Generic Radiation Worker Training Lesson Plan

July 23, 2020

This training is based on the objectives and material presented in ACAD00-007 Rev 1, October 2016.

Revision History

Rev. #	Reason for Revision	Updated by:
Rev 0 - 9, 02/2007-2014	Initial launch and updates	Bob Wood et al
Rev 10, 12/2016	Updated to DNP and ACAD 00-007 Rev 1.	Bob Wood
Rev 11, 12/2017	Material revision based upon exam review. Revised questions and training materials. No additional lesson material added.	Warren Prince
Rev 12, 7/11/2018	Fixed broken links, aligned lesson summary with section summary.	Warren Prince
Rev 13, 7/23/2020	Aligned objectives with ACAD 00-007 Rev 1. Moved to Storyline. Updated all graphics and interactive exercises.	Warren Prince

1.1 Radiation Worker Training Course Learning Objectives

These learning objectives will be evaluated by an exam, from memory, with an 80% passing grade.

Sources of Radiation

1. State the basic structure of an atom, including the three primary components.
2. Describe how radiation results from the nuclear process.
3. List the sources of radiation in the plant, including the following:
    - Fuel
    - Reactor coolant
    - Activation and corrosion products
    - Plant components
    - Reactor operations

Types and Measurement of Radiation

4. State the four types of radiation found in a commercial nuclear power plant.
5. Characterize the four types of radiation by the following:
    - Penetrating ability
    - Methods of shielding
    - Exposure hazard (for example, whole body, skin, eyes)
    - Where found

6. Define total effective dose equivalent (TEDE)
7. Perform conversions from rem to millirem (mrem) and from mrem to rem.

Biological Effects

8. State the effect of radiation on cells.
9. Define “chronic radiation exposure” and the associated risks.
10. Define “acute radiation exposure” and the associated risks.
11. Define “genetic” and “somatic” effects.
12. Compare genetic versus somatic effects of radiation exposure.
13. Identify the possible effects of radiation on an unborn child due to prenatal exposure.
14. Compare the radio-sensitivity of different age groups.

Limits and Guidelines

15. State the purposes of NRC Form-4.
16. State the federal radiation dose limits for TEDE, skin, extremities, and lens of the

eye.
17. State the possible consequences if any federal radiation dose limit is exceeded.
18. State the plant administrative limits and guidelines for radiation dose.
19. State the actions to be taken if administrative dose limits are being approached.
20. State the federal and plant administrative limit or guideline for an embryo or fetus.
21. State the rights of a declared pregnant worker.
22. Recognize the definition of a planned special exposure.

ALARA

23. State the purpose of ALARA (as low as reasonably achievable).
24. Describe the ALARA program.
25. Explain how time may be used to reduce dose, and state methods to implement this concept.
26. Explain how distance may be used to reduce dose, and state methods to implement this concept.
27. Explain how shielding may be used to reduce dose, and state methods to implement this concept.
28. Calculate stay time given a dose rate, current exposure and an exposure limit.
29. State individual responsibilities regarding temporary shielding.

Radiation Dosimetry

30. State the purpose of dosimetry.
31. List the types of radiation detected by the following devices:
    - Primary dosimetry (dosimeter of legal record [DLR])
        - Thermoluminescent dosimeters (TLDs)
        - Optically stimulated luminescence (OSL)
    - Self-reading dosimeters (SRDs)
32. Identify how to wear dosimetry devices properly, including placement and orientation.
33. Identify the modes, methods and frequency for operating and reading SRD.
34. Identify where and when the following dosimetry devices are issued and returned:
    - Primary dosimetry (DLR)
    - SRDs
35. State the action(s) to be taken if the dosimetry is lost, damaged or alarming.

Contamination

36. Identify and compare the following types of contamination:
    - Fixed contamination
    - Loose contamination
    - Discrete radioactive particle contamination
37. State the units used to measure contamination.

38. Explain why contamination is controlled.
39. Describe the sources and indications of contamination, including the following:
    - Spills and leaks
    - Opening contaminated systems
    - Maintenance activities
40. Discuss the methods used to prevent contamination of personnel and areas, including the following:
    - Planning work and conducting pre-job briefings
    - Using protective clothing (PCs)
    - Avoiding potentially contaminated water
    - Avoiding skin contact with contaminated surfaces
    - Using step-off pads
    - Restricting non-routine surveyed areas (for example, overhead areas 7- feet above the floor)
    - Implementing engineering controls
41. State the individual's actions for removing contaminated and non-contaminated materials from the Radiologically Controlled Area (RCA).
42. Explain how to monitor personnel and personal items for contamination, including the use of the following equipment:
    - Friskers
    - Personnel contamination monitors
43. State the actions to be taken upon indication of becoming contaminated.
44. State the method for control of contaminated tools, equipment and materials, including the following:
    - Minimizing materials contaminated
    - RCA tool issue point
45. State the methods used to designate contaminated areas, including postings and step-off pads.
46. Regarding discrete radioactive particles, be able to state the following:
    - The hazards
    - Methods to identify a discrete radioactive particle
    - Sources of discrete radioactive particles
    - Work activities that may result in discrete radioactive particle contamination
    - Special precautions to be used in an area that may contain discrete radioactive particles
47. Identify situations that require immediate exit from a contaminated area (for example, torn PCs, wounds and wet PCs).

Internal Exposure

48. State four pathways for radioactive material to enter the body:
    - Inhalation
    - Ingestion
    - Absorption
    - Open wounds/injuries

49. State the methods used to limit the internal deposition of radioactive materials, including respiratory protection and engineering controls.
50. State the processes by which radioactive material is eliminated from the body (decay and biological).
51. Recognize the methods used to determine the amount of radioactive material deposited in the body, including whole-body counters and bioassays.
52. Define the following:
    - Derived air concentration (DAC)
    - Annual limit on intake (ALI)
    - Committed effective dose equivalent (CEDE)
53. State the relationship among DACs, ALIs, CEDE and TEDE (DAC and mrem per hour relationship).
54. Discuss plant conditions that may increase the potential for airborne radioactivity:
    - Brushing or sweeping
    - Fan(s) blowing in dusty areas
    - Steam leaks
    - Sanding or grinding in contaminated areas
    - Wet contaminated areas drying out
    - Breaching contaminated systems

Radiological Work Permit (RWP)

55. State the function of an RWP.
56. State the responsibility for complying with RWP requirements.
57. State the required action(s) to be taken if the work scope or radiological conditions change so that they are not within the scope of an RWP.
58. Extract information from an RWP (for example, protective clothing, dosimetry, special instructions).
59. State the perquisite requirements for access to overhead areas greater than seven feet above the floor.
60. Extract information from a survey map.

Postings

61. Define and recognize the following radiological areas and postings:
    - Radiologically controlled area
    - Radiation area
    - High radiation area
    - Locked high radiation area
    - Very high radiation area
    - Radiography in progress
    - Airborne radioactivity area
    - Radioactive material area

- Radioactive materials storage area

62. Define and recognize the following radiological postings:
    - Hot spot
    - Low-dose waiting area
    - Discrete radioactive particle area
63. State the potential consequences of violating, moving or altering a radiological posting.

Radiological Alarms

64. Identify the radiological alarms used in the plant.
65. State the proper response to a given radiological alarm.
66. State the potential consequences of ignoring a radiological alarm.

Radioactive Waste

67. Define "radioactive waste."
68. Contrast the disposal costs of radioactive waste versus non-radioactive waste.
69. State the methods for minimizing the generation of radioactive waste.
70. Explain why it is important to keep contaminated and non-contaminated waste separate.
71. Explain why it is important to keep wet and dry contaminated material separate.
72. Explain why it is important to keep contaminated and hazardous waste separate.

Rights and Responsibilities

73. State individual rights and responsibilities regarding the following:
    - Keeping dose ALARA
    - Adhering to instructions provided by radiological protection personnel (including stop work authority), written policies and procedures, radiation work permits, and posted warnings and signs
    - Maintaining awareness of current personal dose
    - Remaining within federal and plant administrative dose limits and guidelines
    - Identifying the actions and reporting responsibilities when abnormal radiological conditions and/or violations of radiological requirements are encountered
    - Understanding the right of the individual and the process to be followed in obtaining personal radiation dose data

1.2 Why Do You Need This Course

This course prepares students to work safely around radiation in a commercial nuclear power plant. It covers a wide variety of topics required to understand the hazards and protective measures taken by the nuclear industry.

At the end of this course, you will know your responsibilities and expectations as a radiation worker.

1.3 Taking this Course

This course is used in conjunction with a practical exercise in which the student is given an opportunity to practice some of the knowledge gained from this course. You must complete both this course and the practical exercise to be qualified to work in areas where radiation is present.

Upon completion of this course, you will have to pass an exam on the material. The exam questions are derived from the objectives for this course. As you go through the lesson, you will see the objectives prior to the material you must learn.

In order to get credit for this course you must make at least 80% on the exam.

1.4 Course Menu

Radiation Worker Training - Main Menu

- All about Radiation
- Controlling Radiation Exposure
- Radioactive Contamination
- Communication and Waste

2. All about Radiation

2.1 All about Radiation - Introduction

All about Radiation - Introduction

In this section:

- You will learn how radiation is released during nuclear power generation.
- You will learn how to identify the different types of radiation found in a nuclear plant, where you will encounter them, and how the characteristics of each type differ from each other.
- Finally, this section will explain how radiation exposure is measured and the possible effects on humans. Throughout this section, you will have the opportunity to test your knowledge with review exercises

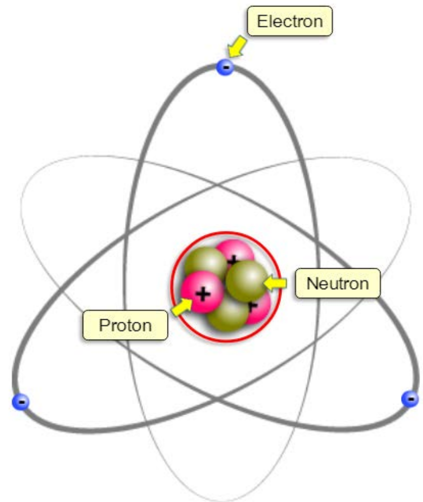
2.2 Parts of an Atom

Objective 1 - State the basic structure of an atom, including the three primary components.

Parts of an Atom

Atoms

Before we start talking about radiation, you must first understand some things about atoms. An atom is the smallest part of an element that retains the characteristics of the element. It means that if an iron atom were broken down into smaller parts it would no longer be iron.



An atom consists of 3 parts: protons, neutrons, and electrons.

The center of the atom is the nucleus. The protons and neutrons are in the nucleus and the electrons orbit around it. Similar to the way that planets orbit around the sun.

Protons **-** Protons are part of the nucleus of the atom. They have a positive charge. The number of protons determines what the element is (for example, oxygen has 8 protons and iron has 26).

Electrons **-** Electrons are small negatively charged particles that orbit around the nucleus of the atom.

Neutrons **-** Neutrons are part of the nucleus of the atom. They do NOT have any charge.

2.3 Radioactive Decay

Objective 2 - Describe how radiation results from the nuclear process.

Radioactive Decay

Even though atoms are very small, they contain a very large amount of energy. An unstable (radioactive) atom is an atom that has excess energy. These atoms will give off the extra energy and will eventually become stable (no longer radioactive).

The process that an atom goes through to become stable is radioactive decay and the energy that is given off is radiation. The radiation we are discussing is called “ionizing radiation”.

Ionizing radiation consists of energy or small particles, emitted from radioactive materials, which can cause chemical or physical damage when they deposit energy in living tissue.

2.4 Radioactive Material

Radioactive Material Emits Radiation

A large collection of radioactive atoms is called radioactive material. Radioactive materials give off radiation in the form of particles and waves. At the end of the process all the excess energy is given off and the atom is stable (no longer radioactive). Some radioactive materials give off all the energy very quickly (seconds) and some take thousands of years.

2.5 What is Radioactive Contamination?

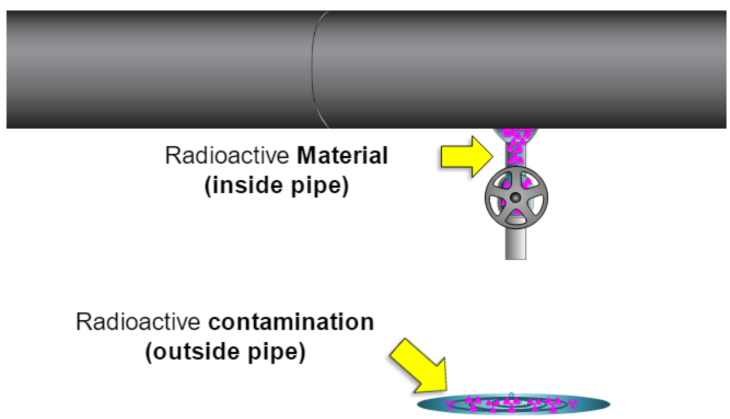
What is Radioactive Contamination?

When radioactive material is in a place it is not supposed to be in (or is not wanted), such as on the floor, it is called radioactive contamination or simply contamination. If it is inside a pipe, it is radioactive material. If it is on the bottom of your shoe, it is called radioactive contamination. No matter where it is, radioactive material gives off radiation.

2.6 Radioactive Contamination

Radioactive Material and Radioactive Contamination

Pipes in a nuclear plant move water and steam through the plant. Radioactive particles and gases can be carried along in the pipe as well. The pipes become a source of radiation.



Radioactive material gives off radiation. Even though the radioactive material is INSIDE the pipe, the radiation it gives off can penetrate through the pipe to work areas.

In this example, workers could be exposed to radiation while working around this pipe. However, they will not get any radioactive material on them. We will talk about how that could happen in a moment.

Some pipes collect more radioactive material than others. In this illustration, radioactive material is becoming trapped in a drain line. It is trapped here and radiation levels increase as more particles end up in the drain line.

The radioactive material is contained in the pipes. Radiation that penetrates the pipe walls will be present in the areas around the pipe. Remember that radiation can penetrate the walls but the radioactive material is still inside the pipe.

In the final illustration, you see water that contains radioactive particles leak onto the floor. Now both the floor and the pipe are radioactive. The difference is that now the radioactive particles are NOT contained. The floor has become contaminated. The contamination can be transferred to other areas.

2.7 Vocabulary Review

New Terms

Atoms - The building blocks of all matter. The smallest part of an element that retains the characteristics of the element.

Proton - Protons are part of the nucleus of the atom. They have a positive charge.

Neutron - Neutrons are part of the nucleus of the atom. They have no charge.

Electron - Electrons orbit around the nucleus of the atom. They have a negative charge.

Unstable (Radioactive) Atoms - An unstable atom is an atom that has excess energy. It is also called a radioactive atom.

Radioactive Decay - The process that an atom goes through to become stable is called radioactive decay.

Radioactive Material - A large collection of radioactive atoms is called radioactive material.

Radioactive Contamination - When radioactive material is in a place it is not supposed to be in (or is not wanted), such as on the floor, it is called radioactive contamination.

Radiation - Radiation is a burst of energy as either particles or waves, given off by a radioactive atom.

2.8 Review – Unstable Atoms

Unstable atoms give off excess energy through radioactive decay. The excess energy is called “radiation”.

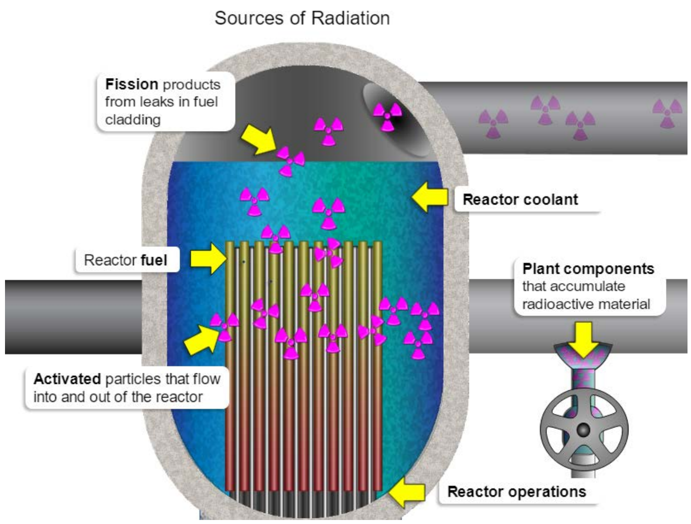
2.9 Sources of Radiation

Objective 2 - Describe how radiation results from the nuclear process.

Objective 3 - List the sources of radiation in the plant, including the following:

- *Fuel*
- *Reactor coolant*
- *Activation and corrosion products*
- *Plant components*
- *Reactor operations*

Sources of Radiation



Most of the radiation at a nuclear plant is inside the reactor. Workers are protected from this radiation by the design of the plant. However, workers can be exposed to radiation while working in a nuclear plant. Where does the radiation come from that workers are exposed to?

