost (U_1) of $1100 if respirators were not used. This exceeds the cost of $1050 when respirators are worn.

Keep in mind that the example presented here was simplified for instructional purposes. In practice, one must consider the following:

1) Studies may not have consistently demonstrated that using a respirator will result in an increase in the time it takes to perform a task.

2) The radionuclide and chemical form involved, as well as the measures taken to ensure that workplace conditions do not deteriorate, must be factored into any controls implemented during the task.

3) Dose rates in a facility are variable, airborne radioactivity concentrations and worker practices.

4) There may be considerable management and worker opposition to accepting internal exposures, especially with respect to radionuclides with long biological half-lives, such as transuranics.

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Part 5 of 5

ALARA Training for Technical Support Personnel

Overhead Transparencies and Handouts

Coordinated and Conducted
for
Office of Health, Safety and Security
U.S. Department of Energy

ALARA TRAINING FOR TECHNICAL SUPPORT PERSONNEL

Overhead Transparencies

Course Content

- Introduction to ALARA
- Types of radiation
- Selected topics in radiation protection
- ALARA principles
- Applications of ALARA to source term reduction and control

Intro-2

Course Content (Cont'd.)

- **Application of ALARA to system design**
- **Application of ALARA to civil/structural design**
- **ALARA design review**
- **ALARA operational review**
- **Optimization**

Intro-3

MODULE 101

INTRODUCTION
TO
ALARA

Module 101 - Objectives

- DEFINE the acronym ALARA
- LIST the ALARA recommendations of the RadCon Manual
- IDENTIFY which groups should participate in ALARA design reviews

101-2

As Low As Reasonably Achievable

Taking into account:

- **social,**
- **technical,**
- **economic,**
- **practical, and**
- **public policy considerations.**

101-4

NCRP 116 ALARA Guidance

- **Justification**
  - **The need to justify radiation dose on the basis of benefit**

- **Optimization**
  - **the need to ensure that the benefits are maximized**

- **Limitation**
  - **the need to apply dose limits**

101-5

Documents that require, direct or recommend considerations for ALARA

- **10 CFR Part 835, "Occupational Radiation Protection"**
- **DOE Radiological Control Standard**
- **Order 5400.5, Ch. 2, "Radiation Protection of the Public and the Environment"**
- **PNL-6577, "Health Physics Manual of Good Practices for Reducing Radiation Exposures to Levels that are ALARA"**

101-6

10 CFR Part 835, "Occupational Radiation Protection"

- **Measures shall be taken to maintain radiation exposure in controlled areas ALARA.**

- **Where use of engineered controls is demonstrated to be impractical - administrative controls and procedural requirements shall be used.**

101-7

MODULE 102

TYPES OF RADIATION

Module 102 - Objectives

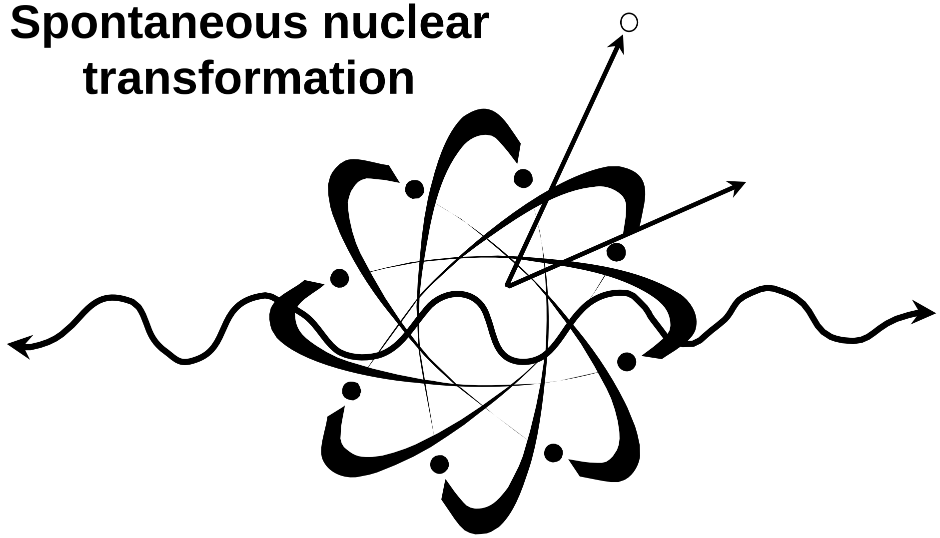
Following self-study and/or classroom review, participants will be able to identify the penetrating abilities in body tissue of:

- **alphas,**
- **betas,**
- **gammas and x-rays, and**
- **neutrons.**

102-2

Radioactivity may be defined as:

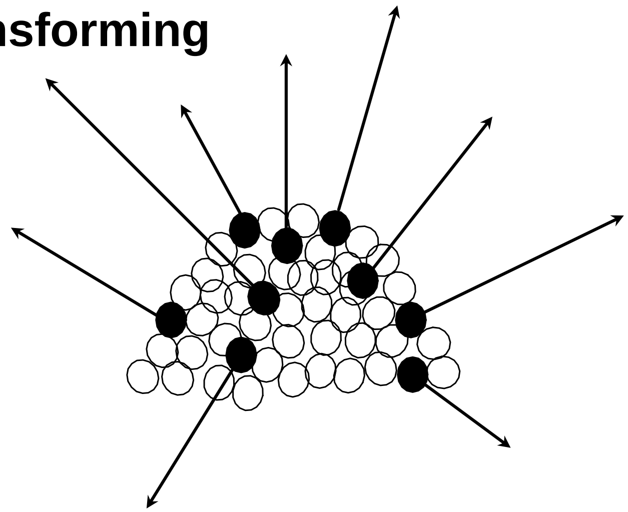
Spontaneous nuclear transformation



102-3

Radioactive material contains:

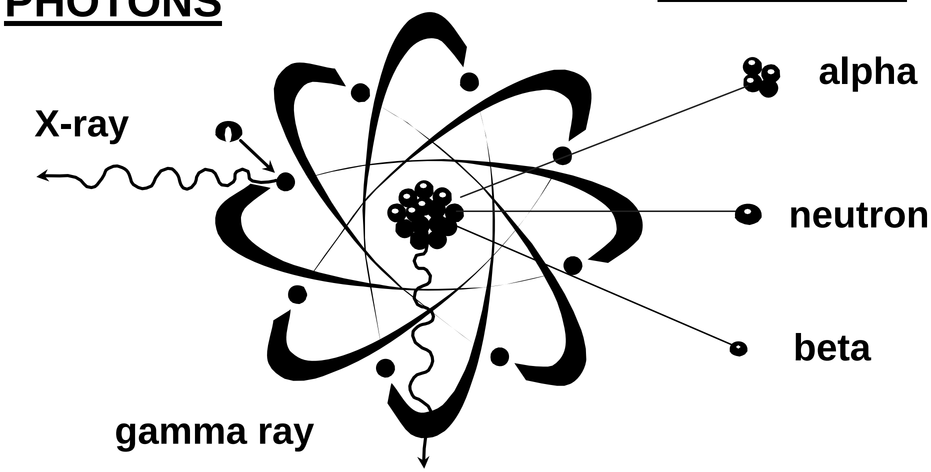
Atoms whose nuclei are transforming



102-4

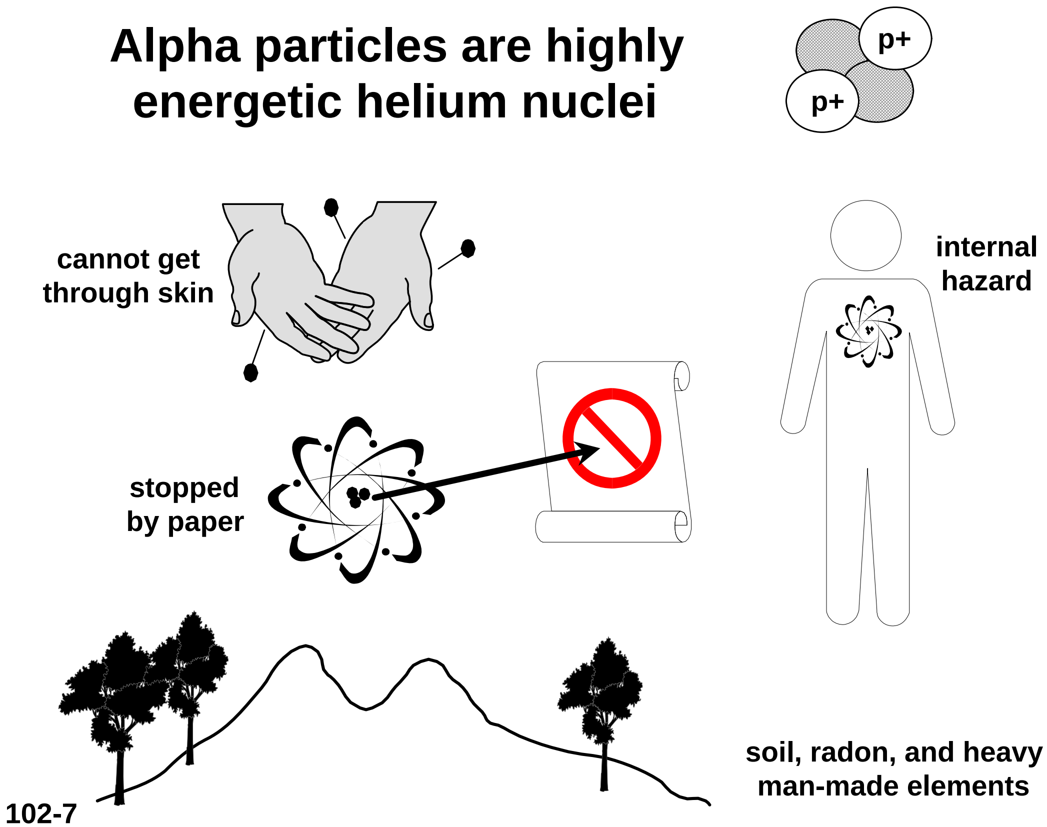
Two general categories of ionizing radiation:

PHOTONS | **PARTICLES**



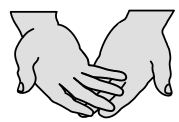
102-5

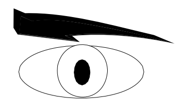
Alpha particles are highly energetic helium nuclei

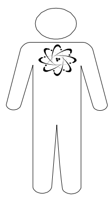


Beta particle: an energetic electron from an unstable nucleus

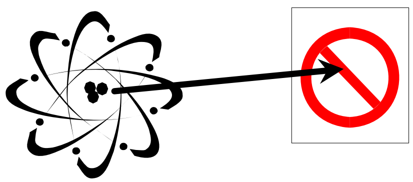
skin, eye, and internal hazard



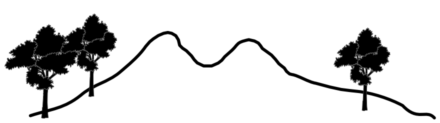




stopped by plastic



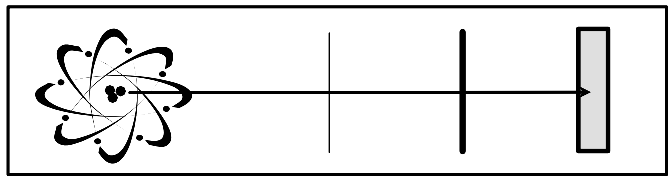
natural food, water, air



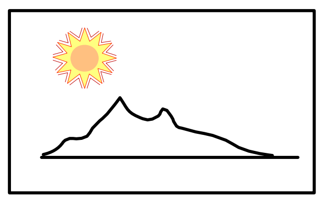
102-8

Gamma and X-rays are photons (massless electromagnetic energy)

stopped by dense shielding



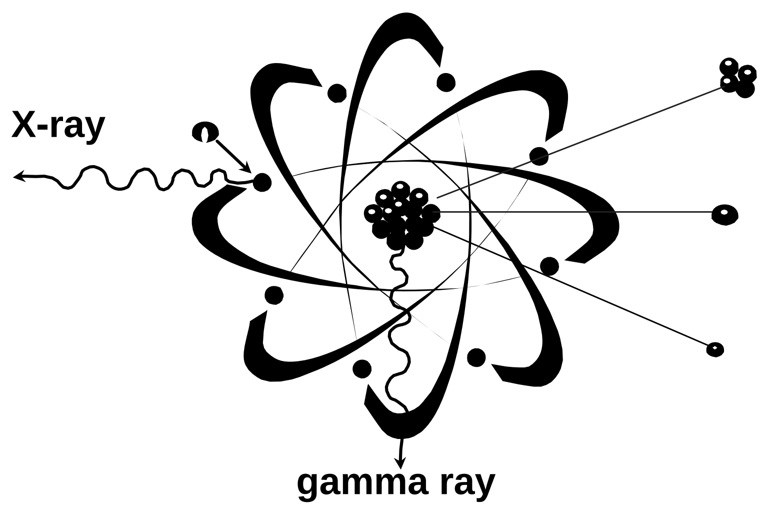
naturally present in soil and in cosmic radiation