Reactor Operations - Operating the nuclear reactor can change radiation levels in some areas of a plant.
Plant Components - Layers of radioactive material can build up over time or become trapped in pipes, pumps, filters, valves and other equipment.
Reactor Coolant - The water that circulates through the reactor becomes radioactive over time, due to corrosion products, and can be a source of radiation.
Fission Products - Pin hole leaks in the metal sheathing around the fuel can allow radioactive gases to escape into the reactor. They can then be carried through steam and water to other areas of the plant.
Activated Corrosion Products - Bits of metal and other debris can be carried by water into the reactor. In the reactor, they become radioactive through a process called "activation".
Reactor Fuel - Nuclear fuel is a source of radiation in a plant. Personnel are not normally exposed to the fuel because it is shielded.

2.10 Fission Products

Creation of Fission Products

Some very large atoms can split and become two atoms when exposed to neutrons that are emitted during the radioactive decay process. The splitting of atoms is called *fission.* Both radiation and heat are created during the fissioning process. The radioactive atoms that result from fissioning are called fission products.

In a nuclear plant, the heat given off is used to heat up water and make steam which turns a turbine and makes electricity. The radiation is a byproduct of the process. The atoms that result from the fission process are radioactive.

By design, fission products should stay in the reactor. The fuel is contained within metal tubes. If a small hole develops in the tubes, the fission products can leak into the water and be carried to other parts of the plant.

2.11 Activation Products

Creation of Activation Products

The radiation inside a nuclear reactor is unique. Neutron radiation can strike materials in the reactor and cause them to become radioactive too. This is called *activation* and only occurs in an operating nuclear reactor.

When the products of corrosion (fine metal particles or debris) are swept by water into the reactor, they can become activated (radioactive). These are called *activated corrosion products.* From the reactor they can be carried by water through pipes to many areas of a nuclear plant.

2.12 Review - Sources

Review - Sources of Radiation

Major sources of radiation at a nuclear plant:

- Fuel
- Reactor coolant
- Activation and corrosion products
- Plant components
- Reactor operations

2.13 Vocabulary Review

New Terms

Activated Corrosion Products - Non-radioactive material that becomes radioactive after exposure to neutron radiation in a nuclear reactor.

Fission Products - Radioactive nuclear fuel in a nuclear reactor gives off energy when the atoms split. This is called fissioning. This results in radioactive atoms called "fission products".

Nuclear Fuel - Nuclear reactors use radioactive fuel. The atoms in the fuel split releasing large quantities of radiation and energy. The energy released heats up the water to make steam.

Plant Components - Plant components are the many thousands of parts and pieces used to generate electricity. Some of these will become radioactive over time and be a source of radiation to workers.

Reactor Operations - A working nuclear reactor is a source of radiation. Operating it and the equipment that supports it can change the radiation levels in a nuclear plant.

Reactor Coolant - The water that flows in and around the reactor.

2.14 Types of Radiation

Objective 4 - State the four types of radiation found in a commercial nuclear power plant.

Objective 5 - Characterize the four types of radiation by the following:

- *Penetrating ability*
- *Methods of shielding*
- *Exposure hazard (for example, whole body, skin, eyes)*
- *Where found*

Types of Radiation

The radiation found at nuclear plants is referred to as ionizing radiation. There are four types of radiation commonly encountered at nuclear power plants. For each you will need to know:

- Penetrating ability
- Shielding methods
- Exposure hazard
- Major sources

2.15 Four Types of Radiation

Four Types of Radiation

An unstable atom will give off radiation in order to become stable again. The types of radiation given off will depend upon the radioactive element. In this example, you will see all 4 types from a single atom, which is not usual. It is shown here to help you understand the differences between each type.

Alpha - Alpha radiation is a byproduct of the nuclear fission process that occurs within the fuel assemblies in the reactor core. Very little dose received at U.S. nuclear plants normally comes from alpha radiation.

Since the fuel is contained in metal rods, the main hazard from alpha radiation exists only if fuel leaks occur or personnel are exposed to alpha radiation from fuel leaks that occurred in previous operating cycles.

Alpha contamination from previous operating cycles can adhere to system piping and components, and become exposed when abrasive work like sanding, grinding, or sand blasting uncovers hidden alpha contamination, which can create a potentially high internal dose hazard.

It is important that the radiation protection staff evaluates conditions for alpha when disassembling components or when scraping, grinding, or otherwise removing top layers of corrosion product deposits. So if alpha radiation can be common in a plant why don't people get exposed to it very much? The answer has to do with alpha's inability to travel very far and penetrate through even very thin materials. As long as the material is not inside your body you will not receive any exposure from alpha radiation. Your good work habits and protective equipment provided to you can prevent it.

Gamma radiation is able to penetrate through piping and components to expose workers. Gamma coming from pipes and other components can penetrate through the metal and into your tissues.

Shielding - The amount of gamma radiation can be reduced by placing dense materials like led, concrete or steel between the radiation sources and the workers. Gamma radiation contributes the most radiation exposure to workers in a nuclear plant. It can strike any tissues in the human body. Radioactive materials that give off gamma radiation are common throughout a nuclear plant.

Beta radiation is a concern mainly when contaminated reactor systems and components are open, such as valves that are disassembled for repair.

The reason for this is that beta radiation can be stopped by plastic or thin metal. It will not penetrate the piping walls. However, corrosion products frequently collect in plant components, so opening them can increase the chances of exposure to beta radiation.

Neutron radiation is normally a concern only when the reactor is running. During reactor operations neutrons are released as part of the chain reaction of the fission process. When the reactor is shut down, the fission process is stopped. Therefore, neutron release is stopped. Neutrons also create activation products. Very little of the radiation exposure to people at a nuclear plant comes from neutron radiation.

Sources of neutron radiation are mostly inside the reactor or associated with highly radioactive used fuel. It is normally not found in high levels where people are working in a plant. Workers performing some highly specialized work activities could be exposed to neutron radiation. Radiation Protection personnel will communicate with workers if this is the case, and will provide monitoring.

2.16 Shielding Materials

Radiation Types and Shielding Materials

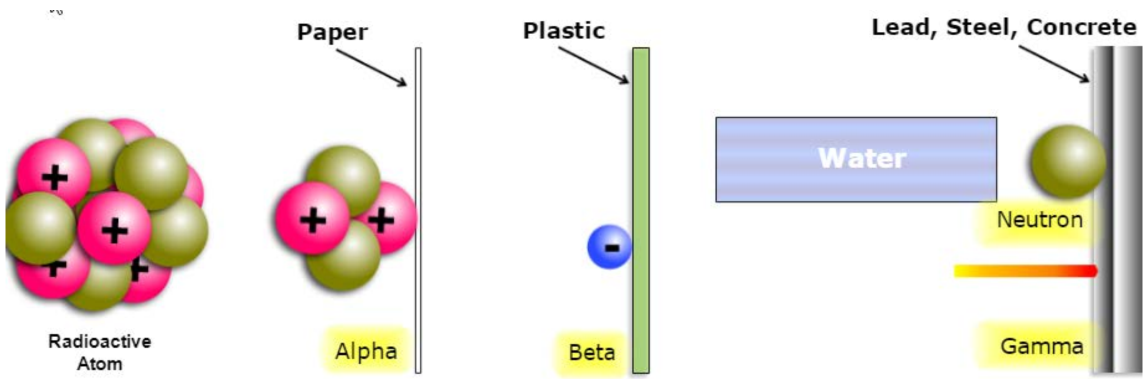
The four types of radiation found at nuclear plants are:

Alpha Radiation - Alpha radiation is very large compared to the other types of radiation. It also has 2 positive charges. Because of its size and the charges, it interacts with other charged particles and cannot go very far. Very thin materials such as paper easily shield it.

Beta Radiation - Beta radiation is a small negative or positive charged particle that is ejected from the nucleus of a radioactive atom. Since it is smaller and has less charge than alpha radiation, it travels further and it takes more to reduce or eliminate it.

Gamma Radiation - Gamma radiation is NOT a particle like the other radiation types. It is just a burst of energy given off by the nucleus of a radioactive atom. Because it has no mass and no charge, it travels far and can penetrate through even thick materials. It can easily penetrate through the walls of a pipe. It takes thick amounts of lead, steel or concrete to stop it.

Neutron Radiation - Neutron radiation occurs when a neutron is ejected from the nucleus of a radioactive atom. Neutrons have a large amount of energy and do not have any charge. The result is an energetic particle that can penetrate many materials. It has to be "slowed down" with water before it can be easily shielded with a dense material like lead, steel, or concrete.



2.17 Review Radiation Types

Review - Radiation Types
The four types of radiation are:

- Alpha
- Beta
- Gamma
- Neutron

2.18 Radiation Characteristics

Radioactive Materials inside Plant Components

Radioactive material inside plant components such as pipes and valves give off radiation. Of the four types of radiation we deal with in a nuclear plant gamma is the one that is common and can penetrate through the metal. That is why almost all the radiation exposure received by nuclear workers comes from gamma radiation. Remember neutron radiation while common in the reactor is not found in other plant components.

2.19 Review - Radiation Types

Review - Radiation Types

Most radiation exposure in a nuclear plant comes from gamma radiation.

2.20 penetration

Radiation Types and the Human Body

Let’s learn about how each radiation type interacts with the human body.

Alpha Radiation - Alpha radiation cannot penetrate into living cells from outside the body. The dead skin cells will prevent alpha from penetrating through to living cells.

Gamma Radiation - Gamma radiation is pure energy and can easily penetrate through to living cells anywhere in the body. Most radiation exposure in a nuclear plant comes from gamma radiation since it also penetrates through equipment and piping, and travels further than the other types.

Beta Radiation - Beta radiation can penetrate into the living skin cells but can't penetrate further. Nuclear workers are not normally exposed to much beta radiation. It cannot penetrate through equipment and pipes so it is ONLY in places where systems are open or leaking.

Neutron Radiation - Neutron radiation is highly energetic neutrons ejected from the nucleus. It can penetrate easily into any living cell. Normally nuclear workers are not exposed to neutron radiation because it is mostly found near an operating nuclear reactor.

2.21 Radiation and the Eye

Radiation Types and the Human Eye

Most of the human eye responds to radiation exposure in the same way as other human tissues. However, the lens of the eye is monitored differently. Alpha radiation and most beta radiation can be stopped (shielded) by the cornea of the eye. Some beta radiation could penetrate to the lens.

Alpha Radiation - Alpha radiation cannot penetrate into to the interior of the eye including the lens. The outer layers will block alpha radiation.

Gamma Radiation - Gamma radiation can penetrate through any human tissues. It can deposit energy anywhere along its path.

Beta Radiation - the cornea of the eye will stop most beta radiation, but it is possible that some beta radiation could penetrate to the lens.

Neutron Radiation - Neutron radiation can penetrate through any human tissues. It can deposit energy anywhere along its path.

2.22 Radiation Source in Pipe

Radiation Types and the Human Body

Typically, radioactive material is on the insides of pipes or other plant components. In typical plant settings:

- Alpha radiation cannot penetrate through the pipe.

- Gamma can penetrate through the pipe and into human tissue.
- Beta radiation cannot penetrate through the pipe.
- Neutron radiation would not be found here. It is normally coming from a nuclear reactor.

2.23 Radiation Source in the Body

Radioactive Material inside the Body

What happens when the radioactive material is inside the body? Radiation that might normally be shielded by clothing and skin layers would be able to strike living tissue.

Alpha Radiation - In this illustration, the alpha radiation will strike living tissues. There is no shielding (such as dead skin cells) to stop the alpha radiation. Alpha can be damaging to living cells but only when the source of alpha radiation is inside the body.

Gamma Radiation - Gamma radiation is pure energy and can easily penetrate through to living cells anywhere in the body. It does not matter if the source of radiation is inside or outside the body. The possible damage to cells is the same.

Beta Radiation - When the source of beta radiation is inside the body it can strike living cells in whatever organs it is near. Recall that when the source of radiation is outside the body, beta radiation only affects the skin layer and lens of the eye.

Neutron Radiation - Radioactive material emitting neutron radiation would not be likely to get into your body. Neutron radiation is ONLY found in or around an active nuclear reactor.

2.24 Measuring Radiation – Rem and Millirem

Objective 7 - Perform conversions from rem to millirem (mrem) and from mrem to rem.

Measuring Radiation - Rem and Millirem

The term, rem, is a measure of any type of radiation in terms of the estimated biological effects. It is used to measure radiation exposure to people. Because measurements of radiation are frequently in very small fractions of rem, the prefix milli, meaning 1/1000, is generally used.

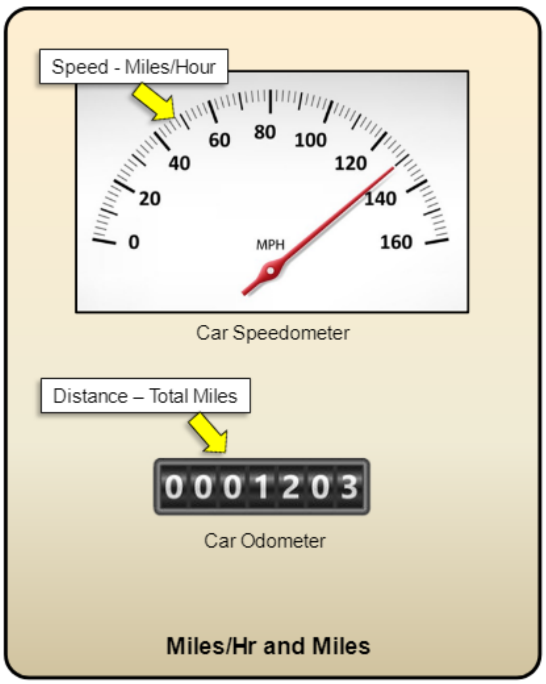
One millirem is one thousandth of a rem; therefore, there are one thousand millirem in one rem. This unit is commonly abbreviated as mrem or mr. You should be able to convert from rem to mill rem and from millirem to rem.

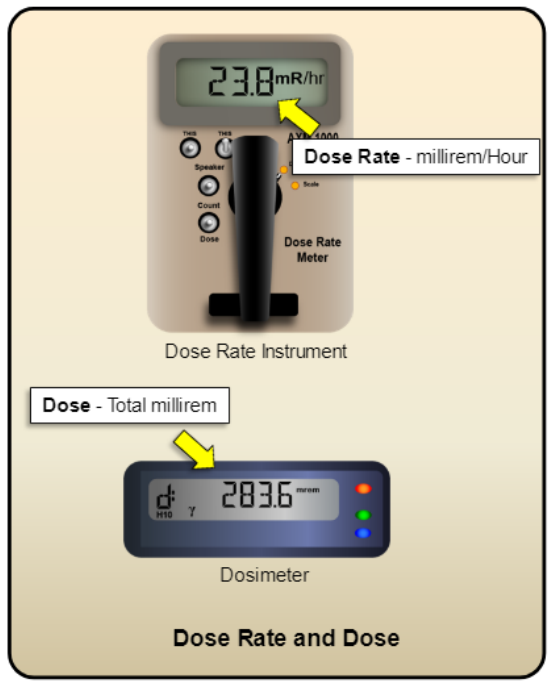
NOTE: At very high dose rates the term rem is NOT used. The term “rad” is technically correct in these situations. You will rarely see the term “rad”. Later you will see this used in the definition of a Very High Radiation Area.

2.25 Compare with Something You Already Know

Compare with Something You Already Know

A good way to learn something new is to compare it with something you already know. In this example, you already know the relationship between miles per hour and the total miles. When talking about radiation exposure the terms are millirem per hour and millirem.





The **dose rate** is how fast you would be receiving radiation exposure. It is measured in millirem per hour or rem per hour. This number goes up and down as you move around the radiation sources.

The **dose** is the total amount of radiation you were exposed to. It is measured in millirem or rem. This number can only go up as you are exposed to more radiation.

2.26 Vocabulary Review

New Terms

Shielding - One of the four characteristics of the radiation types you are required to know. Materials used to reduce or eliminate radiation levels. Typical materials used include lead, water, concrete and steel.

Exposure Hazard - One of the four characteristics of the radiation types you are required to know. The likelihood of receiving radiation exposure from a particular type of radiation.

Sources of Radiation - One of the four characteristics of the radiation types you are required to know. Where the radiation is likely to be found in a plant. What is giving off the radiation?

Penetrating Ability - One of the four characteristics of the radiation types you are required to know. How well does the type of radiation go through materials? How far can it go into a material such as human tissue?

Alpha Radiation - A positively charged particle that consists of two protons and two neutrons bound together. It is emitted by an atomic nucleus undergoing radioactive decay and is identical to the nucleus of a helium atom. Because of their relatively large mass, alpha particles are the slowest and least penetrating forms of nuclear radiation. They can be stopped by a piece of paper.

Beta Radiation - One of the four common types of radiation found in a nuclear plant. Beta radiation is an energized particle the size of an electron. From outside the body it can penetrate to the living skin layers and the lens of the eye but cannot penetrate into the internal organs. Dose to organs could only occur if the radioactive material giving off beta radiation is inside the body.