medical, radioactive materials

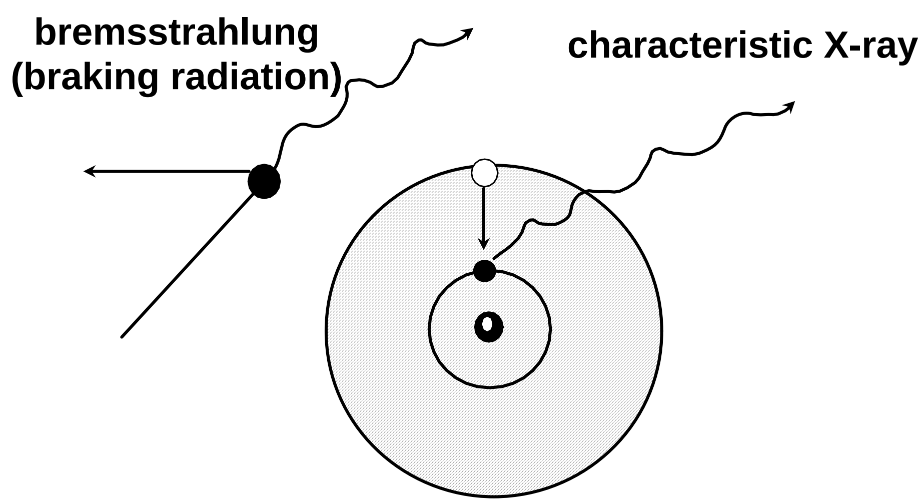
102-9

Gamma and X-rays are identical except for their origin



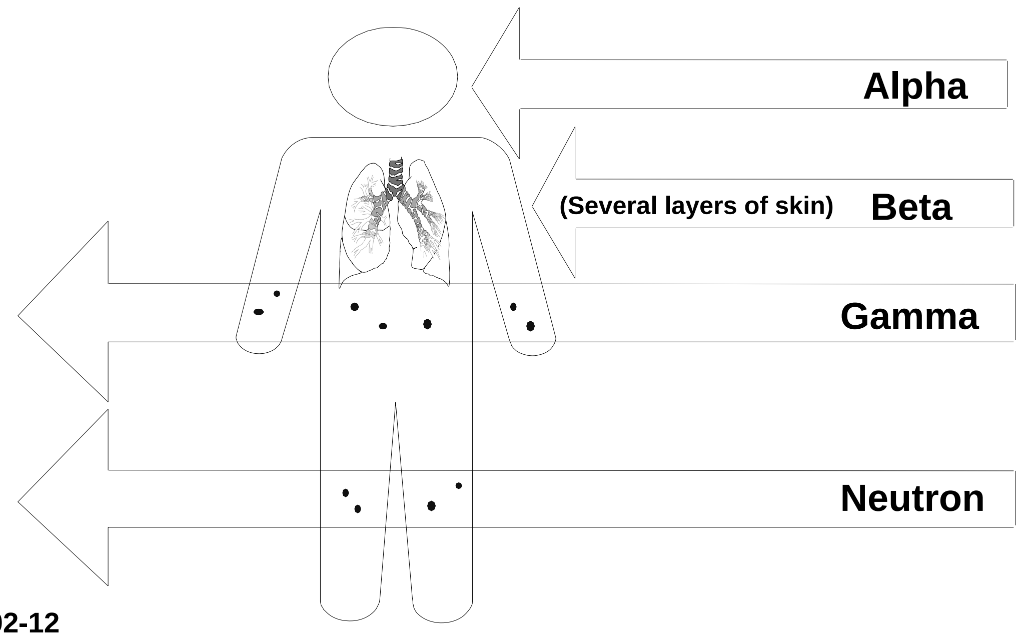
102-10

X-rays come from two sources



102-11

Relative penetrating ability of ionizing radiation in tissue



102-12

MODULE 103

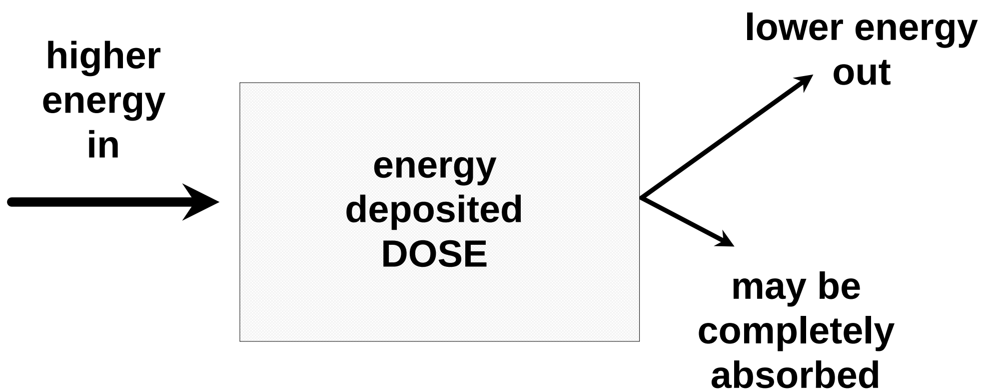
SELECTED TOPICS
IN
RADIATION
PROTECTION

Module 103 - Objectives

Following self-study and/or classroom review, trainees will be able to:

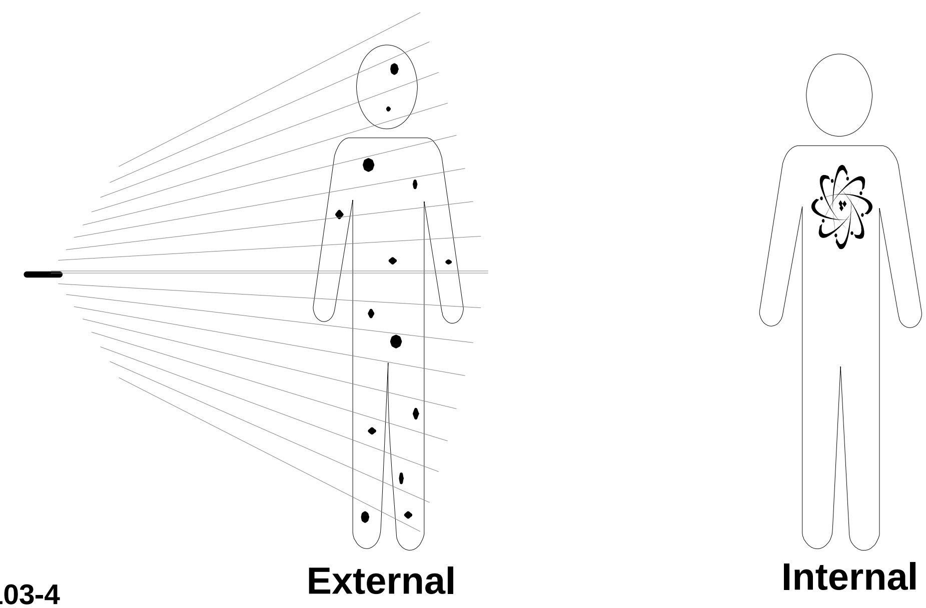
- **LIST four ways radioactive material enters the body.**
- **DEFINE the terms "crud" and activation products.**
- **DISCUSS controls for airborne radioactive material.**
- **DISCUSS methods to process radwaste.**
- **DEFINE the terms "Controlled Area" and "Radiological Area." DISCUSS types of radiological areas.**
- **IDENTIFY types of contamination control measures.**
- **DEFINE scattering and streaming.**

Radiation interacts with the body by depositing its energy in the cells



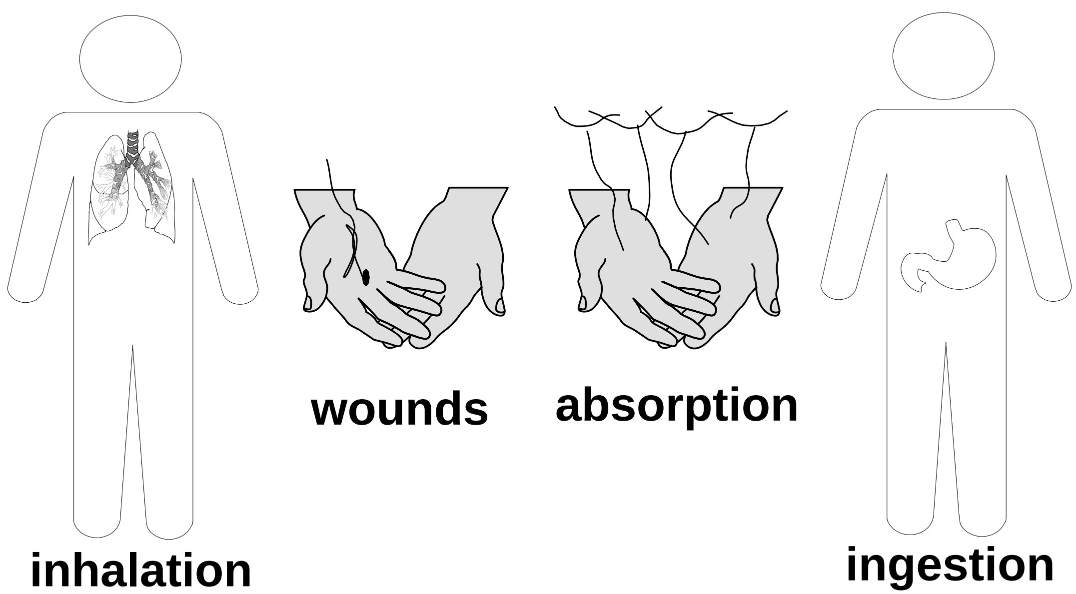
103-3

Dose can be delivered by external or internal sources



103-4

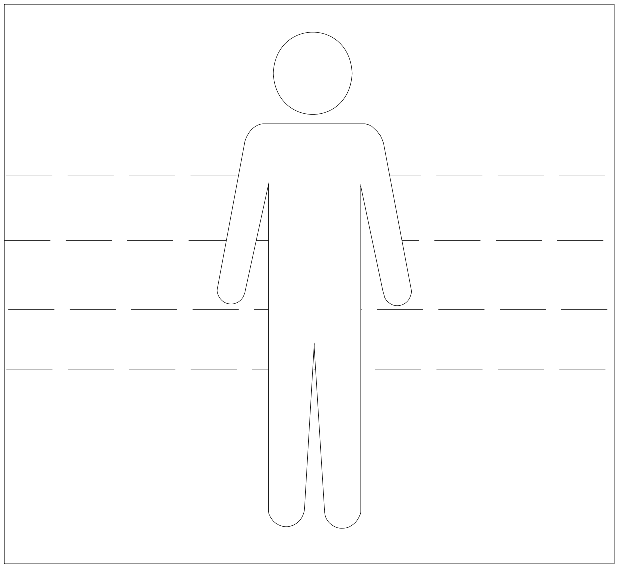
Radionuclides can enter the body in four ways



103-5

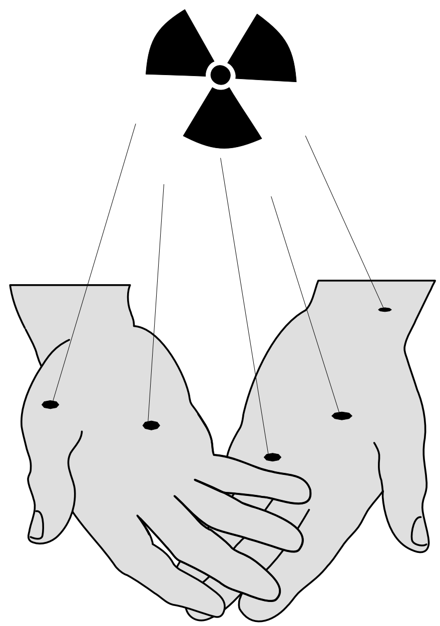
Whole-body dose normally results from penetrating radiation

X-rays
gamma rays
neutrons



103-6

Skin dose may also be delivered by weakly penetrating radiation



103-7

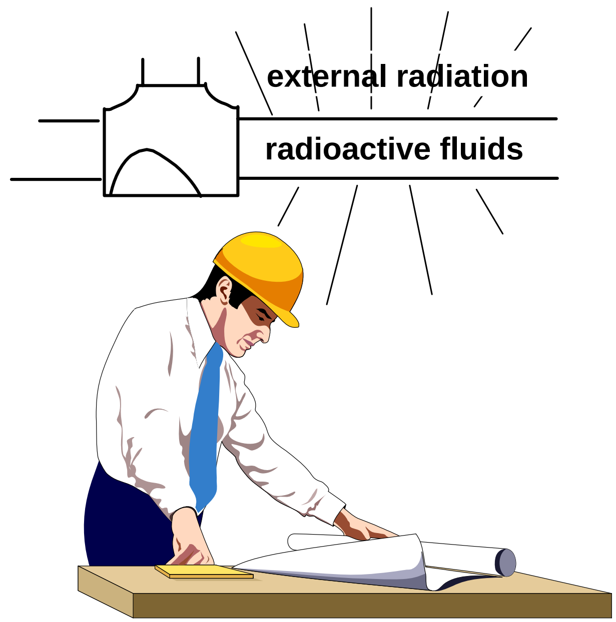
Extremity dose may result from:

- **Handling a source or**
- **Working in a non-uniform field.**

103-8

CRUD is waterborne contamination that:

may deposit as solids in unfavorable spots.



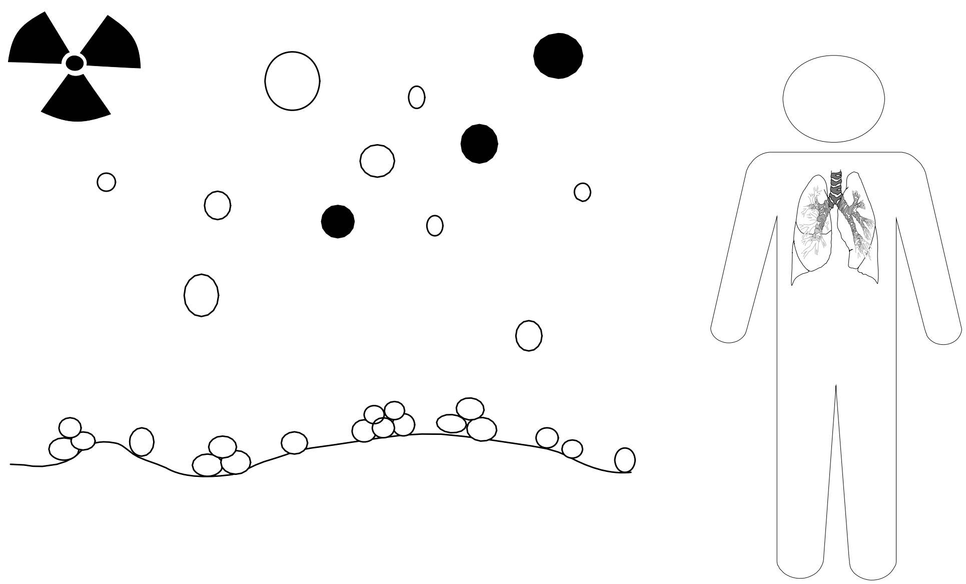
103-9

Some of the best means to reduce the production of CRUD are to:

- **Use low-activation materials so that CRUD is not produced,**
- **Prevent corrosion and erosion of equipment, and**
- **Avoid CRUD traps, such as low-flow areas.**

103-10

Airborne radioactive materials are of particular concern



103-11

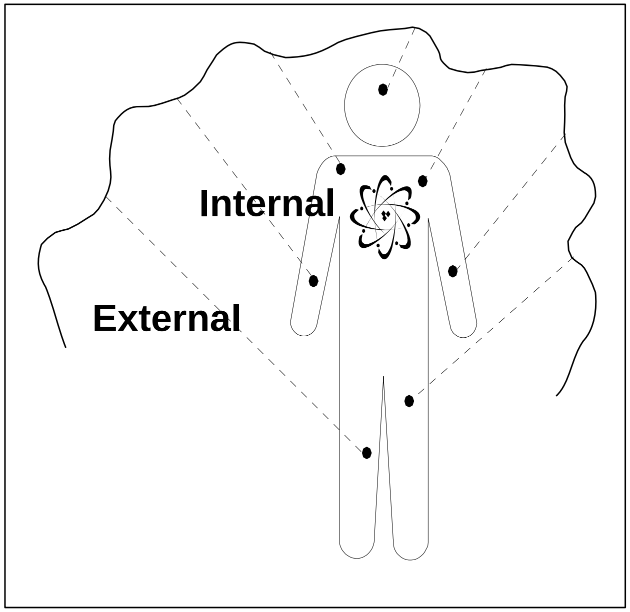
Radioactive materials may become airborne by:

- Release of a gas, such as krypton, xenon, etc.,
- Chemical reactions,
- Volatilization of liquids, and
- Solid materials (particulates) dispersed in air.

103-12

Airborne radioactive materials may create --

an external hazard as well as an internal hazard.



103-13

Protection from airborne hazards may include wearing:

- a respirator,
- a nonporous suit in atmospheres containing absorbable radionuclides, and
- protective clothing.

103-14

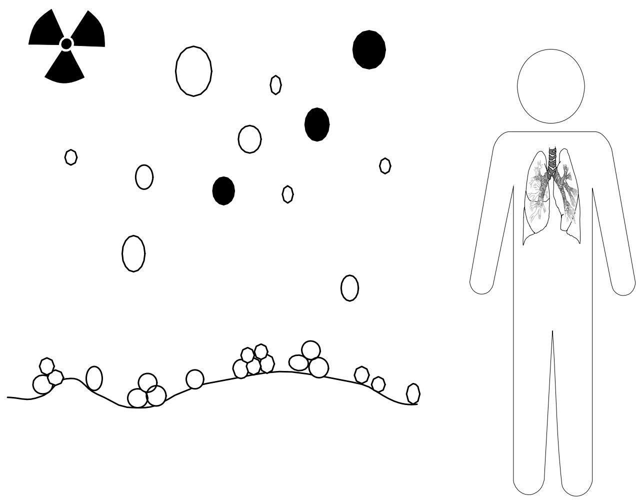
Do not eat, drink, or smoke in radiological areas

103-15

Airborne radioactivity limits are expressed in terms of:

Derived Air Concentrations (DAC)

Breathing 1 DAC for 2000 hours (1 work-year) would result in the annual limit (5 rem wholebody or 50 rem organ).



103-16

Minimization of dose may mean -- don't wear a respirator

HEALTH RISK to the worker may be increased because of heat stress, industrial safety concerns, etc.

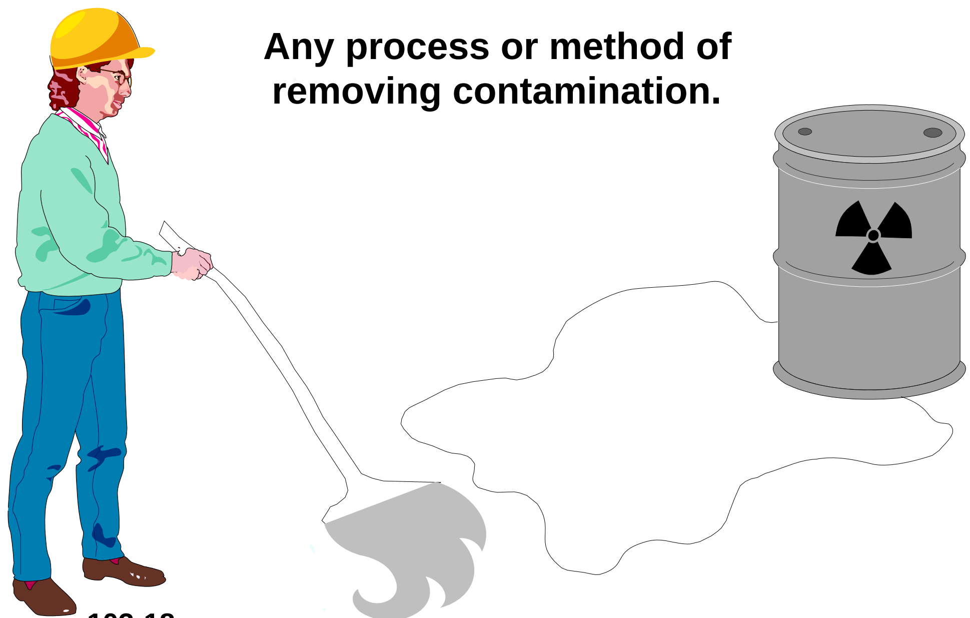
WORK EFFICIENCY may be decreased due to use of respiratory protection, resulting in increased external exposure.

Other controls may be more appropriate!!

103-17

Decontamination is --

Any process or method of removing contamination.



103-18

Provisions for decontamination

- Design,
- Planning,
- Methods, and
- Fixed and removable equipment.

103-19

Radioactive waste or radwaste is:

Any radioactive material or substance that is not considered useful and must be disposed of.

103-20

Types of radwaste include:

- **Solid dry waste (dry active waste) - DAW,**
- **Liquid, and**
- **Gaseous.**

103-21

Methods of processing radioactive waste may include:

- **Filtration,**
- **Volume reduction (incineration or compaction,**
- **Ion exchange processes,**
- **Decay tanks and other containments, and**
- **Dilution.**

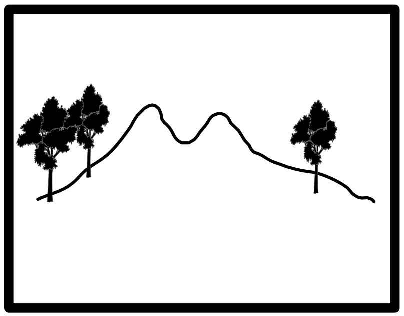
103-22

Special consideration needs to be given to generation of mixed waste

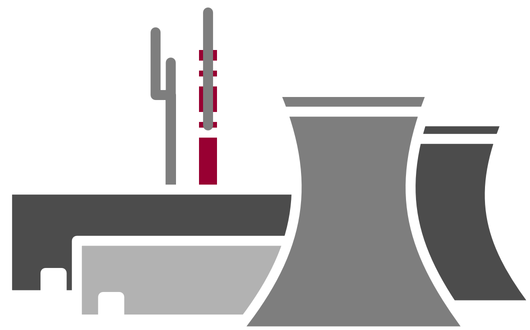
Minimize, Minimize, Minimize!!

103-23

Controlled and Uncontrolled Areas

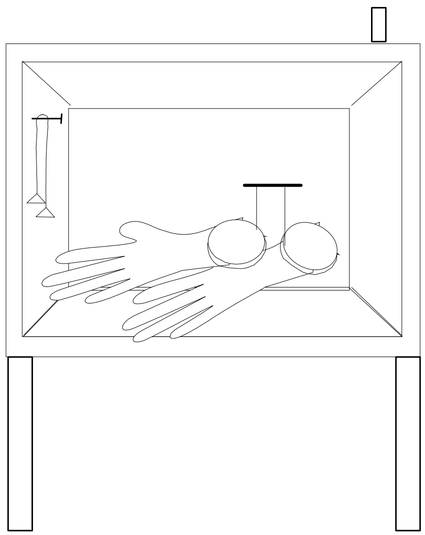


Uncontrolled
(Unrestricted access)



Controlled
(Access controlled for radiation protection purposes)

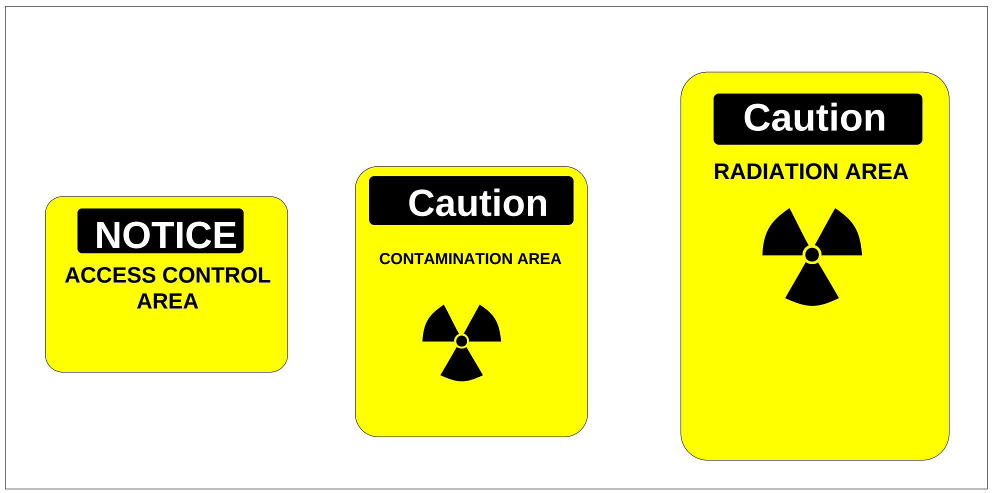
Radioactive Material Area may be an area or structure



103-25

Radiological Areas

GERT/Visitor Orientation or escort required for entry



103-26

A Radiation Area is:

Greater than 5 mrem/hr but not more than 100 mrem/hr.

103-27

Areas of Potentially High Dose Rates

103-28

A High Radiation Area is:

Greater than 0.1 rem/hr but not more than 500 rad/hr.

VERY HIGH RADIATION AREA > 500 rad/hr

103-29

A <u>Radiological Buffer Area</u> may be established for secondary control.

- **Area adjacent to any exit or entry from Contamination Area.**
- **Surround or be contiguous with Radiation Area.**

103-30

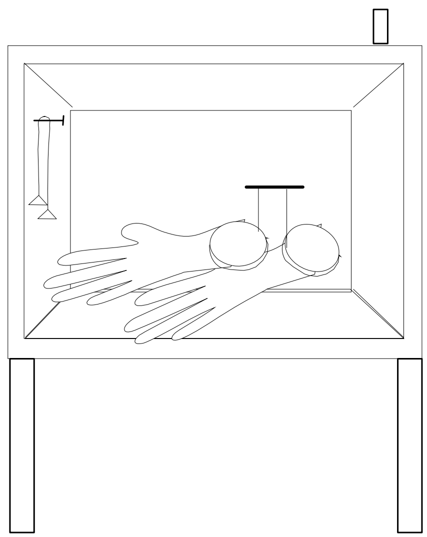
A <u>Contamination Area</u> has contamination levels greater than release values.

High Contamination Area

> 100 X Values

103-31

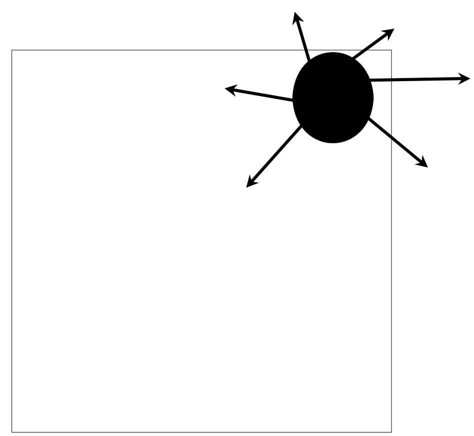
Areas of Potential Surface and Airborne Contamination



103-32

<u>Hot Spot</u> is a localized area where contact dose rates are:

>100 mrem/hr AND > 5 X general area dose rates.