Gamma Radiation - Highly penetrating burst of energy emitted from an unstable atom. Most dose received by nuclear workers comes from gamma radiation. Gamma can penetrate through pipes and other materials and to areas where people are working. Temporary shielding can reduce the radiation levels but not eliminate them.

Neutron Radiation - A highly energetic particle type of radiation emitted during the fission process. Typically, this only occurs inside of an operating nuclear reactor. Nuclear workers are rarely exposed to neutron radiation. Most of the dose received by nuclear workers is from gamma radiation.

Dose and Dose Rate - When the body or any specific organ is exposed to radiation, the amount of radiation that it receives is called ***dose***. This is measured in units called rem or millirem (1/1000 rem).

Dose rate is a measure of how fast the body is receiving the radiation exposure. It is usually expressed in millirem/hr. Just like miles is a measure of distance and miles/hour is how fast you are going.

2.27 Radiation Effect on Cells

Objective 8 - State the effect of radiation on cells.

The human body is made up of millions of cells that, through natural processes, are always dividing, dying, and being replaced by new cells. Excessive exposure to radiation may permanently damage or destroy cells. The possible outcomes when a cell is struck by radiation are:

- Nothing happens, no damage to the cell as a result of radiation exposure.
- The damage to the cell from radiation exposure is extensive and may result in cell mutation but not cell death.
- The cell is damaged by exposure to radiation but repairs itself, before it reproduces.
- Damage to the cell from radiation exposure is so great that the cell dies.

2.28 Nuclear Regulatory Commission

Nuclear Regulatory Commission (NRC)

On upcoming pages, you will see some data provided by the federal government. The agency that governs the nuclear industry is the Nuclear Regulatory Commission (NRC).

Congress created the U.S. Nuclear Regulatory Commission (NRC) as an independent agency in 1974 to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment.

The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection and enforcement of its requirements.

We will refer to the NRC several times in this course. They are a very important part of your job as a nuclear worker.

2.29 Chronic vs Acute

Objective 9 - Define "chronic radiation exposure" and the associated risks.
Objective 10 - Define "acute radiation exposure" and the associated risks.

Chronic Vs Acute Radiation Exposure

Chronic radiation exposure occurs when you are exposed to a small amount of radiation over a long period. The result is an increased risk of a health effect, like cancer.

Acute radiation exposure occurs when you are exposed to high levels of radiation over a short term. The damage is immediate.

All radiation exposure limits and industry policies and procedures conservatively assume that there is some increase in risk with chronic radiation exposure and that risk increases linearly with incremental increases in dose.

The difference between acute and chronic radiation exposure can be shown by using exposure to the sun's rays as an example. An intense exposure to the sun can result in painful burning, peeling and growing of new skin.
However, repeated short exposures provide time for the skin to be repaired between exposures. Whether exposure to the sun's rays is long term or spread over short periods of time, some of the injury may not be repaired and may eventually result in skin cancer.

Scientific studies show an increased chance of health effects such as cancer from high doses, when the dose is delivered over a relatively short period as compared to occupational exposures that are typically low doses that are delivered over a much longer period.

Increased health effects, due to chronic exposure (as received by nuclear workers) have not been proven but are assumed based upon the research with high levels of radiation exposure.

2.30 Risk of Chronic Exposure

Risk of Chronic Exposure

Most exposure received at nuclear power plants (occupational dose) is chronic. Chronic radiation exposure has less risk associated with it than many other common activities and conditions. The federal government provides comparative data for nuclear workers so that we can understand the risks of radiation exposure compared to other risks we already know about. This table compares the risk of receiving occupational dose to the risks you may already know. *Review the table here so that you will be able to compare risks*.

Estimated Loss of Life Expectancy Source: Reg. Guide 8.29 Table 1	
Activity/Condition	**Loss**
Smoking 20 Cigarettes a day	6 years
Overweight by 15%	2 years
All accidents	1 year
Alcohol consumption (U.S. average)	1 year
1 rem/yr for 30 yrs (calculated)	51 days
All catastrophes (earthquake, etc.)	7 days
Medical & diagnostic X-rays (calculated)	6 days

2.31 Acute Exposure Facts

Acute Exposure

Acute radiation exposure is a large dose received in a short period, usually less than 24 hours. During normal nuclear power plant activities, workers should not be exposed to sources of radiation that will result in an acute exposure. The federal government provides this table so that you can know the effects of acute radiation exposure. *Review the table to see the effects.*

Effects of Acute Radiation Exposure	
Acute Dose (rem)	**Probable Effects**
0 - 25	No noticeable effects
25 - 100	Slight blood changes, possible fatigue, nausea
100 - 200	Vomiting in 5 to 50 percent within 3 hours. Fatigue and loss of appetite. Moderate blood changes. Except for blood-forming system, recovery will occur in essentially all cases within a few weeks.
200 - 600	Vomiting, fatigue, and loss of appetite in 50 to 100 percent within 3 hours. For doses over 300 rads, these effects will appear in all cases within 2 hours. Loss of hair after 2 weeks. Severe blood changes accompanied by hemorrhage and infection. Death in up to 80 percent within 2 months; for survivors, recovery period of 1 month to a year.
These effects are based on exposure to the entire body with no medical treatment. (adapted from S. Glasstone, Sourcebook of Atomic Energy)	

Other reliable sources may have different opinions on the effects of these levels of radiation.

2.32 Genetic vs Somatic

Objective 11 - Define "genetic" and "somatic" effects.
Objective 12 - Compare genetic versus somatic effects of radiation exposure.

Genetic and Somatic Effects

Effects of radiation exposure that show up in the person exposed to radiation are called "somatic effects". If reproductive cells are damaged and it is passed on to the next generation, they are called "genetic effects". The chances of genetic effects occurring are very small even with radiation exposure much higher than that experienced by nuclear workers and as of yet have not been proven even at high levels of exposure.

According to NRC (Nuclear Regulatory Commission) Regulatory Guide 8.29, genetic effects clearly caused by radiation have not been observed in human populations exposed to radiation. It includes atomic bomb blast survivors.

The probability of occupational exposure producing a genetic mutation in a worker's offspring is extremely remote.

2.33 Radiosensitivity

Objective 14 - Compare the radiosensitivity of different age groups.

Sensitivity to Radiation and Age

Cell reproduction slows as you age, so younger people are more sensitive to radiation than older people are. Therefore, the embryo is more sensitive than infants are and infants are more sensitive than older children are, and so on. This is called radiosensitivity. The most rapid growth period for people is during the stages prior to birth (e.g. the fetus). Cells are rapidly dividing and radiosensitivity is at its highest.

2.34 How Radiation Affects Unborn Children

> *Objective 13 - Identify the possible effects of radiation on an unborn child due to prenatal exposure.*

How Radiation Affects Unborn Children

Because rapidly growing cells are more sensitive to radiation exposure, a female radiation worker who is pregnant or planning to become pregnant should understand how radiation could affect an embryo/fetus.

Radiation exposure levels experienced by nuclear workers have not been shown to result in health effects to embryo and fetus; however, health effects at very high levels have been documented. Examples include the children of pregnant women exposed to radiation at Hiroshima and Nagasaki nuclear bomb blasts. These health effects include intellectual disability and other birth defects.

Even though nuclear workers are not exposed to these very high levels it is still assumed that children exposed to radiation in the womb could have increased risks. Because of the possible effects to the embryo and fetus there are special limits available to pregnant women.

To put this in perspective it is useful to compare risks. According to NRC Regulatory Guide 8.29, the social factors of drinking and smoking can have a MORE significant impact on fetal development than the risks associated with occupational radiation exposure.

2.35 Vocabulary Review

New Terms

Cell Mutation - One of the biological effects that can result from radiation damage to a cell. A mutated cell survives but has been altered.

Chronic Exposure - Chronic exposure *is a series of small doses spread out over a long period* such as months or years.

Acute Exposure - Acute radiation exposure is a large dose received in a short period, usually less than 24 hours.

Occupational Dose - Radiation exposure received while working at a nuclear plant or other job involving radiation. This does not include radiation exposure from nature, x-rays, medical treatments, etc.

Genetic Effects - Genetic effects appear in future generations of an individual who received the dose and may appear as birth defects or other conditions.

Somatic Effects - Somatic effects are the effects of radiation felt in the person who received the radiation dose.

Radiosensitivity - Radiation has a greater effect on cells that have a higher rate of reproduction. Because cell reproduction slows as you age, younger people are more sensitive to radiation exposure than older people are.

Nuclear Bomb Blasts - Hiroshima and Nagasaki are Cities in Japan, which were bombed by nuclear weapons during World War II. Many studies on radiation exposure are based on the effects of radiation on the people from these areas in Japan.

Federal Risk Comparisons - The federal government provides risk comparison data for nuclear workers in **NRC Regulatory Guide 8.29**, "Instruction Concerning Risks from Occupational Radiation Exposure"

2.36 Summary - All about Radiation

Summary: All about Radiation

- Atoms are made up of protons (positive charge), neutrons (no charge), and electrons (negative charge).
- Energy in the form of radiation is released when an atom splits as part of the fission process.
- Alpha, beta, neutron, and gamma radiation have different characteristics and penetrating abilities.
- Common sources of radiation in a nuclear plant are fuel, plant components, corrosion and activation products, and reactor operations.
- Radiation exposure can be chronic (low dose over a long time) or acute (high dose in a short period of time).
- Radiation effects are genetic (offspring) or somatic (person exposed).
- Younger people are more sensitive to radiation than older people are.
- Dose is the total radiation received by the body.
- Dose rate is how fast dose is received.
- Radiation dose is measured in rem or millirem.

3. Working with Radiation

3.1 Controlling Radiation at Work - Introduction

Controlling Radiation at Work - Introduction

In the section, "All About Radiation" you learned about radiation hazards. In this section, you will begin to see how you can work safely around radiation.
This section covers:

- Radiation Dose Limits and Guidelines
- ALARA
- Dosimetry

3.2 Your Responsibilities

Objective 73 - State individual rights and responsibilities regarding the following:

- Adhering to instructions provided by radiological protection personnel (including stop work authority), written policies and procedures, radiation work permits, and posted warnings and signs

Your Responsibilities

Radiation Protection (RP) Department personnel are responsible for implementing station policies, procedures, and programs, but you are responsible for following them. The RP staff members are the experts on radiation exposure and are available to everyone for assistance.

- You are responsible for following the rules and the RP staff will help you do so.
- You must adhere to all written and verbal instructions provided by RP, including stop-work orders.
- You must also understand and comply with Radiation Work Permits and all postings and signs.

Some of your other rights and responsibilities will be covered throughout this section. If you have any questions about your role in working safely around radiation, contact the RP personnel at your site *before* you go to work.

3.3 Tracking Your Occupational Dose

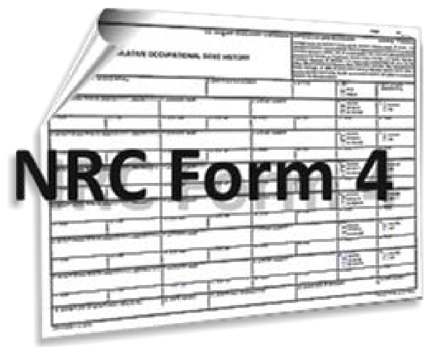
Objective 15 - State the purposes of NRC Form-4.

Objective 73 - State individual rights and responsibilities regarding the following:

- *Remaining within federal and plant administrative dose limits and guidelines*
- *Understanding the right of the individual and the process to be followed in obtaining personal radiation dose data*

Tracking Your Occupation Dose

Dose History (NRC Form 4) - The NRC Form 4 (or equivalent) is required to be updated with previous occupational exposure during the calendar year before a worker may receive more dose than members of the general public. It is your responsibility to ensure that all dose for the calendar year is reported to the company before starting work at the plant. It is also true if you visit another nuclear facility. You have the right to review your dose history at any time. Ask the Radiation Protection personnel how to get access to your records.



3.4 TEDE

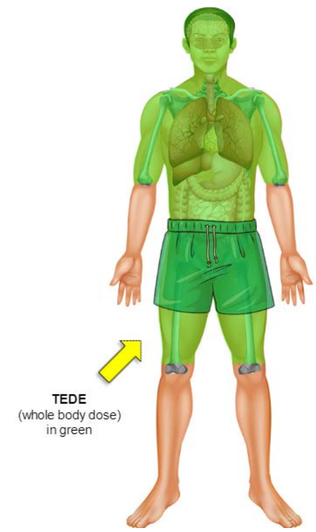
Objective 6 - Define total effective dose equivalent (TEDE)

TEDE (Total Effective Dose Equivalent)

The radiation dose to your body has a special term. It is called TEDE. On the next slide, we will learn about dose limits. A very important term you need to know is TEDE.

TEDE is an acronym that stands for “Total Effective Dose Equivalent”. It is also called “whole body dose”. It is that part of your body that contains your critical organs. TEDE comes from radiation sources outside your body (most common) and from inside your body (usually none to a very small amount). These are added together to result in TEDE.

External dose comes from radiation sources located outside the body. The entire body, inside and out, receives the dose. Most of the dose received by nuclear workers is external.



Internal dose comes from radioactive material deposited inside the body. The majority of this dose is to the organ(s) where the radioactive material is deposited. This normally occurs if a person gets radioactive material inside the body by breathing it in or swallowing it.

Notice the figure. The portions that are highlighted green are the areas of the body associated with TEDE. It does NOT include the portions of the arms and legs that are NOT highlighted green. There are separate limits for all parts of the body. We will discuss these later.

3.5 Dose Limits

Objective 16 - State the federal radiation dose limits for TEDE, skin, extremities, and lens of the eye.

Objective 18 - State the plant administrative limits and guidelines for radiation dose.

Objective 19 - State the actions to be taken if administrative dose limits are being approached.

Radiation Dose Limits and Guidelines

Federal Dose Limits - the Nuclear Regulatory Commission (NRC) sets occupational radiation dose limits. These legal limits are based on the current understanding of the biological effects of radiation. Federal Regulation 10 CFR 20 states that no licensee (nuclear plant) shall allow any person to receive a total occupational dose greater than the legal limits.

The nuclear industry used guidelines to stay well within the federal laws. Consider these guidelines as important as the federal laws.

Because certain parts of the body are more sensitive to radiation than others, different limits have been established for different parts of the body based on the potential biological effects.

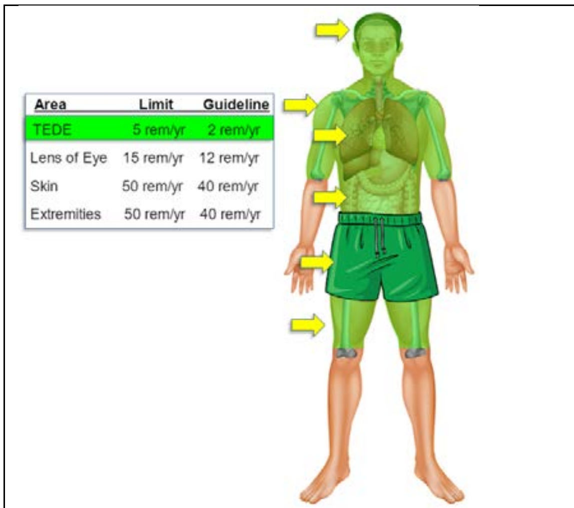
TEDE - TEDE stands for Total Effective Dose Equivalent. It is dose to the parts of your body containing the vital organs. Most of the radiation exposure received by nuclear workers falls into this category. The limit is 5 rem per year. The guideline is 2 rem per year.

Extremities - Extremities are hands and lower arms (including the elbows) as well as feet and lower legs (including the knees). The vital organs are NOT in the extremities. The upper arm and the upper leg that have vital blood forming organs are NOT part of the extremities. The limit to the extremities is 50 rem per year. The guideline is 40 rem per year.

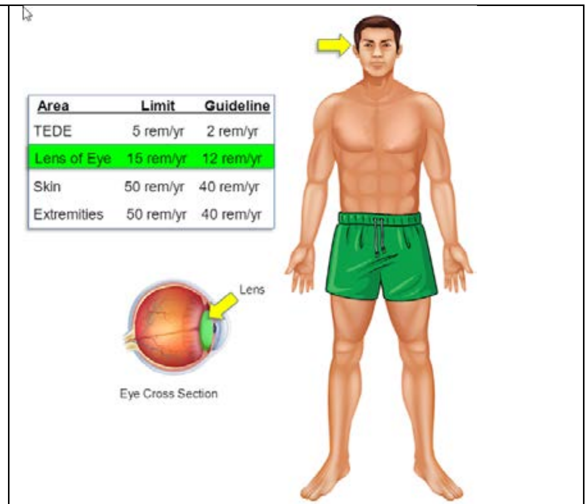
Skin - The skin in this case refers to the skin of the whole body. The same parts of the body as TEDE. The federal dose limit for the skin is 50 rem per year and the guideline is 40 rem per year.

Lens of the eye - Dose to the lens of the eye is monitored separately when required. The federal dose limit to the lens of the eye is 15 rem per year. The guideline is 12 rem per year.

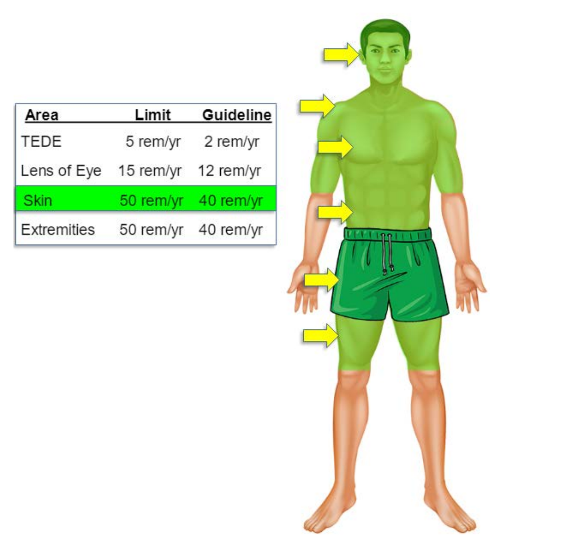
Do not exceed these limits. If you are approaching a limit or guideline, contact the radiation protection staff before going further.



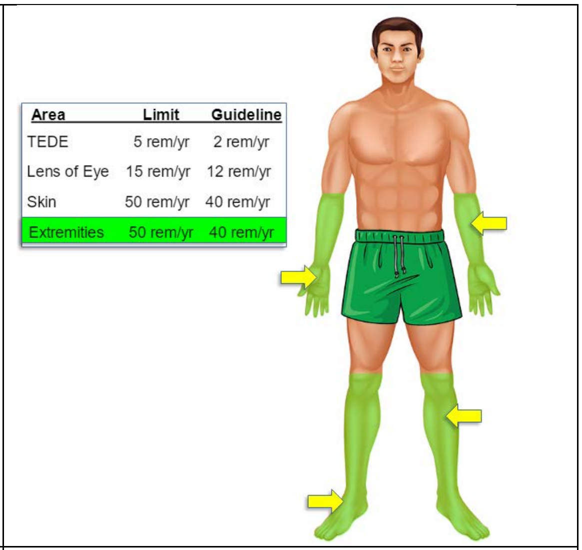
Total Effective Dose Equivalent (TEDE)



Lens of the Eye



Skin



Extremeties

3.6 What Happens if You Exceed Dose Limits?

Objective 17 - State the possible consequences if any federal radiation dose limit is exceeded.

Objective 73 - State individual rights and responsibilities regarding the following:

- *Maintaining awareness of current personal dose*

What Happens if You Exceed Dose Limits?

Exceeding Dose Limits - Exceeding federal dose limits is a serious violation of plant policy and federal law. It can result in a number of possible consequences:

- Increased risk of adverse health effects
- Fines assessed against the plant by the NRC
- Disciplinary action against the individual for willful violation
- Increased NRC regulatory oversight
- If the violation is deemed willful, a worker can face civil penalties that could include fines and jail time.

3.7 Declared Pregnant Worker

Objective 20 - State the federal and plant administrative limit or guideline for an embryo or fetus.

Objective 21 - State the rights of a declared pregnant worker.

Declared Pregnant Worker

A declared pregnant worker is a woman who has voluntarily informed the licensee (the plant), in writing, of her pregnancy and the estimated date of conception. Her declaration remains in effect until she withdraws it in writing or is no longer pregnant.

The woman may decide not to declare her pregnancy. This decision is a personal one. The employer is responsible to ensure that the worker is aware of all the risks associated with radiation exposure to the embryo/fetus.

Both NRC Regulatory Guide 8.13 and 10 CFR 20.1208 contain a dose limit of 500 millirem (TEDE) over the entire term of a pregnancy. When a worker notifies the company in writing that she is pregnant, her dose will be limited to 500 millirem for the duration of the pregnancy to provide fetal protection. This provides an adequate margin of protection for the embryo/fetus.

The industry administrative guideline is 450 millirem for the entire term of the pregnancy, not to exceed 50 millirem per month.

If a woman chooses not to declare her pregnancy, the dose limits will be based on normal radiation worker limits. The company may review alternate work assignments to reduce or eliminate radiation dose for the declared pregnant woman.

3.8 Planned Special Exposures

Objective 22 - Recognize the definition of a planned special exposure.

Planned Special Exposures

A Planned Special Exposure (PSE) is an authorized exposure that is separate from and in addition to the annual dose limit.

Before a worker is authorized to have a PSE, the worker has to be informed of the purpose and circumstances of the planned operation, the estimated doses expected and the procedures to keep the dose ALARA.

PSEs are only allowed in exceptional situations when alternatives for avoiding the additional exposure are not available or are impractical.

Although the use of a PSE is not anticipated, in the unlikely event that it is required, senior management involvement and approval are required first. A worker can only receive this special limit once in his or her career.

3.9 Vocabulary Review

New Terms

NRC Form 4 - A federal form that documents your occupational exposure. A form 4 or equivalent must be completed before you are allowed to receive radiation exposure.

Radiation Dose Limits and Guidelines - Federal dose limits are provided by the Nuclear Regulatory Commission in 10 CFR 20.

10 CFR 20 states that no licensee (nuclear plant) shall allow any person to receive a total occupational dose in excess of the legal limits specified below.

Radiation Protection Department - Radiation protection personnel are your connection with anything having to do with radiation and contamination. Members of the RP staff are experts in radiation and working safely around it. RP has stop work authority. Follow all RP rules and guidelines and obey all signs and postings. Some plants will refer to RP as Health Physics (HP).

Unplanned Radiation Exposure - Radiation dose higher than was expected for the job and area being worked.

Nuclear Regulatory Commission (NRC) - The government agency that oversees the nuclear industry.

Whole Body Dose - Dose to the portion of your body that contains vital organs. It does

NOT include dose to the extremities (lower arms and lower legs). Also known as Total Effective Dose Equivalent (TEDE).

Limit = 5 rem/yr.
Guide = 2 rem/yr.

Extremities - Dose to that part of the body from the elbows to the fingertips and the knees to the toes.

Limit = 50 rem/yr.
Guide = 40 rem/yr.

Declared Pregnant Worker – Pregnant women have an option for a lower dose limit. To get the lower limit they must declare their pregnancy. A declared pregnant woman is a woman who has stated in writing that she is pregnant.

Planned Special Exposure (PSE) - PSEs allow a worker, once in a lifetime, to exceed the federal limits. PSE is an option that could be used in extreme circumstances. These must be planned and have the approval of Sr. Management.

3.10 ALARA – As Low As Reasonably Achievable

Objective 23 - State the purpose of ALARA (as low as reasonably achievable).
Objective 24 - Describe the ALARA program.

ALARA - As Low As Reasonably Achievable

You are required to keep your dose to a reasonably low level for the work that you do. You, your supervisor, and the rest of the plant staff must be thinking of ways to reduce everyone's radiation exposure. There is an assumption for regulatory and radiation protection purposes, that exposure to radiation increases health risks and we must act as if it does.

This concept is called ALARA. ALARA is an acronym for "As Low As Reasonably Achievable". You will hear this term a lot. Management shows their commitment to ALARA by having a formal ALARA program. The ALARA program will include a plant ALARA committee and a daily emphasis on dose reduction.

An ALARA program has many parts and pieces working together. Important parts include:

- Pre Job ALARA Reviews - work activities are reviewed in advance for ALARA consideration.

- Pre Job ALARA Briefings- workers are informed about plans, conditions and given an opportunity for input
- Job Planning - includes worker experience and lessons learned and ALARA reviews
- Training Mockups - allow workers to practice some jobs in a realistic setting before doing the actual work.
- Temporary Shielding Programs - used to reduce radiation levels before work starting
- Proper Ventilation Systems - control the flow of possibly contaminated air.
- Decontamination efforts - reduce the spread of contamination.

3.11 ALARA Briefings

ALARA Briefings

Self-Briefing for Low-Risk Radiological Work

Normally ALARA briefings are performed by the radiation protection staff but there are some exceptions. Self-briefing allows radiation workers to brief themselves on work area radiological conditions without having to interface directly with RP. The worker's supervisor should determine if the worker meets the self-briefing criteria during the task brief. RP may permit workers to use the self-briefing process with these radiological area conditions and activity restrictions.

Self-briefing restrictions:

- Work is categorized as low radiological risk
- No entry or work in High Radiation Areas
- No entry or work in Radiation Areas > 25 mrem/hour
- No entry or work in Contaminated Areas > 10,000 dpm/100 cm2
- No entry or work in posted Alpha or Airborne Radioactivity Areas
- No entry or work in overhead areas above 7 feet

Work that meets bo*th the area and activity restrictions l*isted may use the self-brief process. We will learn more about the terminology associated with these restrictions. For now know that restrictions exist and you can learn more by asking the radiation protection staff.

3.12 Self-Briefing Activity Restrictions

Self-Briefing Activity Restrictions

If a worker is not sure if they meet the conditions for using the self-briefing process or have concerns they should check with RP. Remember, area restrictions are only half of the self-briefing restrictions.

The following ACTIVITY RESTRICTIONS apply to worker self-briefings as the activities could change the work area radiological conditions:

- No abrasive work (cutting, grinding)
- No transfer of materials across Contaminated Area boundaries (unless authorized by RWP)
- No opening of containers with contaminated materials
- No use of ladders, scaffolds or man-lift equipment to access overhead areas above 7 feet
- No contaminated system breaches
- No system operation, such as opening a valve that may allow radioactive material to transfer through a pipe or cause elevated dose rates in the work area or an adjacent area

3.13 Your ALARA Responsibilities

Objective 73 - State individual rights and responsibilities regarding the following:

- *keeping dose ALARA*

Your ALARA Responsibilities

You have many ALARA responsibilities as part of the ALARA Program:

- Practice the ALARA concept.
- Follow procedures and policies.
- Follow all written or verbal instructions from Radiation Protection personnel.
- Know the dose rates in your work area.
- Be aware of your current dose.
- Comply with administrative and federal dose limits.
- Notify Radiation Protection (RP) or your supervisor if you have suggestions on reducing dose. (Some stations give ALARA awards for suggestions that result in less dose.)

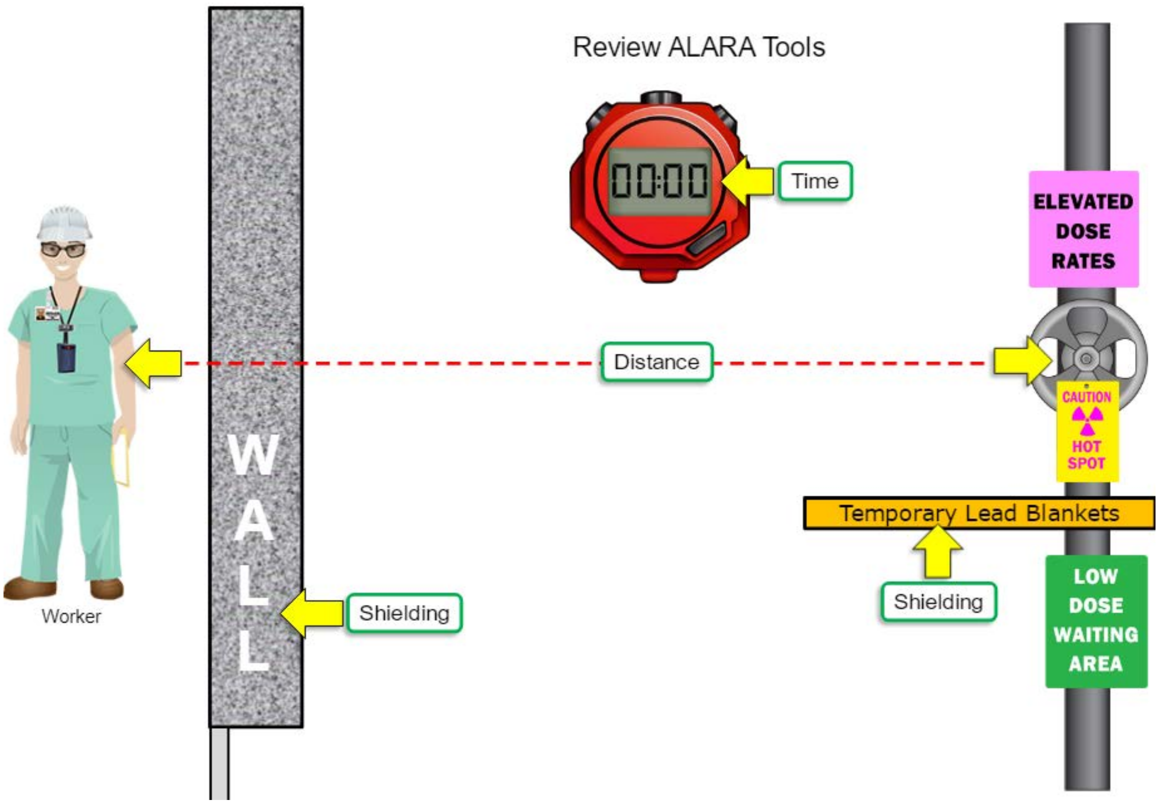
3.14 ALARA Time, Distance, Shielding

ALARA Tools

Three of the most common ALARA tools are

- Time
- Distance
- Shielding

Let's take a look at how each of these can reduce your dose.



3.15 ALARA Time

Objective 25 - Explain how time may be used to reduce dose, and state methods to implement this concept.

ALARA - Time

It makes sense that the more time you spend working around radiation, the more dose you receive. Remember, Dose = Dose Rate times the Time Spent in the area. Using some of the ALARA, components, such as work planning and practicing on mockups, can greatly reduce the time you spend in a radiation area, and so reduce your dose.

3.16 ALARA Distance

Objective 26 - Explain how distance may be used to reduce dose, and state methods to implement this concept.

ALARA - Distance

The distance between you and the radiation source also affects your total dose. The dose rate decreases as you move farther away from the source. How can you increase the distance?

Long-handled tools can often increase the distance between you and the source. Also, if you are reading a work order or discussing the job, move away from the source to increase the distance.

To see how this works move the worker to each set of footprints. As you get closer, you will see that the dose rate increases. You will also see that the total dose goes up faster. Now move him back away from the radiation source and see how that would save dose.

3.17 ALARA Shielding

Objective 27- Explain how shielding may be used to reduce dose, and state methods to implement this concept.

Objective 29 - State individual responsibilities regarding temporary shielding.

ALARA - Shielding

Permanent and temporary shielding in the plant can reduce the dose you receive by reducing the intensity of a radiation field. Remember that radiation can be shielded by different types of material (paper, plastic, lead, concrete, water, etc.), depending on the type of radiation. Led blankets are often used as shielding because they can shield alpha, beta, and gamma radiation.

Lead Blankets as Shielding

Although shielding may reduce dose, installing it can also result in dose to the workers installing it. If the dose required to install it exceeds the dose savings, it does not make ALARA sense. In this case, consider using the other tools (time and distance).

How well does shielding work? That depends upon the type of radiation and how thick the shield is. Alpha can be eliminated with very little shielding. Beta can be eliminated with thick materials. Gamma is normally only reduced by shielding methods available at the plant. If you see shielding in your work place, don’t think that there is no longer any radiation present. If you do not know what the radiation levels are in your work area, ask the radiation protection staff.

Never tamper with, remove, adjust, or modify installed shielding. It was installed under the direction of RP personnel. Altering it in any way can drastically change the dose rates in the area.

RP permission is required before installing, removing, or moving temporary shielding.

Improperly installed temporary shielding can overload the design weight of the component it is intended to shield.

3.18 ALARA - Planning

ALARA - Planning

Planning Strategies:

- Before entering the radiological work area, talk to your co-workers about the job and what you expect to do.
- Make sure the tools you will need are available and in good working order.
- Understand the conditions in the work area.
- Tell RP about your plans.

If any conditions change from what you have planned, contact RP before continuing work.

3.19 Stay Time

Objective 28. - Calculate stay time given a dose rate, current exposure and an exposure limit.

Stay Time - Calculating Stay Time

Stay time is the amount of time you can work in an area where radiation is present. It is based on your current dose and the dose rates in the work area. Stay time may be different for other people because their current dose may be higher or lower than yours.

NOTE: Remember you have to leave the area and will receive dose on the way out. Your stay time should include the time to leave the radiation areas and the additional dose you will receive leaving the area.

Here is how to calculate stay time:

Take your dose guideline and subtract the current amount of dose you have. Take this number and divide it by the dose rate in your current work area.

Remember always communicate with the radiation protection staff about any ALARA planning, including calculated stay times.

Example:

You have an administrative guideline of 2000 millirem and have received 200 millirem so far this year. You are directed by your supervisor to work in an area with a dose rate of 200 millirem/hr. What is the maximum amount of hours you can stay in the area and not exceed your dose limit?

2000 guideline - 200 current = 1800 millirem
1800 millirem / 200 millirem/hr = 9 hours

You can work in the area for 9 hours without exceeding your remaining 1800 millirem dose limit.