103-33

An Airborne Radioactivity Area has levels:

greater than the DAC or 12 DAC-hrs in a week

103-34

Some common entry control measures include:

- Signs and barricades
- Control devices on entrances
- Visible or audible alarms
- Locks
- Administrative controls

103-35

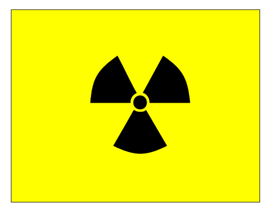
Some types of contamination control measures include:

- Step-off pads
- Protective clothing
- Containment
  - Gloveboxes
  - Hot cells
- Effective ventilation

103-36

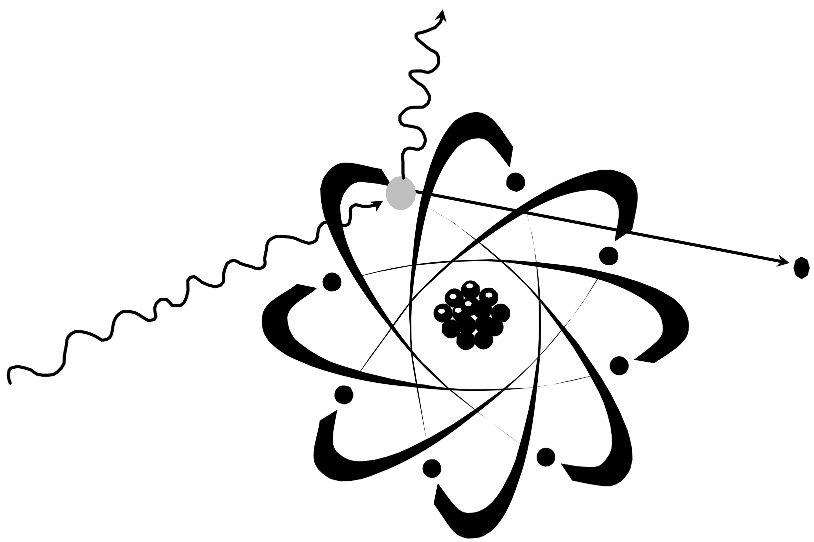
An area may have intermittent hazards

BEWARE!!



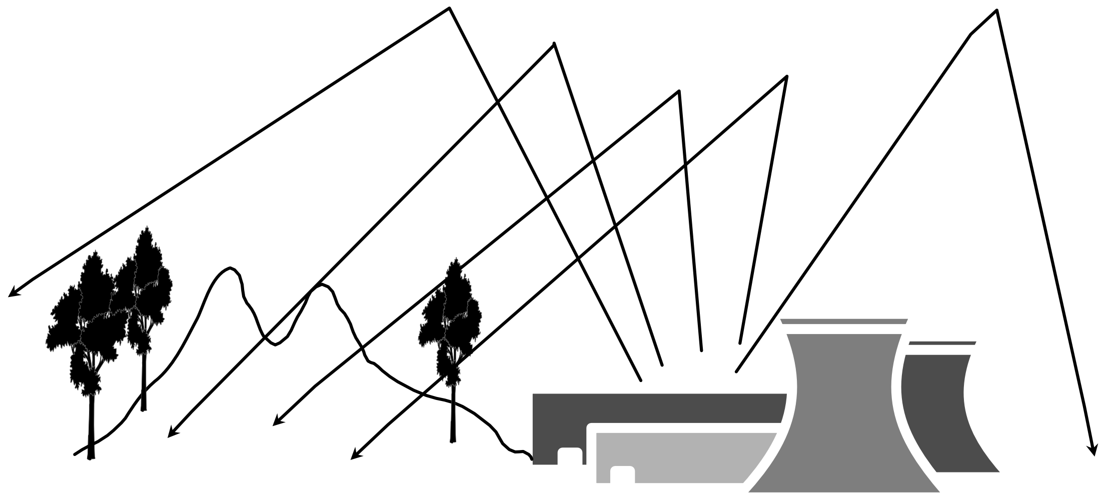
103-37

Scatter is reflected radiation, such as a neutron or photon



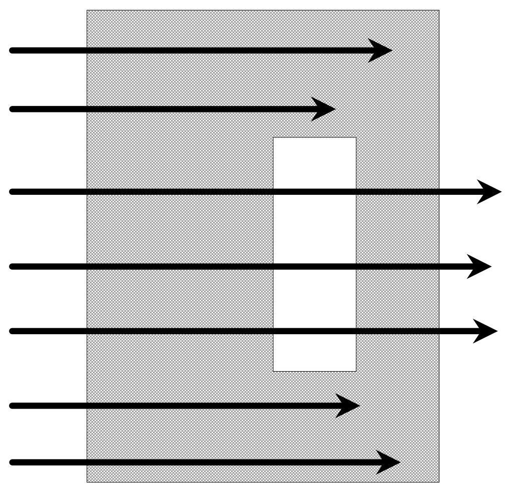
103-38

Outside air can provide significant scatter,"skyshine"



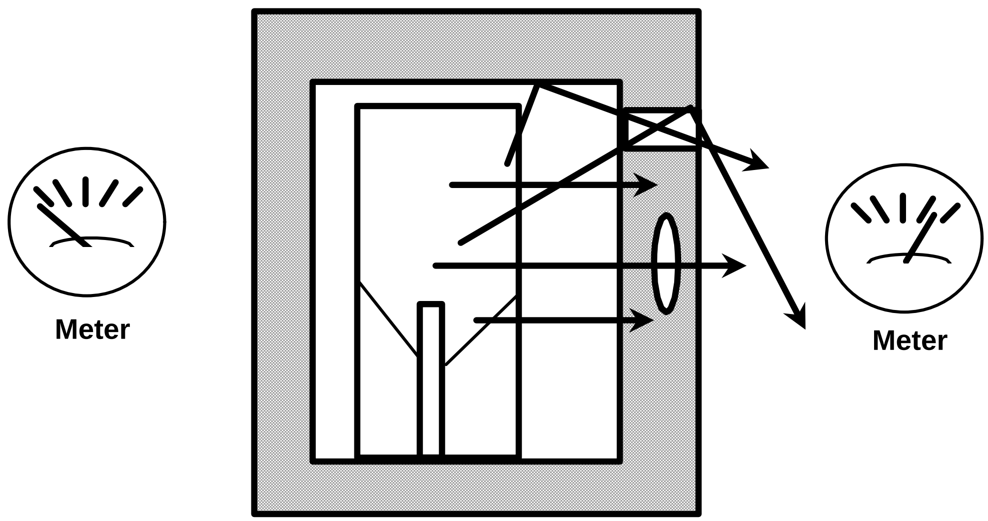
103-39

Streaming results when radiation passes through an opening or void in shielding



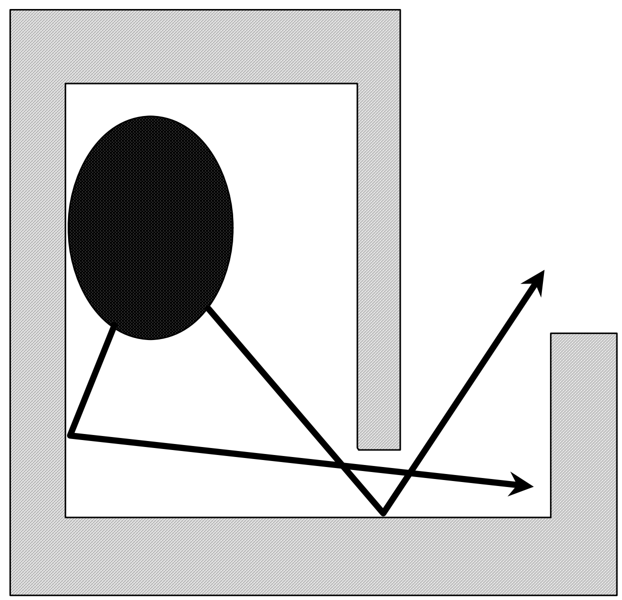
103-40

Scattering and streaming may result in a significant dose rate outside the shield



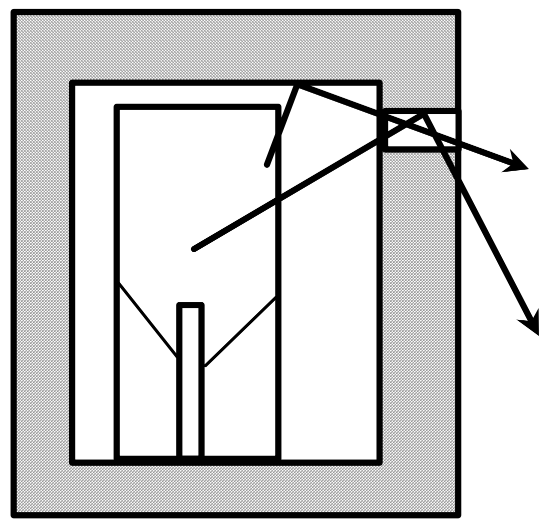
103-41

Scatter paths may occur through a labyrinth entrance



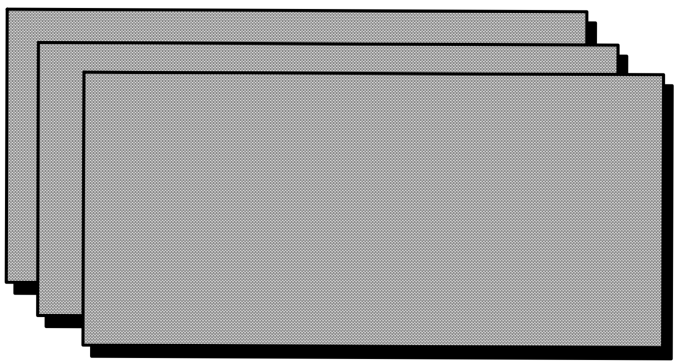
103-42

Scatter paths may occur through a penetration



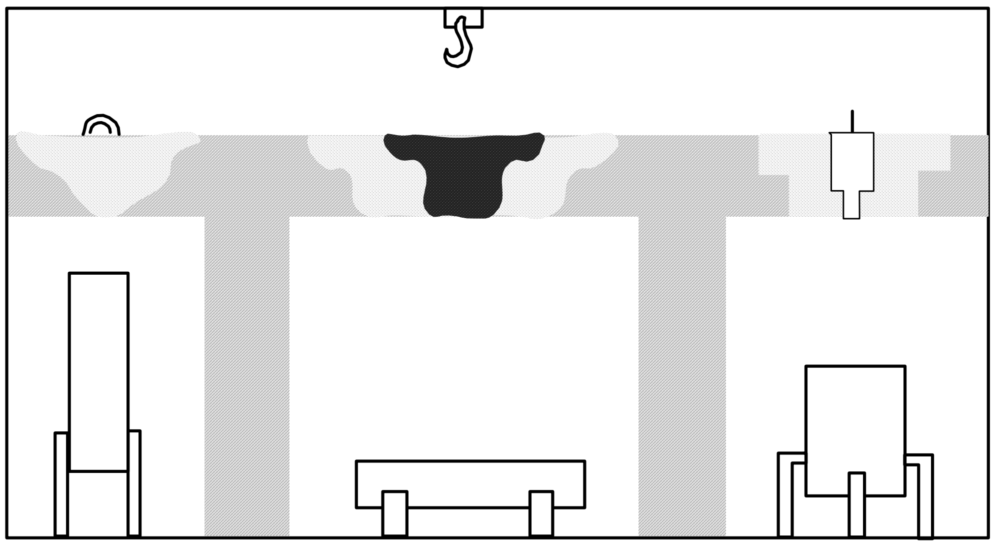
103-43

Removable, overlapping block walls may be used to minimize streaming



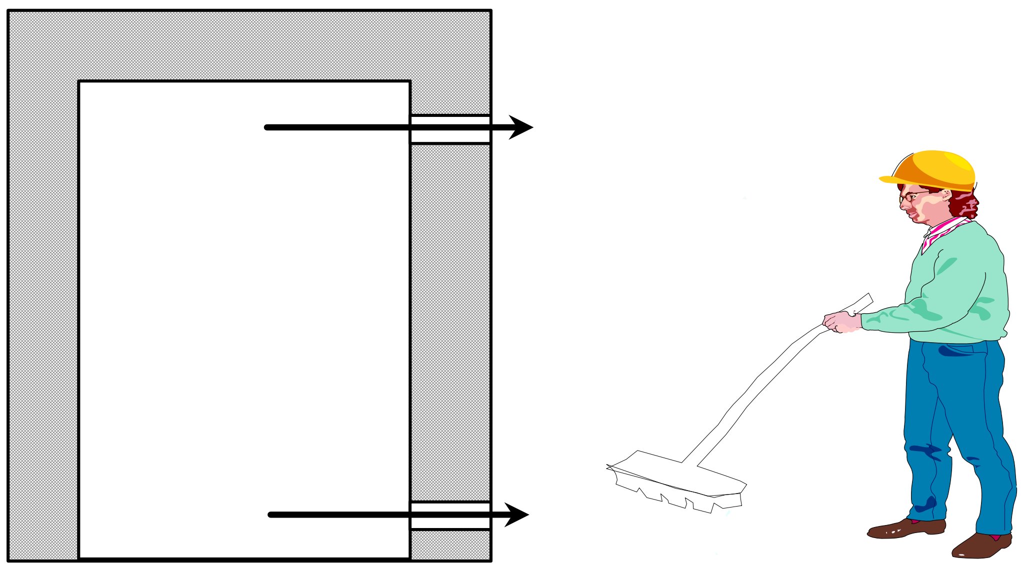
103-44

Typical shield slabs and plugs



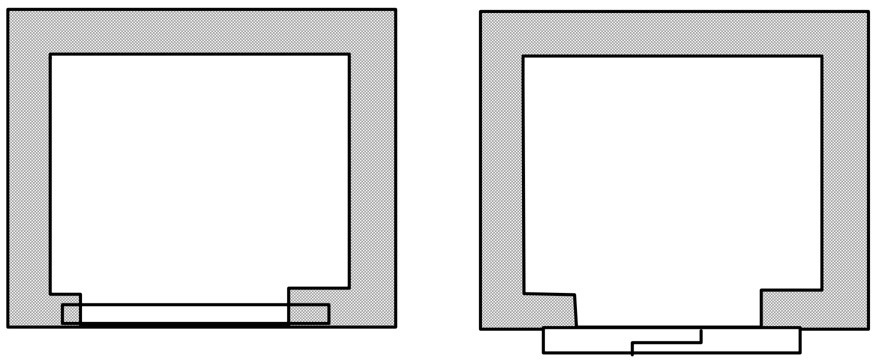
103-45

Pass-through ports should be placed near the floor or ceiling



103-46

Shield door or shield slab arrangement



103-47

MODULE 104

ALARA PRINCIPLES

Module 104 - Objectives

Following self-study and/or classroom review, participants will be able to:

- **IDENTIFY the six fundamental principles used to reduce radiation dose and the release and spread of radioactive materials.**
- **IDENTIFY applications of the fundamental principles.**
- **IDENTIFY appropriate shielding materials used to reduce radiation exposures.**

104-2

Six fundamental principles should be considered

- Eliminate or reduce the source of radiation,
- Contain the source,
- Minimize time in a radiation field,
- Maximize distance from a radioactive source,
- Use radiation shielding, and
- Optimize resources.

104-3

Hierarchy of Controls

Engineered Controls

↓

Administrative controls

↓

Personnel protective measures

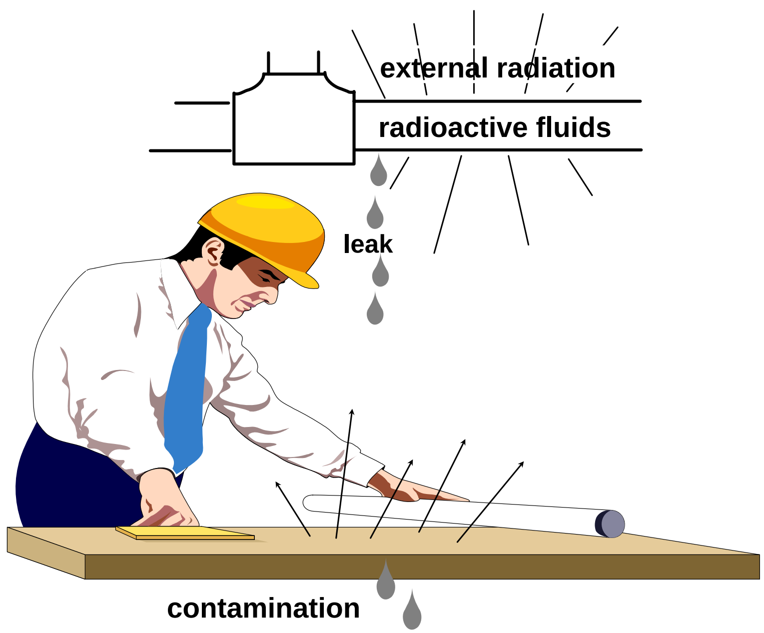
104-4

The first ALARA design principle is to eliminate or reduce the source

- **Removal of source or source elimination,**
- **Source reduction, or**
- **Radioactive decay.**

104-5

The second ALARA design principle is to control and contain radioactivity



104-6

Methods to control and contain radioactive sources include:

- **Containment**
  - leak-tight enclosures
- **Ventilation**
  - circulation, exchange, and filtration of air
- **Filtration**
  - circulation, exchange, processing, and filtration of water or air

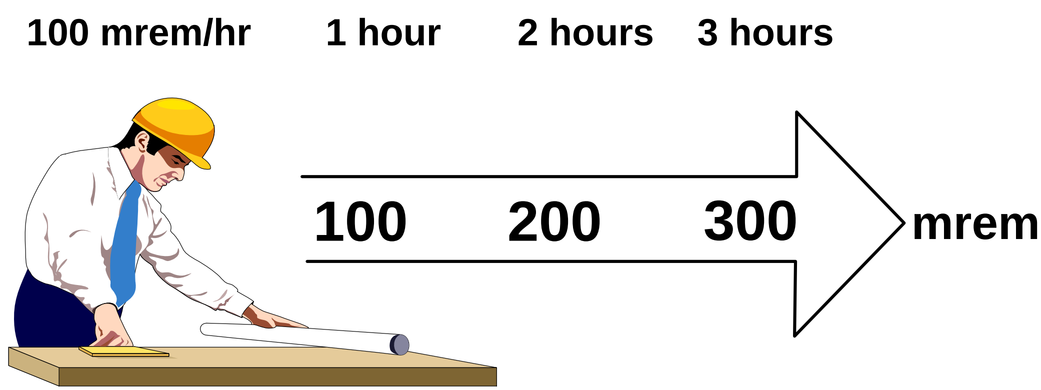
104-7

Protective designs include such items as:

- Ventilated fume hoods,
- Gloveboxes,
- Exhaust systems,
- Water filtration systems, and
- Oversized ventilation cleanup systems.

104-8

The third ALARA design principle is to reduce the time in a radiation field



104-9

Design factors to reduce time spent in radiation fields include:

- Install reliable equipment to reduce maintenance,
- Provide adequate clearance for maintenance and inspections,
- Utilize special tools to speed maintenance and access,
- Remove components from radiological area for repair and calibration, and
- Install permanent lighting and platforms.

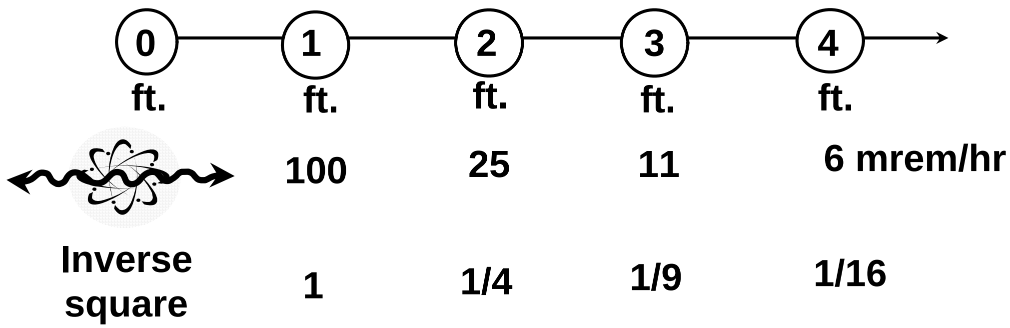
104-10

Typical Distance in Air

- **Alpha:** **1 - 2 inches**
- **Beta:** **10 - 12 feet per MeV of energy**
- **Gamma:** **very long range (weakly interacting)**
- **Neutron:** **very long in air**

104-11

The fourth ALARA design principle is to maximize distance from source



104-12

Design factors to maximize the distance from radioactive sources include:

- **Remote operations,**
- **Locating instruments and readouts in low dose areas,**
- **Provision for removal of components to low dose areas for maintenance, and**
- **Use of remote handling tools for repair, maintenance, and operations.**

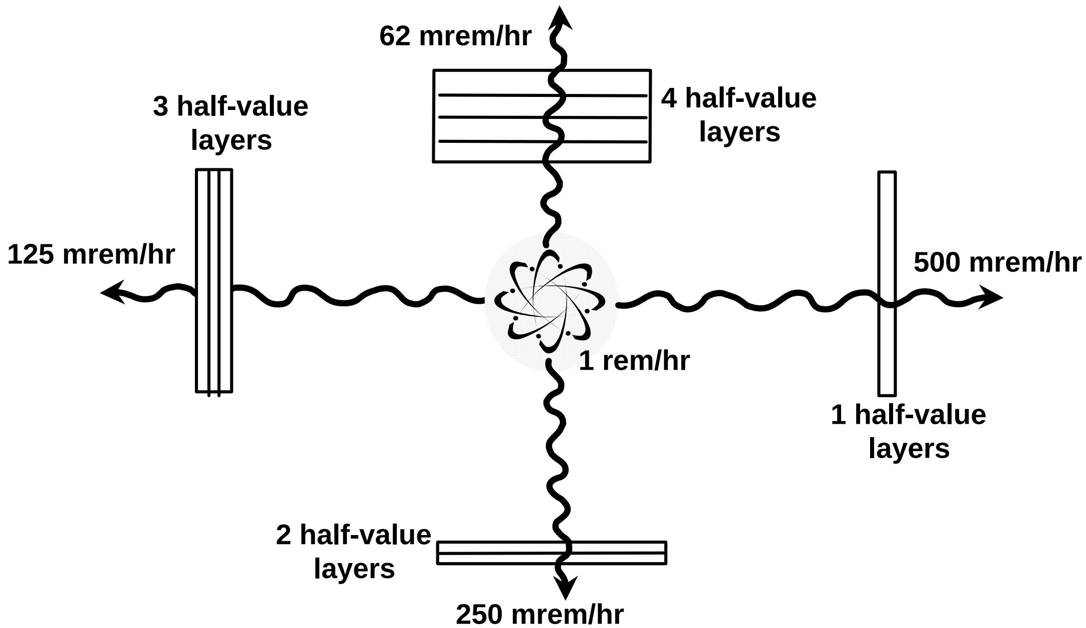
104-13

Design factors to maximize the distance from radioactive sources include (cont'd):

- Use of cameras and microphones to perform remote surveillance and inspections, and
- Equipment should be laid out so as to maximize the distance between workers and the radiation source.

104-14

The fifth ALARA design principle is to use shielding between worker and source



104-15

When incorporating shielding into design you should:

- **Anticipate crud buildup and hot spots,**
- **Use labyrinths for entry and exit,**
- **Install special shields,**
- **Consider space and access for installing temporary shielding, and**
- **Use appropriate shielding materials.**

104-16

Typical shielding materials for the various types of radiation include:

- **Alpha: stopped by piece of paper;**
- **Beta: 1/2 inch Plexiglass, 1/4 inch aluminum - Due to creation of bremsstrahlung consideration must be given to shielding X rays;**
- **Gamma: lead, concrete, steel (high-density materials); and**
- **Neutron: water, polyethylene, concrete (hydrogenous materials).**

104-17

Other factors to consider:

- **Use fortuitous shielding whenever possible.**
- **Correctly layer shielding for structural integrity and attenuation of different types of radiation.**
- **Consider using concrete for stopping any type of radiation.**
- **Dirt is cheap.**

104-18

The sixth ALARA design principle is optimization

Designing to ALARA uses the cost-benefit process of optimization to achieve ALARA.

104-19

Summary - Objectives

- Define the acronym ALARA.
- List the ALARA requirements of the RadCon Manual.
- Identify which groups should participate in ALARA design reviews.
- Identify the penetrating abilities in body tissue of:
  - alphas,
  - betas,
  - gammas and x-rays, and
  - neutrons.

Summary - Objectives (cont'd.)

- List four ways radioactive material enters the body.
- Define the terms "crud" and activation products.
- Discuss controls for airborne radioactive material.
- Discuss methods to process radwaste.
- Define the term "Controlled Area" and "Radiological Area." Discuss types of radiological areas.
- Identify types of contamination control measures.

104-21

Summary - Objectives (cont'd.)

- Define scattering and streaming.
- Identify the six fundamental principles used to reduce radiation dose and the spread of contamination.
- Identify applications of the fundamental principles.
- Identify appropriate shielding material used to reduce radiation exposures.

104-22

MODULE 105

APPLICATIONS OF ALARA

105-1

Module 105 - Objectives

During the presentation of Module 105, participants should be able to demonstrate the application of ALARA principles of source term reduction and control.

105-2

Control radioactive material deposition in liquid systems by reducing:

- **Crud production,**
- **Erosion,**
- **Corrosion loss, and**
- **Deposition.**

105-3

Avoid use of nickel, cobalt or other readily activated material in high neutron fields

- **Surfaces in contact with reactor coolant systems,**
- **Surfaces near neutron emitters, and**
- **In accelerators that produce neutrons.**

105-4

Reduce the loss of material by erosion

- **Use good flow geometry.**
- **Avoid sharp bends, reducers, and rough internal surfaces.**

Reduce the loss of material by corrosion

- **Use corrosion-resistant materials.**
- **Pretreat or precoat surfaces.**
- **Use pH and other chemistry controls.**
- **Provide for wet layup during maintenance and shutdown periods.**

105-6

Reduce deposition of CRUD and/or other radioactive material circulating in the system

- Select appropriate flow velocities.
- Provide strainers.
- Ensure that all equipment and piping runs are drainable and flushable.
- Minimize crevices, elbows, low points, sharp bends, and dead legs.