NOTE: In some cases you will be given a specific amount of dose budgeted for the job. In that case you would calculate the amount of time it would take to get to the budgeted amount of dose. Check with RP if you have any questions.

3.20 Vocabulary Review

New Terms

ALARA - ALARA (acronym for "as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical, consistent with the purpose for which the activity is undertaken, taking into account:

- The state of technology
- The economics of improvements in relation to state of technology
- The economics of improvements in relation to benefits to the public health and safety
- Other societal and socioeconomic considerations
- In relation to utilization of nuclear energy and licensed materials in the public interest

Pre-Job Briefing - A meeting to discuss the upcoming work in a radiation area. The Radiation Protection staff may have required briefings for your job.

Self - Briefing - Under some circumstances Radiation Protection (RP) and your supervisor may decide that you can brief yourself by reading the RP requirements and looking at any information on the area where you will be working. This is ONLY appropriate for certain areas AND job types.

Time - A valuable ALARA tool to reduce exposure. Simply the less time you spend in radiation areas the lower your radiation dose will be.

Distance - Distance is used in ALARA to reduce radiation exposure. The further you are from radiation sources the less radiation dose you will be exposed to.

Shielding - Both built in shielding like walls and other thick materials AND temporary shielding, like lead blankets, can be used to reduce radiation exposure.

Stay Time - The amount of time you can work in a radiologically controlled area performing a job and is based upon your current dose and the dose rates in the work area.

Stay time = (dose limit - current dose) / dose rate in the work area

Mockups - Mockups allow workers to practice some jobs in a realistic setting before doing the actual work.

3.21 ALARA Summary

ALARA Summary

ALARA

- The purpose of the ALARA Program is to keep radiation dose to individuals and the site As Low As Reasonably Achievable.
- Common components of the ALARA Program are pre-job reviews and briefings, job planning, use of mockups, good radiological work practices, and engineering controls.
- Common practices used to reduce dose are time, distance, and shielding.
- Permission is required from RP to install, remove, or move temporary shielding.
- Stay time equals dose guideline minus current dose divided by dose rate in the work area.

3.22 Dosimetry - Introduction

Objective 30 - State the purpose of dosimetry.
Objective 31 - List the types of radiation detected by the following devices:

- *Primary dosimetry (dosimeter of legal record [DLR])*
    - *Thermoluminescent dosimeters (TLDs)*
    - *Optically stimulated luminescence (OSL)*
- *Self-reading dosimeters (SRDs)*

Dosimetry – Introduction

Dosimetry devices accurately measure the amount of radiation a person is exposed to. Normally people working around radiation in a nuclear plant wear two dosimeters:

- The Dosimeter of Legal Record (DLR)
- The Self-Reading Dosimeter (SRD)

Each type of dosimeter has its strengths that make it an ideal choice to measure radiation dose. Dosimeters come in different brands and designs. Each plant site will have their own dosimeters and will instruct you on their use. Always follow the procedures and posted instructions at the plant where you are working.

NOTE: SRDs are an adequate substitution for a DLR under some radiological conditions. They are both very accurate and reliable equipment for measuring radiation exposure.

3.23 Dosimeter of Legal Record (DLR)

Objective 34 - Identify where and when the following dosimetry devices are issued and returned:

- *Primary dosimetry (DLR)*
- *SRDs*

Dosimeter of Legal Record (DLR)

There are two common DLRs used in the nuclear industry
:

- Thermoluminescent Dosimeter (TLD)
- Optically Stimulated Luminescent Dosimeter (OSLD)

Companies usually use one of these types. Both dosimeters provide a permanent record of your dose while working at a nuclear plant. They are very accurate and have no electronic or moving parts, which makes them extremely reliable. However, the user cannot read them. They are read in a laboratory with specialized equipment. These will be referred to as DLRs for the rest of the lesson.

DLR Example

The DLR can measure gamma and beta exposure, and some also measure neutron radiation exposure when needed. There may be an opening in the plastic housing of these devices that allows beta radiation to pass through and be detected. The DLR must be worn so that this window is facing away from the body.

NOTE: **You will be assigned a DLR by the RP Dosimetry Group. You will keep it until the RP Dosimetry Group exchanges it for a new one.** They will periodically exchange the dosimeter for a new one so it can be read. At the end of your assignment, your DLR will be returned to the dosimetry group.

DLRs are obtained through Dosimetry of the Radiation Protection Department. Check with dosimetry personnel or RP staff about the storage of DLRs. Normally DLRs are taken home at the end of the shift. This may differ from site to site so always ask! Proper use and storage of DLRs is extremely important. Common rules include:

- Do NOT put the DLR through any x-ray machine. This includes the x-ray machines on site as well as the ones used at airports for carry-on and check-in items.
- Do NOT store your DLR on granite counters, in/on ceramic dishes, or near other items that may affect it.
- Do NOT store your DLR in direct sunlight or in high temperature areas.
- Do NOT store your DLR near water or allow it to get wet.

Notify RP if your DLR is lost, gets wet, or is damaged in any way.

Return the DLR to Dosimetry upon termination of the security badge (when you leave the plant at the end of the job).

3.24 Dosimetry - Self-Reading Dosimeter (SRD)

Objective 33 - Identify the modes, methods and frequency for operating and reading SRD.

Objective 35 - State the action(s) to be taken if dosimetry is lost, damaged or alarming.

Dosimetry - Self-Reading Dosimeter (SRD)

Because you cannot check your own dose using a DLR, self-reading dosimeters (SRDs) allow you to routinely check your dose while you are working.

- SRDs show your dose on a digital display and provide an audible alarm when they reach a dose or dose rate limit. The SRD provides an accurate personal dose estimate.
- SRDs can measure gamma radiation (some also measure neutron radiation). This is adequate since MOST of the dose received by nuclear workers comes from gamma radiation. Dose from beta radiation is measured by the DLR as mentioned earlier.

NOTE: Unlike the DLRs, the SRDs are normally used on a temporary basis for the day or just one trip into an area where you have to be monitored. You will obtain one, use it, and return it. DLRs on the other hand you will keep until the Dosimetry Group exchanges it for a new one.

SRDs are not permanently issued to individuals and are used as required to enter the RCA. The issue location is normally at the RCA Access Point and you should utilize the dose tracking computer system to login your SRD. Upon exiting the RCA, log-out utilizing the dose tracking system and return your SRD to the storage location.

Face of SRD

Check your SRD periodically while in the RCA, and more often in elevated dose rate areas. Should the alarm activate, place your work in a safe condition, exit the area, and report to RP or take the actions, which you were briefed to take. To avoid an accumulated dose alarm, exit the RCA upon receiving 80% of the dose limit.

When you leave the area where dosimetry is required, your SRD dose is recorded into a dose tracking computer system; you can see your updated dose before your next entry.

Remember the RP staff may decide to use the SRD alone. The SRD is extremely reliable and accurate for many situations. The DLR can be omitted for some jobs but this must be approved by RP.

Leave the area and notify radiation protection personnel if your dosimetry is lost, alarming for any reason, damaged, or does not appear to be working. Remember, tracking your dose MUST be done correctly whenever working in the areas where radiation is present. There are no exceptions.

3.25 DLR and SRD Side-By-Side Comparison

DLR and SRD Side-By-Side Comparison

DLR - Provides a permanent legal record of your occupational dose
SRC - Provides a real-time estimate of your occupational dose. Can be used in place of a DLR.

DLR - Measures gamma, neutron, and beta radiation
SRD - Measures gamma radiation

DLR - Can only be read by RP personnel using special equipment
SRD - Allows you to routinely check your own dose while you are working

DLR - Has no audible alarm
SRD - Has audible alarm

Note: In some cases, legal dose will be assigned based on SRD readings

3.26 Wearing Dosimetry

Objective 32 - Identify how to wear dosimetry devices properly, including placement and orientation.

Wearing Dosimetry

Self-reading dosimeters and dosimeters of legal record are normally worn together on the front of the body between the neck and the waist and no more than a hand width apart. Both are normally required for entry into areas where you must be monitored for radiation. RP will give you instructions if an SRD is used alone.

Make sure your dosimetry faces away from the body (with the beta window out). This allows skin dose and dose to the lens of the eye to be measured. Remember, when you learned about the different kinds of radiation, that beta radiation could be stopped by plastic. If the DLR is facing the wrong way, the plastic will shield the beta radiation and it will not be measured.

In some cases, RP personnel may require more than one set of dosimeters or may relocate your dosimetry. For example, if the radiation levels are much higher at head level they may move your dosimetry to the head. Do not relocate your dosimetry unless directed by RP but let them know if you believe it does need to be relocated.

3.27 Review - Wearing Dosimetry

Review - Wearing Dosimetry

Dosimetry is worn on the front of the body, between the neck and the waist. The DLR and the SRD should not be further than a hand width apart.

3.28 Vocabulary Review

New Terms

Dosimetry - Devices used to track your radiation exposure. There are two main types.

- Dosimeter of Legal Record (DLR)
- Self-Reading Dosimeter (SRD)

Dosimeter of Legal Record (DLR) - The dosimeter of legal record or DLR is used to keep up with our official dose. It cannot be read by looking at it. It must be sent off to a lab to be read.

Self-Reading Dosimeter (SRD) - The self-reading dosimeter or SRD is an electronic device used to measure radiation exposure. It can interface with the computer that tracks your dose. It also has built in alarms.

T**LD (thermoluminescent dosimeter) -** The TLD or thermoluminescent dosimeter is a type of DLR. OSLDs and TLDs are both types of DLRs. You do not need to know the difference between them for this course.

OSLD (optically stimulated luminescent dosimeter) - The OSLD or optically stimulated luminescent dosimeter is a type of DLR. OSLDs and TLDs are both types of DLRs. You do not need to know the difference between them for this course.

3.29 Learning from the Mistakes of Others

Unplanned Radiation Exposure Operating Experience

A worker was repairing a valve actuator when he received 110 mrem of radiation exposure because he did not monitor his dose and leave before the dosimeter alarmed. In addition, he continued working while his dosimeter was alarming. This exceeded his allowed dose limit of 100 mrem.

After receiving the continuous dose alarm, the worker stayed in the area, finished torqueing the four remaining actuator bolts, and then picked up the tools to take them to the tool room. The worker thought it was more important to complete the job than exit the area as expected. He should have left the area BEFORE receiving the alarm.

3.30 Dosimetry Summary

Dosimetry Summary

This dosimetry lesson covered:

- Dosimeters of legal record (DLR) and self-reading dosimeters (SRD) monitor worker radiation dose.
- DLRs measure beta, gamma, and neutron radiation. SRDs are primarily used for gamma.
- DLRs provide the permanent dose of record but cannot be read by the worker.
- SRDs provide the worker with an accurate, easily read, dose and can also show dose rate.
- DLRs and SRDs are normally worn together on the front of the body between the neck and waist facing out about a hand width apart. Do not relocate dosimetry unless directed otherwise by RP.
- Leave the area and notify RP, if your DLR/SRD is lost, is alarming (unless approved by RP), is damaged, or does not appear to be working.

3.31 Summary - Limits, ALARA, Dosimetry

Section Summary

Topics covered in this section include:

- Radiation Dose Limits and Guidelines
- ALARA
- Dosimetry

4. Radioactive Contamination

4.1 Contamination Introduction

Radioactive Contamination

Radioactive material is any material that emits radiation. Radioactive *contamination* is radioactive material in an undesired location. In this section, you will learn the different types of contamination, how contamination is measured, where you may find contamination in the work place, and how to prevent the spread of contamination. You will also find out how to identify contaminated areas and how to work safely inside such areas.

This section is divided into two parts:

- Contamination
- Internal Exposure

4.2 Contamination – Operating Experience

Contamination Operating Experience

A technician at a nuclear plant became contaminated while calibrating a containment spray system transmitter. During the job, the technician disconnected a tube that was attached to a hand pump. The tube was run up and over an overhead pipe.

When the tube was disconnected, a vent path through the hand pump allowed residual water to leak out onto the technician. A bag had been placed under the fitting to control leakage, but it was ineffective due to the force of the water generated by the height of the tubing.

If the hand pump vent path had been isolated, the water would have stayed within the tube. A contributing factor to this event was that contamination control was not discussed during the pre-job brief.

4.3 Contamination - Types

Objective 36 - Identify and compare the following types of contamination:

- *Fixed contamination*
- *Loose contamination*
- *Discrete radioactive particle contamination*

Types of Contamination

The three types of contamination are *fixed contamination*, *loose contamination, and* *discrete radioactive particles*. Both fixed and loose contamination may become airborne from work activities around the plant.

Once in the air, these contaminants can get into the body and cause internal exposure. Airborne contamination will be covered later in this lesson.

Remember: "**loose contamination**" is radioactive material that can get on you or your clothes.

"**Fixed contamination**" can only get on you by becoming "loose contamination" first. Grinding or sanding are common activities that could cause the change.

4.4 Contamination - Fixed

Fixed Contamination

Fixed contamination is embedded in an object and cannot be easily removed by normal cleaning techniques. However, certain activities such as welding and grinding can cause fixed contamination to become airborne. Tools with fixed contamination are used inside radiologically controlled areas. They may be marked with the color purple or yellow to identify them as having fixed contamination.

Each plant may have its own method to control the use of contaminated tools. Make sure you know and obey the methods used where you are working. **Remember: fixed contamination is attached to the surface and cannot easily come off.**

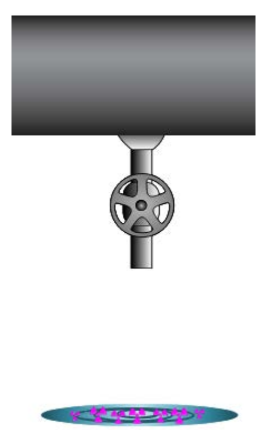
4.5 Contamination - Loose

Loose Contamination

Loose contamination can be easily spread to clean areas. Loose contamination can also become airborne, especially from activities such as sweeping or using a fan in a contaminated area.

Areas where loose contamination is present have to be posted. These areas are called “contaminated areas”. Either contaminated areas have loose contamination present OR the work activities could cause fixed contamination to become loose.

Grinding, sanding, welding and other similar activities can dislodge fixed contamination.



A leaking pipe or valve can be a source of “loose contamination”.

Remember: loose contamination is NOT attached to the surface and can be easily spread.

4.6 Discrete Radioactive Particles

Objective 46 - Regarding discrete radioactive particles, be able to state the following:

- *The hazards*
- *Methods to identify a discrete radioactive particle*
- *Sources of discrete radioactive particles*
- *Work activities that may result in discrete radioactive particle contamination*
- *Special precautions to be used in an area that may contain discrete radioactive particles*

Discrete Radioactive Particles

Discrete radioactive particles are very small but highly radioactive. If a discrete particle gets on your skin, the legal dose limit could be exceeded. Additionally, if a discrete particle enters your body, it can cause an internal dose. Discrete radioactive particles come from nuclear fuel and activated corrosion products. That is why they are normally found *inside* the pipes and other components connected to the reactor. How will you know if you are in an area likely to have discrete particles?

RP personnel will identify these areas and provide special instructions for lowering the chances of these particles spreading to other parts of the plant. The instructions may include:

- Special monitoring of personnel in the work area by RP
- Using disposable protective clothing
- Personnel checking themselves for discrete particles immediately after leaving the area

You can avoid spreading discrete radioactive particles by following the work instruction provided by RP personnel. They will be provided for you either in writing (on the radiation work permit) or verbally, before you enter the area.

4.7 Monitoring for Discrete Radioactive Particles

Monitoring for Discrete Radioactive Particles

Since discrete particles are very small, it is important to monitor yourself carefully when exiting a contaminated area. One way to monitor yourself for contamination is using a handheld instrument called a “frisker”. This is often the first line of defense. Automated equipment will also be used at exits.

Due to the small size of a discrete radioactive particle, the frisker must be very close to the particle to detect it. Once found, the discrete radioactive particle will cause the frisker reading to go up very quickly. Exits also have equipment designed to monitor personnel for contamination. The personnel contamination monitors are very sensitive and can detect very small quantities of radioactive contamination including discrete radioactive particles. Make sure you use the equipment properly EVERY time you go through an exit equipped with these monitors.

4.8 Measuring Loose Radioactive Contamination

Objective 37 - State the units used to measure contamination.

Measuring Loose Contamination

Contamination is measured in disintegrations per minute (dpm) or counts per minute (cpm).

Loose surface contamination is detected by wiping a piece of cloth or paper, commonly called a *smear*, over a surface area about 100 cm^2 and measuring the radiation being emitted from the *smear*. Results are reported as $dpm/100cm^2$. Contamination that can be found with a smear could also get on you or your clothing, and be tracked around.

Friskers are one tool used to measure contamination.

Remember: Loose contamination is sampled by rubbing a "smear" over floors and other surfaces. Smears are simply pieces of cloth that contamination will stick to if it is present. If radioactive material (contamination) got on the cloth it will be detected with instruments used by RP technicians. The **measurement is expressed in $dpm/100cm^2$**.