105-7

Reduce deposition of CRUD and/or other radioactive material circulating in the system (cont'd.)

- **Generally use butt welds, consumable inserts, and freeze fits (smoother welds).**
- **Generally use full-ported valves (plug, gate, or ball valves instead of globe valves).**
- **Choose straight-tube, vertical heat exchanger rather than U-shaped, horizontal ones.**

105-8

Provide for proper contamination control measures

- Contamination in one area should not result from minor or moderate incidents that occur in any other radiological area.
- Outside radiological areas, radioactive surface contamination should not exceed release values.
- Select equipment that can be readily, easily, and completely dismantled.

105-9

Provide for equipment decontamination

It is ALARA to select a method that reduces the dose to the worker while reducing the volume of radwaste produced.

105-10

MODULE 106

APPLICATIONS OF ALARA TO FACILITY AND SYSTEM DESIGN

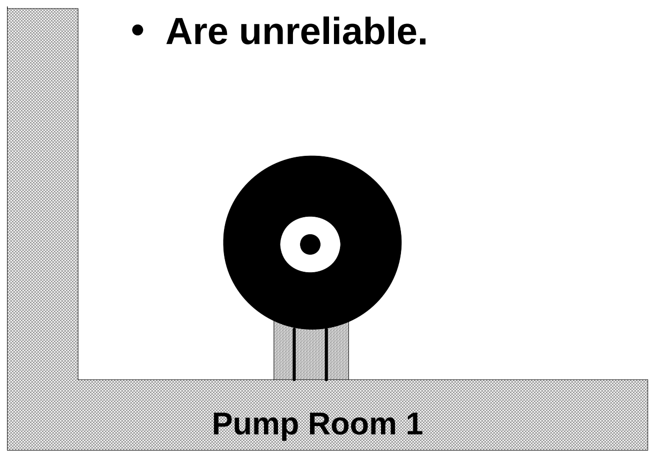
Design features and ALARA considerations:

- Reliability and equipment qualification;
- Ventilation;
- Mechanical/electrical;
- Radwaste systems; and
- Sampling, monitoring, and instrumentation.

106-2

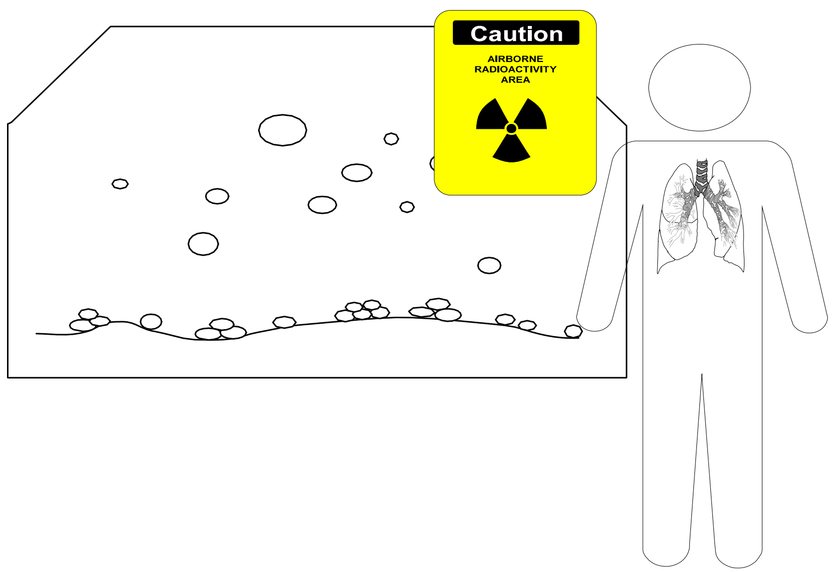
The engineer must consider which components --

- Require large amounts of maintenance.
- Are unreliable.



106-3

Materials and equipment selection qualification for the expected use



106-4

Airborne Radioactivity and HVAC

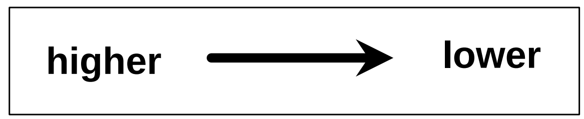
106-5

Ventilation systems provide protection during the following two tasks:

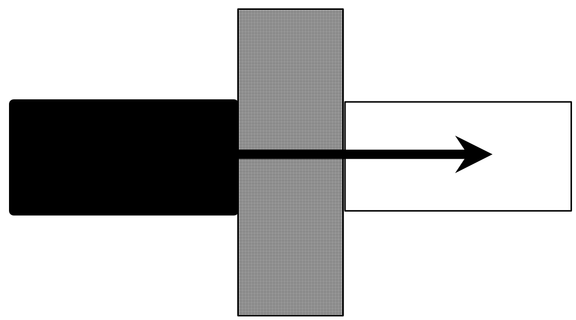
- Normal work
- Accidental releases

Ventilation systems must have two essential features:

Appropriate Differential Pressure (DP)



High Efficiency Particulate Air (HEPA) Filtration

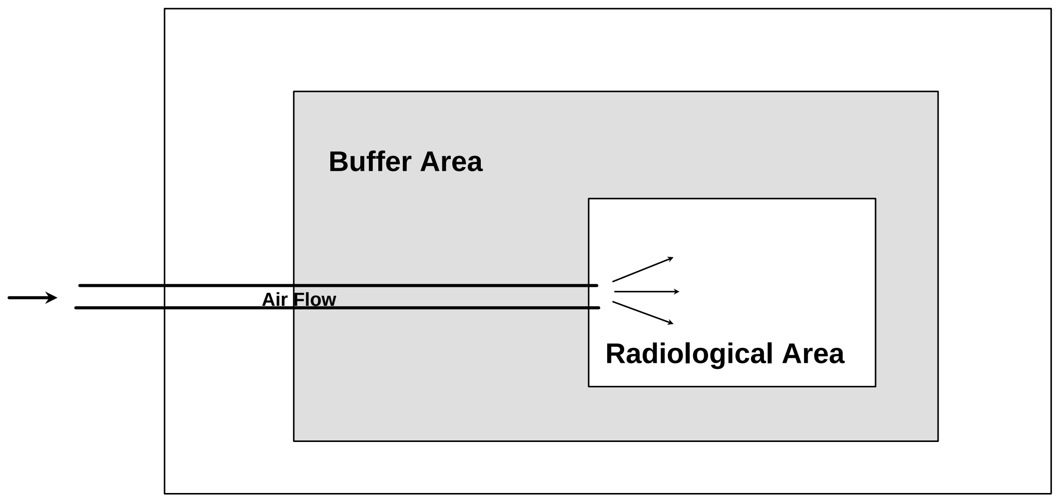


106-7

A System of Differential Pressure Should be Used

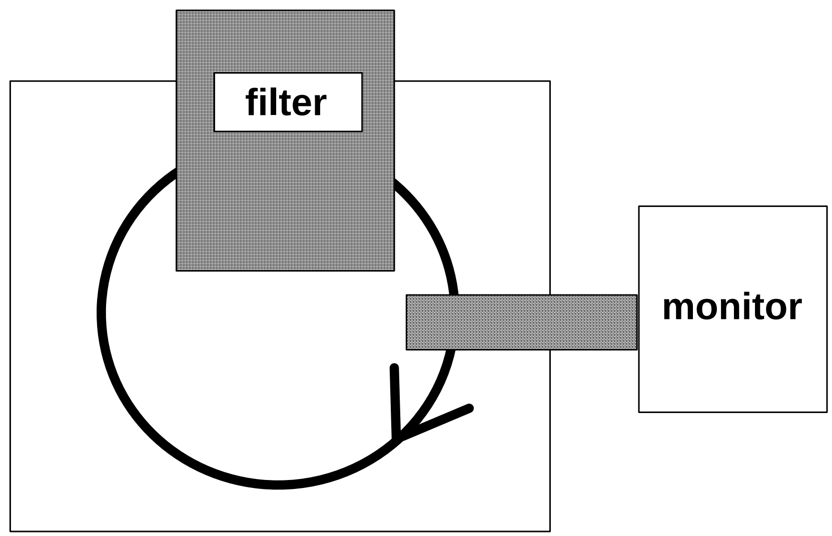
106-8

Direct air flow from areas with less to higher potential for contamination



106-9

Room air may be recirculated - if adequately filtered and monitored



106-10

Avoid drawing contaminated air across walkways, work areas, and breathing zones

106-11

For ventilation and filtration, the design engineer should address:

- Proper type/location,
- Ease of maintenance, and
- Monitoring.

106-12

Similar areas do not always require identical ventilation characteristics

Ventilation design criteria need to accommodate a measure of flexibility. This is essential for localizing and containing airborne radioactive contamination.

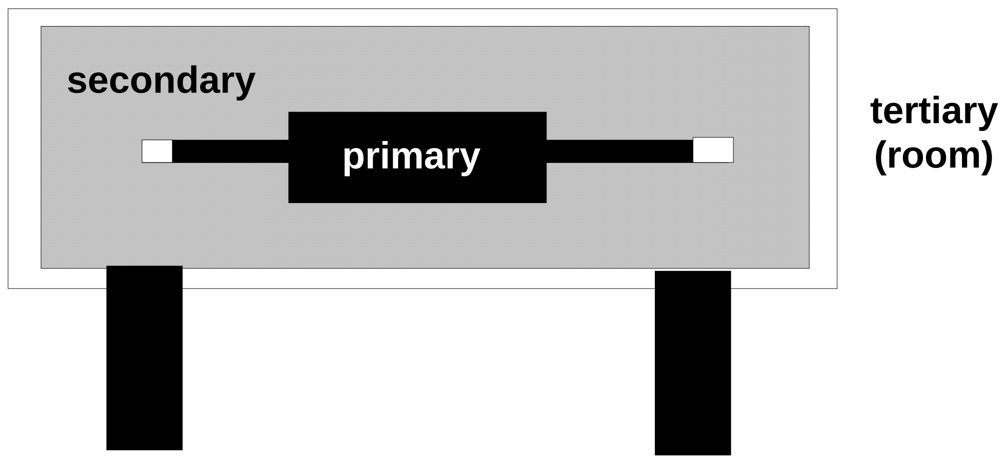
106-13

Containment

106-14

Containment is an area --

enclosed by a set of barriers either passive or active.



106-15

Gloveboxes and other handling enclosures are --

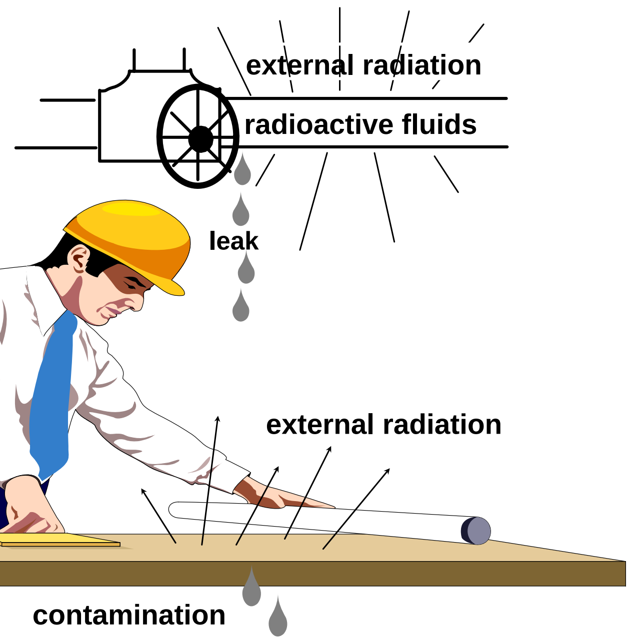
- **Primary containments when materials are handled, processed, or stored in open containers or not contained at all.**
- **Gloveboxes are secondary containments when the radioactivity is actually contained in a piping system, vessel, instrument, etc., inside the box.**

Mechanical and Electrical Systems

106-17

Valves

Operation and maintenance of valves are two major contributors to workers' dose.



106-18

Generally use full ported valves:

- **Plug,**
- **Gate, or**
- **Ball valves.**

106-19

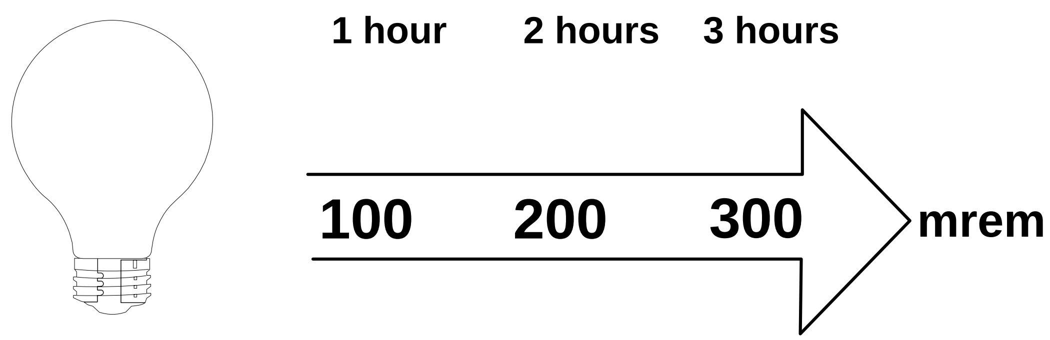
Pumps

Pumps and valves can be a source of dose and contamination during maintenance or repair.

106-20

Electrical Systems

The use of long-life bulbs can decrease maintenance time.



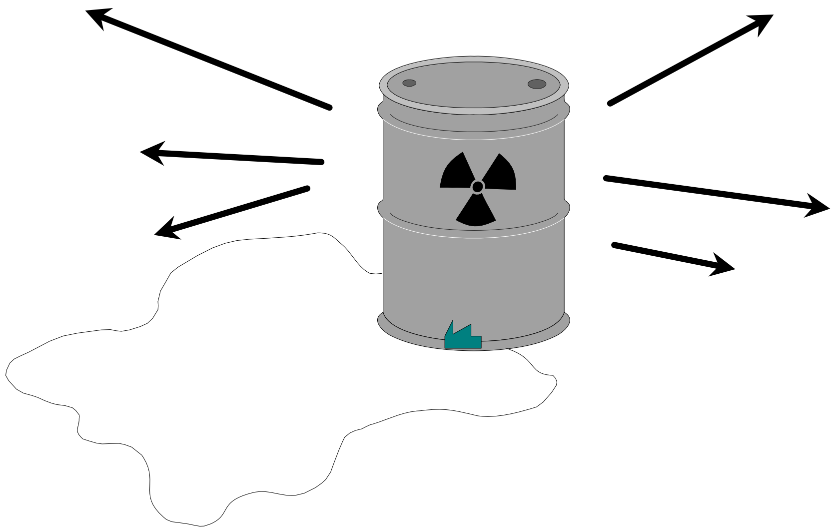
106-21

MODULE 107

APPLICATION OF ALARA FOR VARIOUS ENGINEERING DISCIPLINES

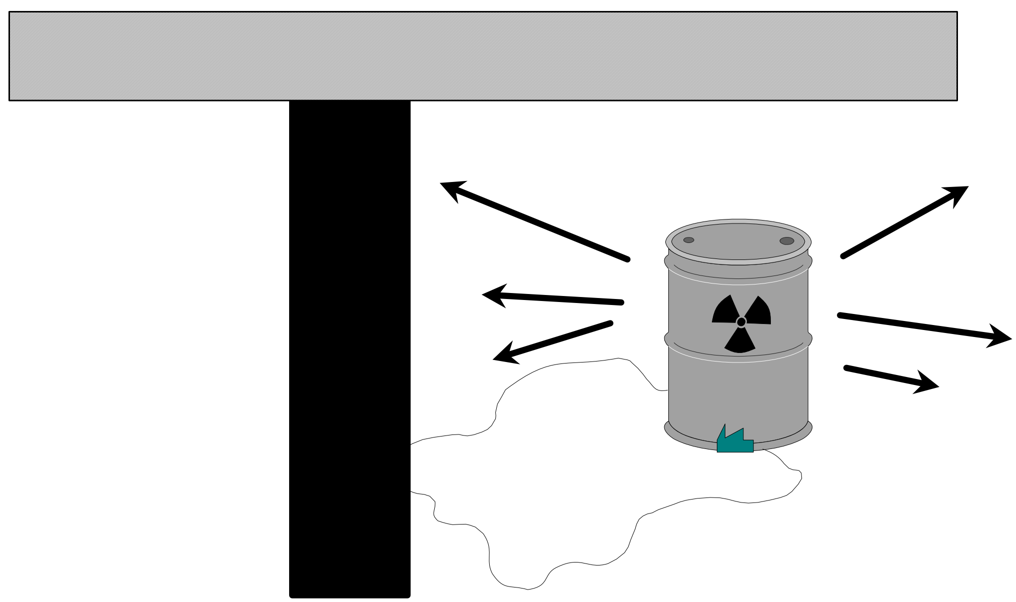
This module addresses radiation dose assessment and radiological design considerations of new facilities and the modification of existing facilities.

Radiological designs should address anticipated dose risk



107-2

Support structures can provide shielding but could also hinder maintenance



107-3

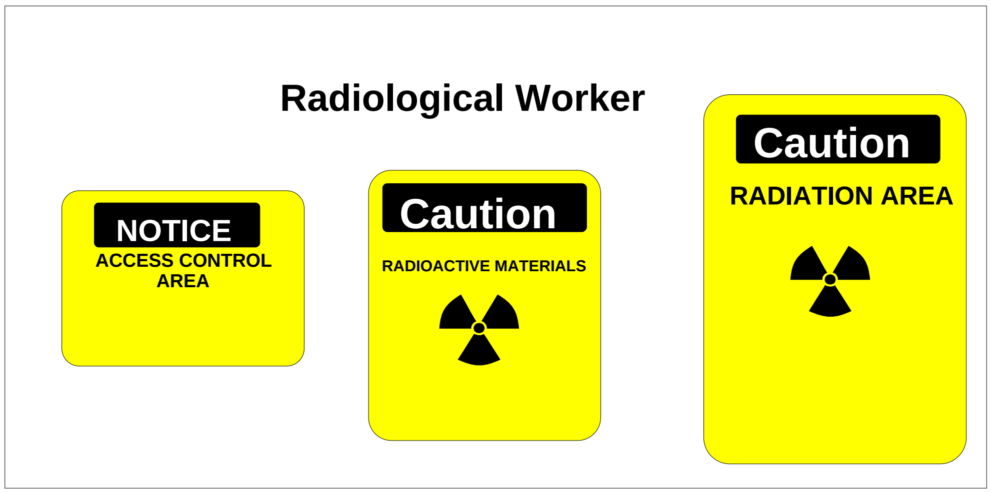
Assessing Radiation Doses

Designers should provide for anticipated dose risk by analysis of task and process.

107-4

General low-level dose-rate operations areas

GERT/visitor, orientation or



Access Control

Process areas may be higher dose rate areas.

107-6

It is important to minimize multiple sources of dose.

107-7

Controls in high-dose-rate areas may include:

- Remote operations of equipment and systems.
- Isolation of processes from general work areas.

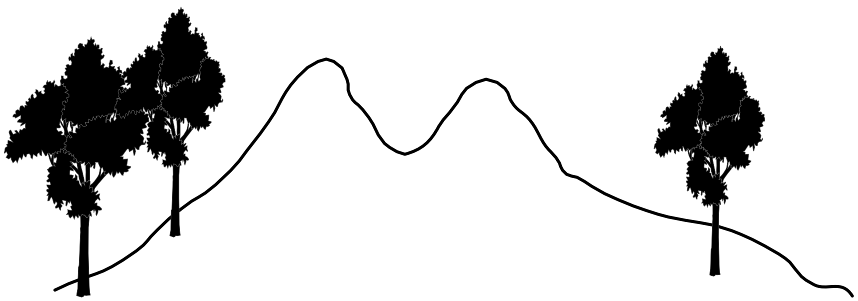
107-8

Building layout is an important factor in controlling personnel dose

Proper layout reduces casual or transient exposures to radiation fields by segregating heavily used corridors and work areas from areas of elevated dose rates and potential contamination.

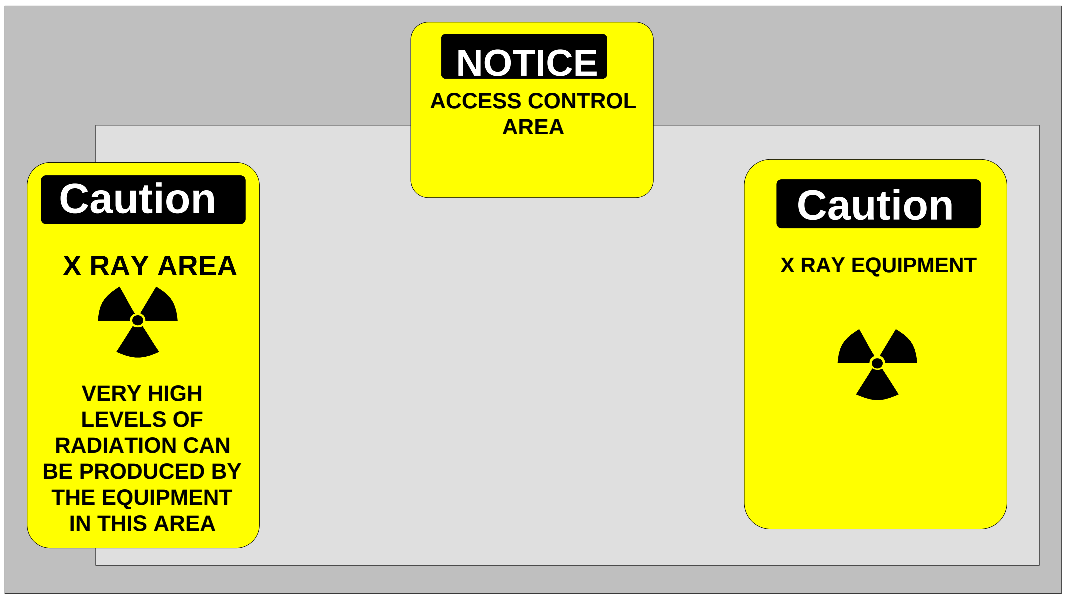
107-9

Plan for eventual decontamination and decommissioning (D&D)



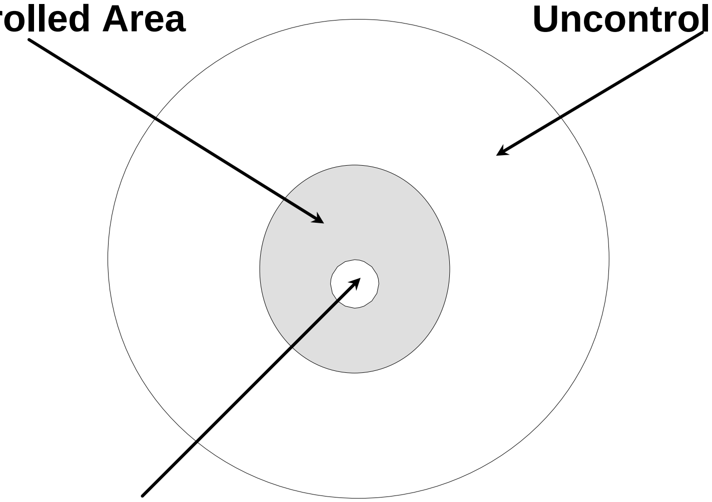
107-10

A system of sequential areas can aid in control of personnel dose



107-11

General Access and Controlled Area are two major types of occupancy areas



107-12

Traffic and Access

- Locate frequently used pathways in low-dose rate areas.
- Ensure that doorways are wide enough and large enough.
- Radiological areas should be made as small as possible.

107-13

Contamination Control Design

Contamination control measures may consist of --

- **curbs,**
- **gutters, or**
- **other liquid controls.**

107-14

RADIOACTIVE WASTE

107-15

Location for the temporary storage of radioactive waste must be designed:

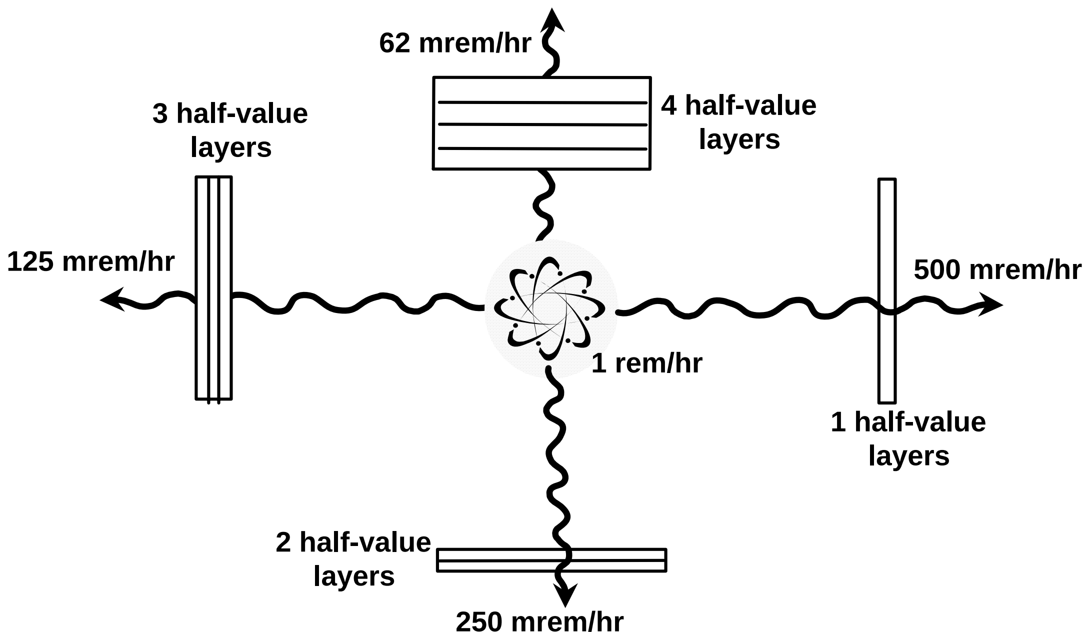
- Into the overall building plan.
- For each area where radioactive materials are handled.