4.9 Measuring Fixed Contamination

Measuring Fixed Contamination

Because fixed contamination cannot be removed by using a smear, a radiation count rate meter (*frisker)* is used to measure it directly. Results are usually reported as cpm (counts per minute) above background radiation levels.

Remember: fixed contamination is measured directly using an instrument such as a frisker. The measurement is in cpm (counts per minute). This can be converted to dpm (disintegrations per minute).

4.10 Why Control Spread of Contamination?

Objective 38 - Explain why contamination is controlled.

Why Must Contamination Be Controlled?

Good radiological work practices are needed to control contamination. Without control, contamination could be spread to places away from the plant such as homes, cars, and public places. This could result in unmonitored radiation dose and possible exposure to the public.

In addition, once detected, it would take a lot of work to clean up the uncontrolled area, monitor to make sure everything was decontaminated, and dispose of the radioactive waste generated.

4.11 Sources of Contamination

Objective 39 - Describe the sources and indications of contamination, including the following:
- *Spills and leaks*
- *Opening contaminated systems*
- *Maintenance activities.*

Sources of Contamination

The major sources of contamination in a nuclear plant are fission products from the nuclear reaction and activated corrosion products (such as rust and metal). As long as the radioactive material is kept inside the reactor systems, there is no contamination. However, as with any large system of pipes and valves, leaks and spills occur. In addition, the systems have to be opened for sampling and maintenance. When systems that carry radioactive water are open, it creates the opportunity for contamination (radioactive material in an undesired location).

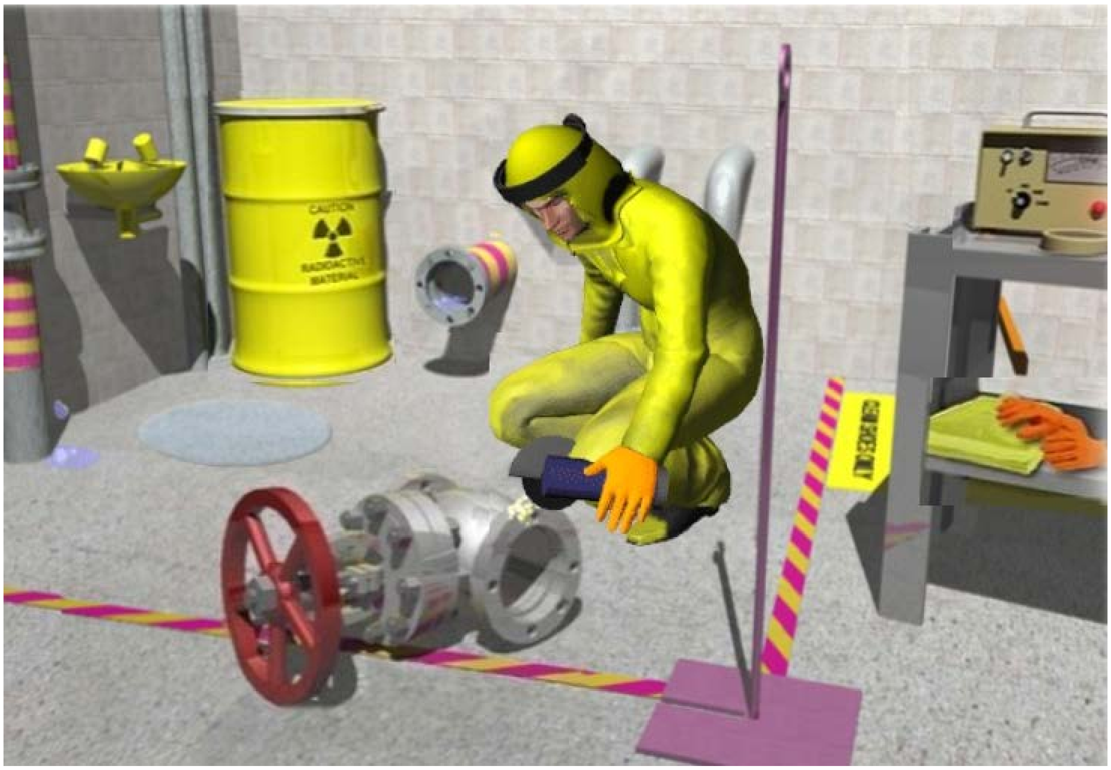
4.12 Indications of Radioactive Contamination

Indications of Possible Contamination

Once the radioactive material is outside the system, it can be spread and contaminate other plant components, areas, or even you. Here are some things that may indicate the presence of contamination:

- Leaking from components that carry radioactive water
- A pipe or component that is removed from a potentially contaminated system, or maintenance on potentially contaminated systems
- Water standing near or spraying from a contaminated system
- A rise in frisker counts or frisker alarms

If system leaks are identified, notify supervision and enter into the station's Corrective Action Program (CAP). A good practice is to avoid stepping in water or on floor drains when in Radiologically Controlled Areas.



Common indications that loose radioactive contamination may be present.

4.13 Contamination - Boric Acid

Boric Acid Corrosion Control Program

Many PWR systems contain boric acid and there are numerous potential leakage locations. White or Brown/Red crystalline substances on components external surfaces may be indicative of a leak and/or corrosion.

It is everyone's responsibility to identify boric acid leaks at the station and enter it into the corrective action program

Required action, when evidence of boric acid leakage is observed:

- Enter the information on the boric acid leak into your corrective action program
- For Active or Excessive leaks notify the Shift Manager of the condition to address the issue in a timely manner


Boric acid leak in a nuclear plant.

4.14 Contamination - Boric Acid

Boric Acid Corrosion Control Program

The program's purpose at Pressurized Water Reactors is to:

- Provide a systematic method to address the corrosive effects of boric acid leakage
- Ensure boric acid corrosion does not degrade the Reactor Coolant System (RCS) pressure boundary
- Ensure boric acid does not degrade plant structures, systems or components
- Reduce spread of radioactive contamination and improve general housekeeping/appearance at the station

4.15 Preventing Spread of Radioactive Contamination

Objective 40 - Discuss the methods used to prevent contamination of personnel and areas, including the following:

- *Planning work and conducting pre-job briefings*
- *Using protective clothing (PCs)*
- *Avoiding potentially contaminated water*
- *Avoiding skin contact with contaminated surfaces*
- *Using step-off pads*
- *Restricting non-routine surveyed areas (for example, overhead areas 7 feet above the floor)*
- *Implementing engineering controls*

Preventing Contamination Before Work Starts

It takes much less time and effort to prevent contamination than it does to clean up the contamination. There are ways you can prevent the spread of contamination before, during, and after your work.
Before the work:

- Have a good plan for the job.

- Have a pre-job briefing to discuss the plan, hazards, and contingencies. (Invite RP to attend if appropriate.)
- Inspect protective clothing to identify potential tears or holes.
- Determine which tools/equipment you will need, and see if they are available inside the radiologically controlled area.
- Use engineering controls as available.
- Understand and follow requirements in the Radiation Work Permit.

4.16 Preventing Spread of Radioactive Contamination (cont.)

Preventing Contamination While Working

During the job:

- Contact RP personnel for entry into areas that are not routinely monitored for contamination, such as overheads and cable trays.
- Stop work and notify RP personnel of any changes in job scope including opening systems, need for abrasive work, use of alternate tooling or equipment, etc.
- Obey all postings and signs.
- Limit entry into contaminated areas and take only the tools/equipment you need to do the work.
- Use protective clothing when working on a contaminated system.
- Don’t step on, place items on, or reach over contaminated boundaries. Check with RP if your work requires you do one of these.
- Check with RP before placing hoses and extension cords on a contaminated boundary. They may have to be sleeved or fastened down.

4.17 Prevention Spread of Contamination – End of Job

Preventing Contamination at the End of the Job

After the work:

- Exit the contaminated area at the approved location, usually marked by step-off pads.
- Contact Radiation Protection for instructions on how to remove tools and equipment from the Contaminated Area
- Have all materials checked for contamination before removing them from the contaminated area.
- Return tools to the appropriate storage location within the radiologically controlled area.
- Carefully monitor yourself for contamination.

4.18 Protective Clothing

Protective Clothing

The purpose of protective clothing (PCs) is to prevent loose contamination from getting on you or your clothing. PCs are normally made out of regular cloth (or in some cases plastic or paper) and do not have any special properties. The contamination gets on the plant's designated clothing rather than your own. This helps prevent the spread of contamination through the plant.


Protective clothing is designed to keep contamination off you and your clothes.

4.19 What to Wear

Protective Clothing

There are many variations on protective clothing (PCs) requirements used in the nuclear industry.

Coordinate your work with the Radiation Protection (RP) staff so that you can wear the correct clothing for the job and area of the plant.

Each entry into a nuclear plant can be different depending upon the work you do and the area you are going to visit. Maintain a close relationship with the RP staff.

The ultimate goal with PCs is to keep radioactive contamination off you and your clothing so that it is not spread around.

In addition you will normally need the following:

- Hard hat
- Safety glasses
- Hearing protection
- Safety shoes
- Security badge
- Gloves (safety)

Personal Work Clothes

Many entries into a nuclear plant are made in regular work clothes. Most areas of the plant are NOT contaminated so you do not need protective clothing.

Requirements may vary according to the situation or plant. Check with Radiation Protection personnel at any facility where you work.

Scrub Suits

Scrub suits are the clothing of choice for many nuclear workers. They may be provided at some nuclear plants. They can be worn under protective clothing.

Requirements may vary according to the situation or plant. Check with Radiation Protection personnel at any facility where you work.

Booties and Gloves

The minimal clothing for a ***contaminated area*** includes covering for your hands and feet.

This would include:

- Glove liners
- Gloves
- Shoe covers
- Rubber over shoes

Requirements may vary according to the situation or plant. Check with Radiation Protection personnel at any facility where you work.

Full Dress in Protective Clothing

Most areas are NOT contaminated but IF you are entering a contaminated area you may be required to wear coveralls in addition to the coverings for your hands and feet. You would wear:

- Glove liners
- Gloves
- Shoe covers
- Rubber over shoes
- Coveralls

Requirements may vary according to the situation or plant. Check with Radiation Protection personnel at any facility where you work.

Full Dress in Protective Clothing with Hood

A full set of protective clothing may include a hood. The hood adds extra protection around your face and head. You would wear:

- Glove liners
- Gloves
- Shoe covers
- Rubber over shoes

- Coveralls
- Hood

In addition to you will normally need the following:

- Hard hat
- Safety glasses
- Hearing protection
- Safety shoes
- Security badge
- Gloves (safety)

Requirements may vary according to the situation or plant. Check with Radiation Protection personnel at any facility where you work.

Full Dress with Respirator

In areas likely to have airborne contamination, respirators may be required. Respirators are not preferred since they restrict both vision and communication. This causes personnel to work longer in radiation areas.

- Glove liners
- Gloves
- Shoe covers
- Rubber over shoes
- Coveralls
- Hood
- Respirator

In addition to you will normally need the following:

- Hard hat
- Safety glasses
- Hearing protection
- Safety shoes
- Security badge
- Gloves (safety)

Requirements may vary according to the situation or plant. Check with Radiation Protection personnel at any facility where you work.

Plastics

Working in wet areas may mean you need to wear plastic coveralls and shoe covers. You would wear:

- Glove liners
- Gloves
- Plastic shoe covers
- Rubber over shoes
- Plastic coveralls
- Hood
- Respirator

In addition to you will normally need the following:

- Hard hat
- Safety glasses
- Hearing protection
- Safety shoes
- Security badge
- Gloves (safety)

Requirements may vary according to the situation or plant. Check with Radiation Protection personnel at any facility where you work.

4.20 Using Protective Clothing

Using Protective Clothing

You will get your PCs at designated dress-out areas and put them on before entering contaminated areas.

Personal items that could become contaminated should not be taken into contaminated areas. This includes:

- Wallets
- Watches
- Keys
- Etc.

4.21 Using Protective Clothing

Using Protective Clothing

Protective clothing generally *does not protect against radiation dose.* It is for contamination control. *Protective clothing must always be worn to enter contaminated areas.* For PCs to be effective, they must be used correctly. If protective clothing becomes torn, wet, or rendered ineffective, take action immediately:

- Stop work
- Leave the contaminated area
- Monitor yourself for contamination

Notify RP personnel if you have contamination on your skin or body.

4.22 Equipment Used to Monitor for Contamination

Objective 42 - Explain how to monitor personnel and personal items for contamination, including the use of the following:

- *Friskers*
- *Personnel contamination monitors*

Objective 43 - State the actions to be taken upon indication of becoming contaminated.

Using a Frisker

You will use two main types of contamination monitors at any plant: a frisker and a personnel contamination monitor (PCM).

Friskers are the first line of defense. They are very easily set up anywhere frisking is needed. RP personnel place these in the plant in strategic locations to make sure contamination is not spread through the plant.

Frisker with hand-held probe.

When exiting, personnel will use an automated personnel contamination monitor. Obey the signs and use the equipment provided as you walk around the plant.

4.23 Using a Frisker

Using a Frisker

Friskers use a hand-held probe coupled with a meter that you use to check yourself for contamination.

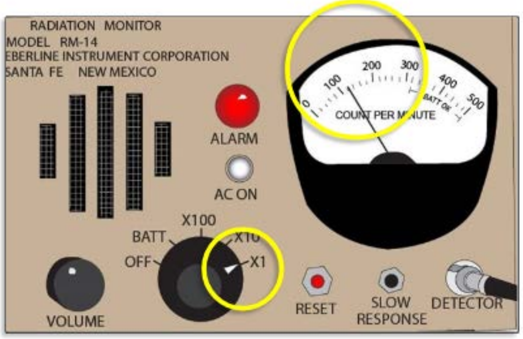
Before you pick up the probe:

- Check to ensure the frisker is turned on
- Set to the X1 scale and

- The display is less than 200 counts per minute (cpm).

Monitor your hands by passing them; one at a time, about one half inch above the frisker probe at a speed of about 2 inches per second. Monitor the front and back of each hand.

Check the count rate on the meter. If it increases by more than 100 cpm and stays above that level, or if the monitor alarms, stay in the area and contact RP.



Frisker is on, on the X1 scale and the background is less than 200 cpm.

4.24 Using a Frisker

Using a Frisker

If your hands are clean, remove the frisker probe and frisk your body the same way you did your hands. Pay special attention to the soles and tops of your shoes. You should also frisk other items such as notebooks, pens, and flashlights before leaving the area. Be sure you leave the frisker with the probe facing upward, ready for the next worker. Upon exit from areas where elevated alpha contamination hazards exist, workers may be required to frisk using alpha monitoring equipment under direction of qualified personnel (RP).

4.25 Using a Personnel Contamination Monitor

Using a Personnel Contamination Monitor

When preparing to leave the radiologically controlled area (RCA), you will be required to use a second type of contamination monitor, the personnel contamination monitor (PCM). This monitor has several radiation detectors that monitor your entire body. It is more sensitive to radiation than a frisker is and will detect very low levels of contamination. That coupled with very large detectors makes the PCM the best way to find contamination on your body.


Personnel checking for contamination with PCMs.

Friskers are good at pinpointing where the contamination is located but PCMs are the best at finding out if contamination is present. A PCM should be the very last instrument used before leaving.

- Do not take personal items or sharp objects into the PCM, as they can puncture the detectors.
- Personal objects must be surveyed and released at the direction of RP personnel.

- If the PCM alarms, exit in the same direction from which you entered. Do not exit into the clean area. Notify RP for assistance.

4.26 Removing Materials from the RCA

Objective 41 - State the individual's actions for removing contaminated and non-contaminated materials from the RCA.

Removing Material from the RCA

The last barriers to stop radioactive contamination from leaving the RCAs are the main RCA control points. All personnel will exit through one of these control points. PCMs and "Tool and Equipment Monitors" (TEM) are stationed at these exits to ensure that no radioactive material leaves the RCAs. Remember:

- Radiation Protection (RP) personnel MUST check items that were in a contaminated area.
- Only RP staff can use hand held friskers to determine that items are clear of contamination and ready to be removed.
- Signs will be posted at the exits to let personnel know what equipment to use.

Typically, you and what you are wearing are checked by PCMs. Some items must be checked for contamination by using a TEM. Follow the posted instructions OR contact the RP staff for assistance.

4.27 Frisker vs PCM

Frisker vs Personnel Contamination Monitor

Personnel contamination monitors (PCMs) do a better job at finding contamination on personnel. Why?

Detectors:

- PCM - state of the art, sensitive large detectors.
- Frisker - older technology with much smaller detector.

Use:

- PCM - automated leaving less room for human error.
- Frisker - hand held, very slow reaction time, easy to miss something.

Due to their portability, friskers are still used. The small detector in the probe makes it easy to pinpoint contamination for cleanup and documentation.

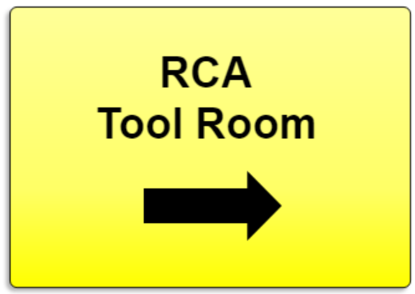
4.28 Tools and Equipment

Objective 44 - State the method for control of contaminated tools, equipment and materials, including the following:

- *Minimizing materials contaminated*
- *RCA tool issue point*

About Your Tools and Equipment

Tools, equipment, and materials can become contaminated during work on contaminated systems and components. The plant Maintenance Department has a tool room inside the radiologically controlled area, commonly referred to as the "RCA tool crib" or "RCA tool room." It is stocked with most of the common tools needed for work on any system or component. Use tools issued from this room for work in radiologically controlled areas and return the tools when you are finished.



Do not take new or uncontaminated tools into radiologically controlled areas unless they are absolutely necessary for work *and* they are not available in the RCA tool room.

Contact RP Personnel for instructions on removing tools and equipment from Contaminated Areas. Check with RP before taking tools into the RCA that you expect to remove later and will be free from contamination when you do.

4.29 How to Recognize Contaminated Areas

Objective 45 - State the methods used to designate contaminated areas, including postings and step-off pads.

How to Recognize Contaminated Areas

Common identifiers include:

- **Signs** with the words "Contaminated Area"
- **Step off pads** on floor at exit/entrance point
- **Yellow and magenta rope or ribbon** at boundary

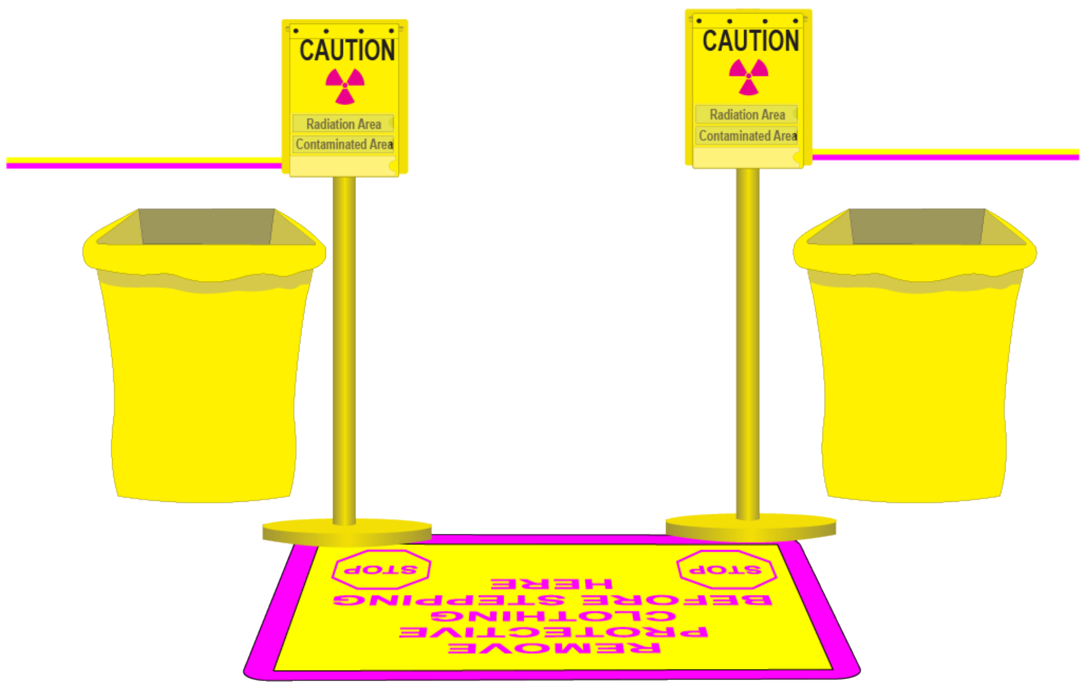
Signs and barriers are used to identify contaminated areas. They are yellow with a magenta or black three-bladed symbol. Yellow and magenta rope and/or tape will also be used to separate contaminated areas from clean areas. These barriers are considered to be an invisible wall. You must not reach across them unless authorized/directed by RP personnel or station procedures.

A step-off pad usually designates the entrance and exit to contaminated areas. Step-off pads are only used to reduce the spread of contamination. If you see a step-off pad, you know the area is definitely contaminated AND protective clothing will be required.

4.30 How to Recognize Contaminated Areas

How to Recognize Contaminated Areas

Remember when you enter a **contaminated area** you will need protective clothing to prevent contamination from getting on you and your clothing. Note the telltale signs that you are about to enter a "contaminated area" in the graphic below:



Contaminated area entrance. Notice the Step-Off-Pad, the yellow and magenta rope, and the Contaminated Area signs.

4.31 Alpha Contamination

Alpha Contaminated Areas

Recall that alpha radiation is not an external hazard. The radioactive material would have to be inside your body for you to receive any alpha radiation exposure. Because of the nature of alpha radiation, areas that are contaminated with alpha are treated differently. Radiation protection (RP) personnel are experts on how to work in these areas.

Areas with alpha contamination will be posted accordingly, or the worker will be informed of the alpha hazard by RWP, pre-job briefings, surveys, or other methods used by RP personnel. Alpha contaminated areas will be designated as Level II or III with Level III areas having the highest risk and most protective RP controls

4.32 When to Leave

Objective 47 - Identify situations that require immediate exit from a contaminated area (for example, torn PCs, wounds and wet PCs).

Do I Leave Now?

Some situations will require you to exit a contaminated area immediately:

- You tear or cut your PCs
- You suffer a cut, abrasion, or other type of open wound
- Your PCs get wet from a leak, spill, or profuse sweating
- Your dosimeter is alarming or is lost, or you observe any other abnormal condition
- RP personnel direct you

Plant procedures may require you to contact RP for any or all of the above conditions.

Time to leave the area!

4.33 Vocabulary Review

New Terms

Radioactive Contamination - Radioactive material in an unwanted location. This occurs when radioactive material gets outside the place it is intended to be. When this happens, the radiation it releases is no longer controlled and the radioactive material can easily be spread to other areas.

Loose Surface Contamination - Contamination is radioactive material in an unwanted location. Contamination can be categorized as fixed and loose. Loose contamination can easily be spread from one area to another. The nuclear industry uses a variety of techniques to reduce the spread of contamination. This includes the use of protective clothing, postings, step off pads, and restrictions on sweeping, use of fans, and many others.

Fixed Radioactive Contamination - Contamination is radioactive material in an unwanted location. Contamination can be categorized as fixed and loose. Fixed contamination is not easily removed or spread around. Protective clothing is not normally required unless there is "loose contamination" present.

Discrete Radioactive Particles - Tiny specks of highly radioactive material. A large dose could be received over a very small part of the body due to the presence of a discrete particle. Radiation protection personnel will have special control measures to detect and prevent the spread of discrete particles.

Disintegrations per Minute (dpm) - A rate measurement of radiation. Each interaction is counted. Each interaction reflects one disintegration. The average number of interactions per minute is calculated and is expressed as counts per minute (cpm). Since no instrument can detect all the disintegrations, an estimate of the total number is calculated based on the ability of the instrument. This is expressed as disintegrations per minute (dpm).

Counts per Minute (cpm) - A rate measurement of radiation. Each interaction is counted. Each interaction reflects one disintegration. The average number of interactions per minute is calculated and is expressed as counts per minute (cpm). Since no instrument can detect all the disintegrations, an estimate of the total number is calculated based on the ability of the instrument. This is expressed as disintegrations per minute (dpm).

Smear - Loose surface contamination is detected by wiping a piece of cloth or paper, commonly called a *smear*, over a surface area about 100 cm2 and measuring the radiation being emitted from the *smear*. Results are reported as dpm/100cm2. Large area smears are also used. A large piece of material is wiped over a large floor area to determine the presence of radioactive contamination.

Frisker - A device used to detect and measure radioactive contamination. It consists of a meter and a hand held probe.

Radiological Work Practices - Techniques used by nuclear workers to reduce radiation exposure and prevent the spread of contamination.

4.34 Vocabulary Review

New Terms

Engineering Controls - Physical measures that prevent radioactive material from becoming airborne or that remove it from the air (such as adding filters to ventilation systems, shifting ventilation flow paths, repairing leaks quickly, and enclosing the source of the contamination).

Protective Clothing (PCs) - Clothing made of cloth, plastic, or paper that is designed to keep radioactive contamination off people and their own belongings. Protective clothing is commonly referred to as PCs. PCs are not designed to "protect" people from radiation exposure. Most of the dose nuclear workers receive is from gamma radiation which would go through any clothing.

Probe - Part of an instrument used to detect radiation. The probe contains a detector, which detects radiation, and the results are displayed on an instrument. A common example of this is the frisker.

Personnel Contamination Monitor (PCM) - When preparing to leave the radiologically controlled area (RCA), you will be required to use a second type of contamination monitor, the personnel contamination monitor (PCM). This monitor has several radiation detectors that monitor your entire body. It is more sensitive to radiation than a frisker is and will detect very low levels of contamination.

Radiologically Controlled Area (RCA) - An area designated by Radiation Protection (RP) in which additional controls are prescribed due to increased risk from exposure to radiation or radioactive materials.

Tool and Equipment Monitor (TEM) - A radiation monitor used to find contamination on tools, equipment, and other hand held items.

RCA Tool Crib or Tool Room - The plant Maintenance Department has a tool room inside the radiologically controlled area, commonly referred to as the "RCA tool crib" or "RCA tool room." It is stocked with most of the common tools needed for work on any system or component. Use tools issued from this room for work in radiologically controlled areas and return the tools when you are finished.

Step-Off-Pad - A rectangular, often sticky pad that is stepped on upon exiting a contaminated area. These are one of the indications that the area is a contaminated area.

Contaminated Area (CA) - An area determined by Radiation Protection personnel to have a quantity of loose radioactive contamination at levels high enough that it could be easily spread. Radiation Protection will define these areas and designate them with signs, barriers, and step

4.35 Summary Contamination

Summary: Contamination

Topics covered in the lesson included:

- The three main types of surface contamination are loose contamination, fixed contamination, and discrete radioactive particles.
- Loose and fixed contamination may become airborne because of work activities or poor work practices.

- Indications of potential contamination are leaks from components that carry radioactive water, components removed from a potentially contaminated system for maintenance, water standing near or spraying from a contaminated system, or a rise in frisker counts or frisker alarms.
- Good radiological work practices such as work planning and prejob briefings, use of protective clothing and engineering controls, and avoiding contact with contaminated surfaces can help avoid and control contamination.
- Yellow and magenta (or yellow and black) signs with a three-bladed symbol, barrier rope or tape, and a step-off pad at the entry/exit identify contaminated areas.
- Do not reach across contaminated area boundaries without RP approval.
- Immediately exit a contaminated area if your PCs become torn or wet, your dosimeter is alarming for an unplanned dose rate or accumulated dose, you suffer a cut or laceration, or if directed to exit by RP.
- Friskers and whole-body personnel contamination monitors are used to check personnel and equipment for contamination. Remember, PCMs are the more sensitive of the two instruments.
- Use tools and equipment issued from a RCA tool room, if possible. Take only the material/tools you need into contaminated areas.

4.36 Internal Exposure Pathways

Objective 48 - State four pathways for radioactive material to enter the body.

- *Inhalation*
- *Ingestion*
- *Absorption*
- *Open wounds/injuries*

Internal Contamination

Loose contamination can be an internal dose hazard. There are 4 major pathways to loose contamination getting into your body:

- Inhalation - breath it in
- Ingestion - swallow it
- Absorption - enter through the skin
- Open wounds or sores - gets into the wound

Recall that TEDE is the dose from both internal and external exposure. So far, we have mostly talked about external sources of radiation. Now let us discuss internal sources. That is the radioactive material is inside your body.

The most likely way for radioactive material to enter the body is through inhalation of airborne radioactive material.

Airborne contamination can be an internal exposure hazard. Because of this, RP personnel must monitor airborne radioactivity areas. Work in these areas may require the use of radiological respiratory equipment.

4.37 Limiting Inhaled Radioactive Contamination

Objective 49 - State the methods used to limit the internal deposition of radioactive materials, including respiratory protection and engineering controls.

Limiting Inhaled Radioactive Contamination

To limit inhalation of radioactive material, the station must prevent it from becoming airborne or prevent personnel from breathing it. The preferred method is to prevent or remove airborne radioactivity using engineering controls such as temporary ventilation, filtering devices, enclosing the source, or shifting ventilation flow paths.

However, use of respirators can reduce efficiency and increase time in radiation areas. This could actually increase total effective dose equivalent (TEDE). Respirators can result in more external dose than the internal dose they save. The end result is TEDE can be higher due to respirators. We will talk about this later.

You must be trained and qualified to wear respiratory protective equipment.

4.38 Preventing Ingestion of Internal Radioactive Contamination

Preventing Ingested Contamination

Good radiological work practices can help reduce the possibility of ingesting radioactive material. Do not take food, drink, tobacco products, or even cosmetic products into radiologically controlled areas. Eating, drinking, using any type of tobacco, or applying cosmetics while inside the RCA is prohibited. *Don't do it!*

In some areas where heat stress or exhaustion may be a problem, RP will establish drinking stations. Follow the rules carefully when using them.

4.39 Prevention of Internal Contamination – Skin Absorption and Wounds

Preventing Other Internal Contamination

Radioactive material can be absorbed through your skin, especially if your PCs get wet. When working with liquids, check with Radiation Protection to see if plastic or rubber clothing should be worn over your PCs. Notify RP if your PCs become wet. Make sure that all open wounds are covered, that RP personnel are aware of them, and that they have approved you to work in the contaminated area. Finally, if you become injured while working in the RCA, leave the area and notify RP personnel as soon as possible.

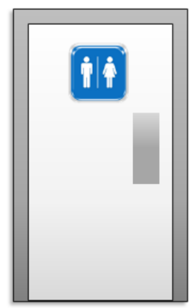
4.40 Removal of Internal Radioactive Contamination

Objective 50 - State the processes by which radioactive material is eliminated from the body (decay and biological).

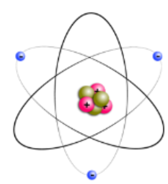
Getting Rid of Internal Radioactive Material

Once radioactive material enters the body, *two* primary processes will eliminate it:

- Biological processes will naturally occur, causing many types of internal contamination to be eliminated from the body.
- Radioactive decay will naturally occur, reducing the amount of radioactive material as time passes.



Biological Processes



Radioactive Decay

Both the biological and radiological decay processes are dependent on the type of material. The time the material stays in your body varies from several hours to many years.

Alpha is a special hazard. The long decay time and the potential to remain in the body longer can result in increased dose.

4.41 Measuring Internal Radioactive Contamination

Objective 51 - Recognize the methods used to determine the amount of radioactive material deposited in the body, including whole- body counters and bioassays.

Measuring Internal Radioactivity

Although the body contains naturally occurring radioactivity (potassium from foods and beverages, for example), you should only be concerned about preventing internal dose received from radioactive material deposited because of your work.

A whole-body counter directly measures the amount and type of gamma radioactivity in your body.

There are two primary ways to determine the type and amount of radioactivity in your body:

- A whole-body counter directly measures the level of radioactivity in your body and what type of radioactive material is present.
- Bioassays determine the amount of radioactive material by analyzing urine and/or fecal samples. Determining internal alpha contamination may require repetitive bioassay samples along with whole body counts.

When working in areas with high alpha contamination, workers may be required to wear personal air samplers to monitor the amount of airborne contamination they are breathing.

4.42 Committed Effective Dose Equivalent (CEDE)

Objective 52 - Define the following:

- *Derived air concentration (DAC)*
- *Annual limit on intake (ALI)*
- *Committed effective dose equivalent (CEDE)*

Objective 53 - State the relationship among DACs, ALIs, CEDE and TEDE (DAC and mrem per hour relationship).

Committed Effective Dose Equivalent

Federal law regulates the amount of internal exposure you can receive. *Committed effective dose equivalent (CEDE)* is the amount of internal dose that relates organ dose to the whole-body dose. The term "committed" refers to dose received from radioactive material that is inside the body. The entire dose that will be received while the material is in the body is calculated and assigned to the person. Think of it as a "commitment" to receive the dose over time.

4.43 Annual Limit on Intake (ALI)

Annual Limit on Intake

The next two terms, ALI and DAC, are closely related to each other. It also helps to remember the Federal Dose Limits you learned earlier. *Annual limit on intake (ALI)* is the concentration of airborne radioactive material that you would have to take internally to receive 5 rem committed effective dose equivalent *or* 50 rem to any organ. Simply stated: one ALI equals the amount of radioactive material you would have to breathe in to reach the federal limit for either TEDE or CEDE.

ALI = Person breathing in = 5 rem CEDE or 50 rem to any one organ.

4.44 Measuring Airborne Radioactivity Derived Air Concentration (DAC)

Derived Air Concentration

A *Derived air concentration (DAC)* is the concentration of radioactive material in the air that would result in one ALI if breathed for 2000 hours (about one year of normal work time). ALI equals 5 rem, which you would get by breathing 1 DAC for 2000 hours. Remember that 5 rem equals 5000 millirem. So the equation for one DAC-hour would be as follows:

- 1 DAC-hr. would be 5 rem/2000 hrs.
- (5000 millirem/2000 hr.) = 2.5 mrem/DAC-hr.