107-16

SHIELDING, PENETRATIONS, and ROUTING

107-17

Obtain information on shielding from a specialist



107-18

Penetrations and Routing

- **Have experts from all affected disciplines review a planned penetration before the hole is made.**

- **Don't route ducts and pipes containing radioactive material where people are located.**

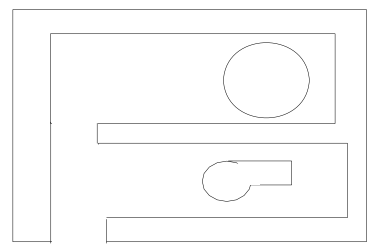
107-19

Separation, Segregation, Placement, and Isolation

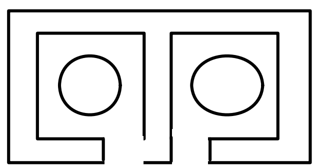
107-20

Separation - by radioactivity or maintenance requirements

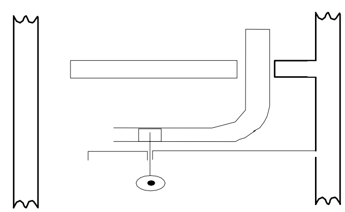
tank & pump



twin tanks



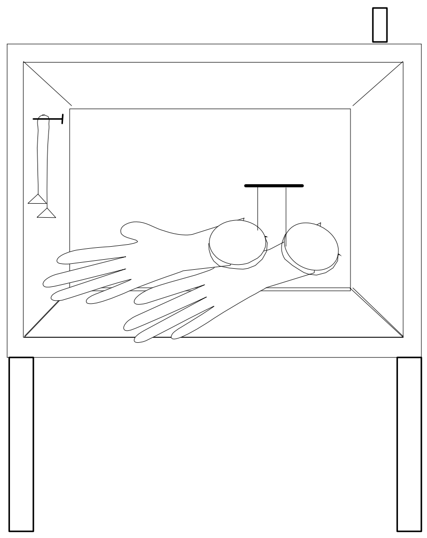
valve & reach rod



107-21

Segregation of areas and systems by --

Radioactivity, concentration, or potential for contamination.



107-22

Placement

Place components with lower dose rates, higher access requirements, or more active characteristics nearest to the access point for the group. Place components with higher dose rates, lower access requirements, or more passive characteristics farthest from the access point for the group.

107-23

Isolation of equipment

- **Properly place isolation valves to minimize dead legs.**
- **Minimize pipe runs in valve aisles.**

107-24

Redundancy

Provide adequate redundancy and backup capability, especially in systems of high radioactivity content and safety systems. Provide appropriate cross-connections to achieve.

107-25

Accessibility, Laydown, and Storage

107-26

Human Factors

107-27

Designs should address human factors such as:

- Vision
- Hearing
- Physical limitations
- Heat stress

107-28

Module 108

ALARA DESIGN REVIEW

An ALARA design review is a systematic review of the design and construction of equipment/facilities to ensure that ALARA considerations are evaluated, incorporated if reasonable, and documented for modification to existing and new facilities that involve the potential for exposure to ionizing radiation.

108-1

10 CFR 835.1001 requires that

“engineered controls and administrative controls shall be used for facilities and equipment to keep radiation doses in controlled areas ALARA."

108-2

The ALARA design review is conducted in five discrete phases:

- **Dose assessment,**
- **Determination - Conduct or Not Conduct Review,**
- **Select reviewers,**
- **Selection of Criteria and Conduct of Review**
- **Documentation of the ALARA process.**

108-3

Perform dose estimates from the information gathered, including:

- Layouts and location diagrams;
- Number and types of workers;
- Nature of each task;
- Time spent by each worker per task;
- Paths to and from;
- Physical features; and
- Dose rates, wall thickness, etc.

108-4

Revise dose estimates as more design information becomes available

- **A walkdown of the installation with construction and radiological control personnel may be valuable at this time.**
- **Detailed dose information is needed for selection of design alternatives.**
- **The detailed dose assessment involves dose estimation for operation, maintenance, inspection, and installation of equipment.**

108-5

After initial dose assessment - Should an ALARA design review be performed?

First issue --

Does the design change involve work on a radioactive or potentially radioactive system?

108-6

The Second issue is -- Will this design change cause additional concerns?

- Create a new radiological area?
- Create or increase routine maintenance, operations, or inspection?
- Cause workers to exceed a threshold, such as 1 rem or greater?

If any of these criteria are met, additional occupational dose will result and further review should be conducted.

108-7

An ALARA design review need not be conducted

- If the answer to all 3 questions is "NO."
- If no radioactive or potentially radioactive components, systems or areas are involved.
- If there is one-for-one replacement of equipment or if the design does not present the practical opportunity to incorporate dose reduction features.

108-8

ALARA design review team key personnel

- Design Team
- Contributor Group
- ALARA Review Coordinator
- Radiological Control and/or ALARA Representative(s)

ALARA Design Review is performed at each key stage of design or modification.

108-9

Minimum objectives to be considered in ALARA reviews

- **Protect the public and facility personnel from hazards**
  - **Normal operations**
  - **Anticipated operational occurrences**
  - **Design Basis Accidents**
- **Review the general facility layout.**
- **Verify that the ventilation system is adequate.**

108-10

Minimum objectives to be considered in ALARA reviews (cont'd.)

- **Evaluate and confirm the adequacy of radiological control devices.**
- **Verify that shielding meets ALARA requirements.**
- **Assess the adequacy of planned radiation monitoring.**
- **Radiological requirements and ALARA considerations should be balanced.**

108-11

The design shall address all health hazards

- The release of hazardous materials under normal operating conditions and anticipated operational upset occurrences shall be less than release guideline values.

- Consideration shall be given to the frequency of occurrence and the effects.

108-12

Designs for new facilities and major modifications to existing facilities should be based on:

- **Individual dose <500 mrem/yr.**
- **Discharges should not degrade ground water.**
- **Control of contamination by containment.**
- **Efficiency of maintenance, operations, decontamination and decommissioning.**

108-13

Designs for new facilities and major modifications to existing facilities should be based on: (cont'd.)

- **Components should be selected to minimize the buildup of radioactivity.**
- **Support facilities for donning and removal of protective clothing and for personnel contamination monitoring when required.**

108-14

The ALARA Design Review Checklist contains the following:

- **Preliminary questions that serve to sort out which groups of questions in the main list are needed;**
- **Main checklist, a series of questions grouped by subject;**
- **Disposition sheet on which individual answers may be discussed and resolutions may be recorded.**

108-15

An ALARA Design Review should be considered near the end of each stage

If the reviewer recognized any issues of potential radiological impact not covered by the checklist, these issues should be noted.

108-16

Also consider impact of "nonrad" additions on radiological items

Not only new or newly added features, but also existing features that might be affected must be addressed.

108-17

Optimization analysis is required and is presented in Module 110

Optimization includes costs of ALARA measures, dose savings, and intangible variables such as worker concerns, administrative concerns, etc.

108-18

Documented ALARA review should contain

- Design documentation;
- Review approvals; and
- Copies of the report.

108-19

MODULE 109

ALARA OPERATIONAL REVIEW

An ALARA operational review is a systematic pre- and post-job review of high-dose activities to ensure that ALARA controls are planned, evaluated, implemented where reasonable, and documented.

10 CFR 835.1003 requires --

During routine operations, the combination of engineered and administrative controls shall provide that the occupational dose to general employees does not exceed the limits and that the ALARA process is used.

Reviews can be done when required by procedure or as requested.

109-2

An ALARA operational review should be performed for any of the following:

- **Nonroutine jobs or operations in which any individual may receive a dose > 100 mrem or where there is uncertainty in the predicted dose.**
- **Routine jobs or operation in which an individual might receive > 300 mrem.**
- **Any job or operation in which the collective dose is expected to exceed the facility-specific trigger level.**

109-3

An ALARA operational review should be performed for any of the following: (cont'd.)

- **Any job or operation in which any individual may exceed the administrative control level.**
- **Any job or operations in which the dose is greater than an ALARA goal.**
- **Any job or operation in which airborne levels may potentially exceed 10 percent of the DAC.**

109-4

The operational review is conducted in addition to the Radiological Work Permit (RWP)

A simplification of this process would be appropriate for small, uncomplicated operations. The operational review could support RWP preparation or the reviews.

109-5

Here is an aid (checklist) in performing RWP review; it includes:

- **Pre-Job Planning section**
- **Pre-Job section**
- **Operational Review section**
- **Disposition sheet**

109-6

MODULE 110

OPTIMIZATION ANALYSIS

"Optimization" may be defined as arriving at an optimal solution to a problem or selecting the best from among the available alternatives in accordance with a given analytical method.

10 CFR 835.1002 requires radiation exposure optimization

10 CFR 835 states, "Optimization methods shall be used to assure that occupational exposure is maintained ALARA in developing and justifying facility design and physical controls."

110-2

Optimization Guidance

- **DOE Order 5400.5, Ch. 2, "Radiation Protection of the Public and the Environment"**
- **ICRP 55, "Optimization and Decision-Making in Radiological Protection"**

110-3

Optimization Guidance(cont.)

- RadCon Standard Article 312
  - Minor activities
  - Major activities
- PNL-6577, "DOE, Health Physics Manual of Good Practices for Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)"

PNL-6577 addresses the minimum steps for cost-benefit analysis

- **Identify all possible options.**
- **Estimate individual and collective dose.**
- **Identify cost for all viable options.**
- **Determine cost in dollars per person-rem avoided.**

110-5

The purpose of an optimization analysis is to determine if the cost is justified

This is in accordance with the idea of balancing dose reduction considerations against technological, social, operational, and economic considerations.

110-6

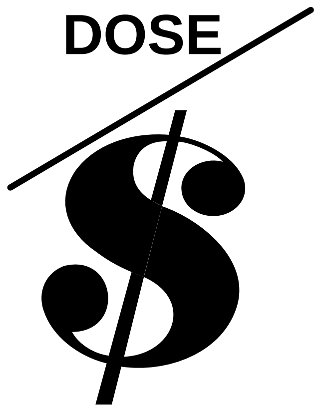
Determination of Alternatives

- Informal analysis.
- Other considerations (status quo) is one alternative.
- Formal optimization analysis.

110-7

One analytical method is the Cost Benefit Analysis (CBA)

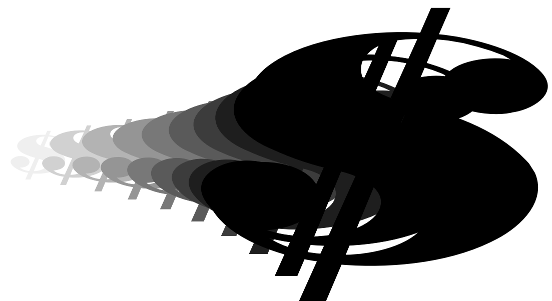
This is done like the traditional CBA, except that dose is considered as one of the cost factors.



110-8

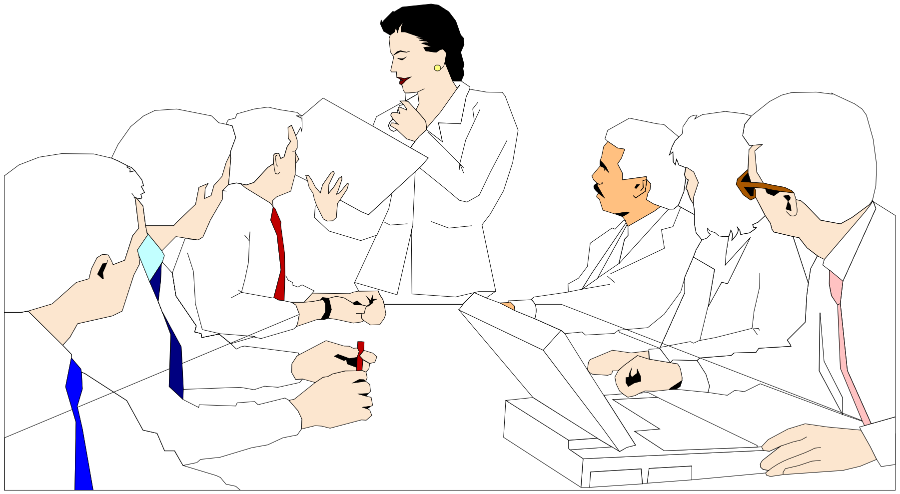
Cost and savings must be estimated over the life of the new technique

In addition, inflation should be factored in.



Yesterday -- Today -- Tomorrow

CBA should be done by the project/ operations engineer or designee



110-10

There are four major steps to the CBA

- Describe feature, measure and radiological aspects.
- Calculate costs.
- Determine the net benefit.
- Perform subjective factor analysis and/or sensitivity analysis.

110-11

CONCLUDING MATERIAL

Review Activity:			**Preparing Activity:**
DOE	Operations Offices	Field Offices	DOE-HS-11
NA	NNSA Service Center		
HS	CH	OH	**Project Number:**
EM	ID	GFO	FSC 6910-0069
NE	NV		
SC	OR		
	RL		
	OAK		
	SR		
	RP		

National Laboratories	Area Offices
BNL	Pantex Site Office
LLNL	Ashtabula Area Office
LANL	Carlsbad Area Office
PNNL	Columbus Area Office
Sandia	Fernald Area Office
FNL	Los Alamos Area Office
	West Valley Area Office
	Kirtland Area Office
	Pinellas Area Office
	Kansas City Area Office
	Miamisburg Area Office