The example on the next screen should help explain. **Just remember that 1 DAC-Hr. = 2.5 millirem.** So if you breathe for an hour in an area with a concentration of 1 DAC you would receive 2.5 millirem.

4.45 When Are Respirators Worn

To Wear a Respirator or Not - An Example

Consider this: Chris is assigned to repair a door. The area has a dose rate of 24 millirem/hr and also has some airborne radioactivity. (1 DAC). From experience with this door, Chris knows it will take *three hours* to make the repair *with a respirator* and that it will take *two hours* to fix the door *without a respirator*.

If the job is done without a respirator, he will be in the area for 2 hours and receive 2 DAC-hours or 5 mrem of internal dose.

- Remember 1 DAC-hour = 2.5 millirem
- The 5 millirem is all the dose he will receive over time the radioactive material is inside his body.

4.46 Activities that Increase Airborne Radioactivity

Objective 54 - Discuss plant conditions that may increase the potential for airborne radioactivity.

- *Brushing or sweeping*
- *Fan(s) blowing in dusty areas*
- *Steam leaks*
- *Sanding or grinding in contaminated areas*
- *Wet contaminated areas drying out*
- *Breaching contaminated systems*

Activities That Can Increase Airborne Radioactivity

As mentioned earlier, in many other situations loose or fixed contamination could become an airborne problem. Grinding, sweeping, fan using, and welding in contaminated areas are a few examples. Other examples are as follows:

- Open contaminated systems
- Steam leaks from contaminated systems
- Wet contaminated areas once they have dried
- Removal of insulation
- Rapid evaporation of volatile chemicals or hot water

Most internal dose events occur when workers create airborne radioactivity by deviating from approved work plans. NOTE: Airborne alpha contamination can result in significantly more internal dose than equivalent quantities of beta-gamma contamination. Extra precautions may be taken if alpha contamination is present.

Find the indications of airborne radioactivity in this graphic.

4.47 Internal Contamination – Operating Experience

Internal Contamination - Operating Experience

Changing Job Scope Results in Internal Exposure

In 2010, a maintenance team was briefed to prepare for welding a new section of piping in the reactor coolant storage system. The task preview included discussion of the use of a flapper wheel to buff the exterior of the previously cut pipe followed by welding of the new pipe section into place.

While performing work in the field, the maintenance worker determined that an extra inch of original system pipe needed to be removed for the new pipe section to fit. A side grinder was used to remove this section of pipe without consulting with radiation protection personnel. As a result, airborne radioactivity was created when the side grinder disturbed the oxide layer on the piping.

Four workers had to submit multiple fecal samples in order to evaluate their internal dose from alpha contamination. Had radiation protection personnel been consulted before changing job scope, the proper radiological controls could have been used to prevent the significant alpha airborne event.

Always notify radiation protection personnel when the scope of the job you are performing changes in any way: the work to be performed, the method, or the tool(s) to be used.

4.48 Vocabulary Review

New Terms

Inhalation, Ingestion, and Absorption - Ways that radioactive contamination can enter your body. A fourth way is through open cuts or wounds.

- Inhalation is breathing in the radioactive contamination.
- Ingestion is swallowing the radioactive contamination.
- Absorption is when the radioactive material goes through the skin.

Internal Deposition - The process by which radioactive material (contamination) enters and stays in the body.

Respiratory Protection - Preventing the inhalation of airborne radioactive materials (contamination). This includes using respirators as a way to reduce the amount of radioactive material breathed.

Derived Air Concentration (DAC) - The concentration of radioactive material in air that would result in one ALI if breathed for 2000 hours. 1 DAC for 1 hour would result in 1 DAC-Hour which is equal to 2.5 millirem.

Annual Limit on Intake (ALI) - The amount of airborne radioactive material that you would have to take internally to receive 5 rem effective dose equivalent or 50 rem to any organ. The amount of radioactive material you would have to breathe in to reach the federal limit for either TEDE or CEDE.

Committed Effective Dose Equivalent (CEDE) - The amount of internal dose that relates organ dose to the whole-body dose. The word committed refers to dose from internal sources. It is part of TEDE.

Airborne Radioactivity Area - An area in which airborne radioactivity exists in excess of 0.3 Derived Air Concentration (DAC) or 12 DAC-hours in a week. This is the level of airborne contamination at which protection is considered. Preventing airborne is always considered first. Use of ventilation systems and HEPA filtration systems can remove contamination from the air. Work practices such as wetting surfaces while grinding and others can also be effective.

Whole Body Counter - Directly measures the level of radioactivity in your body and what type of radioactivity it is. Whole body counters are extremely sensitive at detecting gamma radiation. The result of a whole body count is an accurate assessment of which radioactive materials are present and in what quantity. Whole Body Counters are used for investigative purposes. Personnel Contamination Monitors are also sensitive enough to detect internal contamination and are normally used.

Bioassay - Determines the amount of radioactive material by analyzing samples such as fecal material or urine.

4.49 Summary - Radioactive Contamination

Summary: Internal Exposure

Topics covered in this lesson include:

- Airborne loose contamination can become an internal dose hazard.
- There are four ways contamination can enter the body:
  - Inhalation
  - Ingestion
  - Absorption
  - Through open cuts or wounds
- Welding or grinding on contaminated material, sweeping in contaminated areas, and opening contaminated systems are some of the ways contamination can become airborne.
- Internal radioactive material is removed from the body through biological processes or radioactive decay.
- Internal contamination is detected through bioassays or the use of a whole-body counter.
- CEDE = internal dose that relates organ dose to whole-body dose
- DAC-hr. = 2.5 millirem
- 2000 DAC = 1 ALI
- 1 ALI = 5 rem CEDE or 50 rem to any organ

5. Signs and Postings

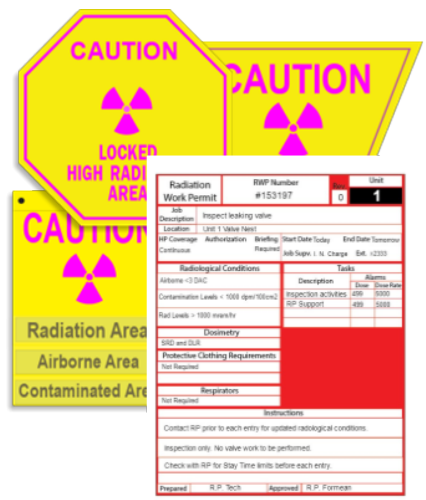
5.1 Radiation Work Permits, Posting, Alarms, Waste

Radiation Work Permits, Radiological Posting, Alarms and Waste

> *Objective 55 - State the function of an RWP.*
> *Objective 58 - Extract information from an RWP (for example, protective clothing, dosimetry, special instructions).*

This section covers:

Radiation Work Permits - Radiation Work Permits (RWPs) are used to control activities in radiologically controlled areas. You will use RWPs every day and be expected to be able to read and understand the permit.



Radiological Posting - We will also cover the signs and other posting that Radiation Protection personnel use to communicate with you.

Radiological Alarms - The plants are equipped with monitoring devices that alarm when radiation levels are too high. We will learn about them and your responsibilities.

Radiological Waste - We will also learn about your responsibilities with the disposal of radioactive waste.

5.2 Radiation Work Permits - Contents

Radiation Work Permits - Contents

Each nuclear plant may have a different software package for preparing RWPs. However, the same general information is contained in all of them. This information includes:

- Scope of work authorized by the RWP.
- Accumulated Dose Allowed
- Maximum work area Dose Rate
- Authorized Contamination Levels and protective clothing requirements.
- Dosimetry Requirements
- Expected Radiological Conditions
- RP Special Instructions

The higher the radiological risk, the more detailed the RWP and the more requirements, such as obtaining a radiological brief.

In many cases, an ALARA plan with additional requirements may be used to describe radiological work planning and execution.

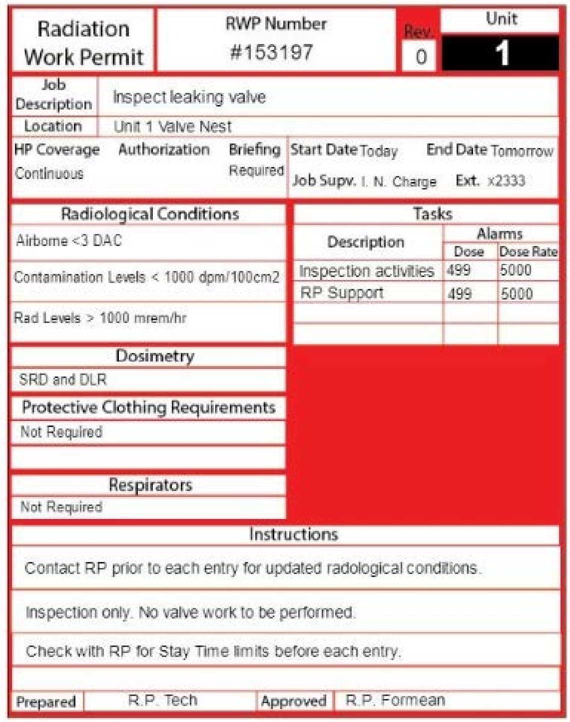
5.3 Radiation Work Permits - Functions

Radiation Work Permits

A Radiation Work Permit (RWP) contains details about a Radiologically Controlled Area (RCA). The RWP is one of the most important tools a radiation worker has for achieving ALARA goals.

The major functions of an RWP are:

- Authorize entry into radiologically controlled areas.
- Provide detailed work requirements such as dosimetry, protective clothing, precautions, and special instructions.
- Provide radiological conditions for the work area.



Radiation Work Permit | RWP Number #153197 | Rev. 0 | Unit 1

Job Description: Inspect leaking valve

Location: Unit 1 Valve Nest

HP Coverage: Continuous | Authorization | Briefing Required | Start Date Today | End Date Tomorrow | Job Supv. I. N. Charge | Ext. x2333

Radiological Conditions

Airborne <3 DAC

Contamination Levels < 1000 dpm/100cm2

Rad Levels > 1000 mrem/hr

Tasks

Description	Alarms: Dose	Alarms: Dose Rate
Inspection activities	499	5000
RP Support	499	5000

Dosimetry

SRD and DLR

Protective Clothing Requirements

Not Required

Respirators

Not Required

Instructions

Contact RP prior to each entry for updated radiological conditions.

Inspection only. No valve work to be performed.

Check with RP for Stay Time limits before each entry.

Prepared: R.P. Tech | Approved: R.P. Formean

You must read, understand, and agree to follow the requirements of the RWP before entering a radiologically controlled area.

5.4 RWPs Your Responsibility

Objective 56 State the responsibility for complying with RWP requirements.

Your Responsibilities with RWPs

The requirements shown on the RWP protect you and your co-workers from radiological hazards. Failure to follow the requirements of the RWP may result in increased dose, spread of contamination, or other radiological problems. Failure to comply could also result in the plant being fined or other regulatory actions, as well as possible disciplinary and regulatory actions for the individual.

5.5 Operating Experience – Wrong RWP

Use of Wrong RWP Operating Experience

Two radiation workers entered a room that was posted as a High Radiation Area while signed onto a Radiation Work Permit (RWP) that does not allow access to such areas. The individuals could have had a significant unplanned radiation exposure, but fortunately did not. This event happened because the individuals did not read the RWP before entering the area and they were signed onto the incorrect RWP. Also, the RP technician failed to provide an area survey as well as a proper RP briefing and job coverage to the personnel entering the area before authorizing use of a general access RWP.

5.6 RWPs When Conditions Change

Objective 57 - State the required action(s) to be taken if the work scope or radiological conditions change so that they are not within the scope of an RWP.

When Conditions Change

Radiological conditions can change quickly in some circumstances. Monitor your dose closely by checking your dosimeter often. Dose rates can rise quickly if the reactor power level changes, a system is drained, or temporary shielding is altered. In addition, the job scope can change from the original plan. Suppose you are about to disassemble a valve, but when you loosen the first few bolts, water begins to drain (and you thought the system was already drained). The radiation levels could be dramatically different from what was planned. In any of these types of situations, place work in a safe condition, inform others in the area, leave the area, and immediately notify RP of the changes.

5.7 RWPs Working in the Overhead

Working in the Overhead

Objective 59 - State the perquisite requirements for access to overhead areas greater than 7 feet above the floor.

The radiation protection staff surveys your work area and sets the RWP requirements based upon their surveys. Typically, the survey ends at 7 feet above the floor level. The reason for this is that the distance between two floors in a plant might be quite large (15 feet or more). These areas are not normally accessed so it saves dose to survey them when needed. **If you have to work in areas over 7 feet above the floor level, check with RP to get an up to date survey first.**

5.8 Survey Maps

Objective 60 - Extract information from a survey map.

Radiological Survey Maps

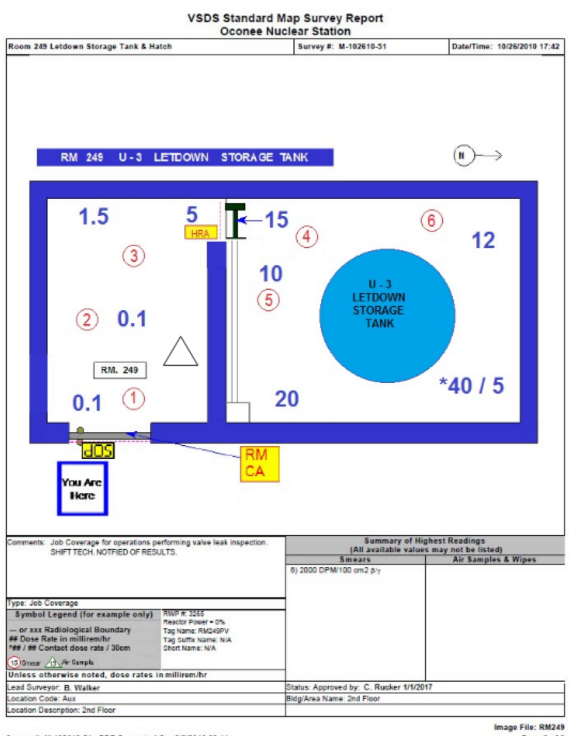
Radiological surveys are performed by Radiation Protection Personnel to determine the radiological hazards present in the area, they may be performed as part of a routine surveillance program or they can be job specific.

You should be able to look at a map and know what the following symbols mean:

- A number on the map is the dose rate in millirem/hr at least 30 cm from the source of radiation.
- A number on the map inside a circle is the location of a smear.
- A triangle is the location of an air sample.
- *#/# Upper number is dose rate on contact with the source. The lower number is at 30 cm from the source.

------------ or xxxxxxxxxxxx indicates radiological boundary.

5.9 Example Survey Map



5.10 Radiological Postings

Objective 61 - Define and recognize the following radiological areas and postings:

- *Radiologically controlled area*
- *Radiation area*
- *High radiation area*
- *Locked high radiation area*
- *Very high radiation area*
- *Radiography in progress*
- *Airborne radioactivity area*
- *Radioactive material area*
- *Radioactive materials storage area*

Radiological Postings

Radiological postings inform you of the radiological hazards in the work area. It is very important that you know what each sign means!

- **Radiation Area**: An accessible area in which a person could receive a whole-body dose greater than 5 millirem in one hour (5 mrem/hr) at 30 centimeters (about 12 inches) from the source.
- **High Radiation Area**: An accessible area in which a person could receive a whole-body dose greater than 100 millirem in one hour (100 mrem/hr) at 30 centimeters (about 12 inches) from the source.
- **Locked High Radiation Area**: An area with greater than 1000 mrem/hr dose rate at 30 cm (about 12 in.) from the source of the radiation. It is kept locked to prevent inadvertent exposure.
- **Very High Radiation Area**: An accessible area in which a person could receive a dose in excess of 500 rads in one hour (500 rad/hr) at 1 meter from the source. VHRAs are posted with the words Grave Danger.

5.11 Radiological Posting Continued

Radiological Posting - Continued

Here are some more signs that you need to know.

- **Radiologically Controlled Area** (RCA): An area designated by Radiation Protection (RP) in which additional controls are prescribed due to increased risk from exposure to radiation or radioactive materials.
- **Radioactive Materials Area**: An area in which radioactive material is used, stored, or transferred.
- **Radioactive Materials Storage Area**: An area in which has been designated for the storage of radioactive material.
- **Contaminated Area:** An area having loose (smearable) contamination equal to or greater than 1000 dpm/100 cm² (100 net counts per minute using a frisker probe) beta- gamma or 20 dpm/100 cm² alpha.
- **Airborne Radioactivity Area:** An area in which airborne radioactivity exists in excess of 0.3 Derived Air Concentration (DAC) or 12 DAC-hours in a week.
- **Radiography in Progress:** An area or room where a special high intensity source is used to X-ray plant components.

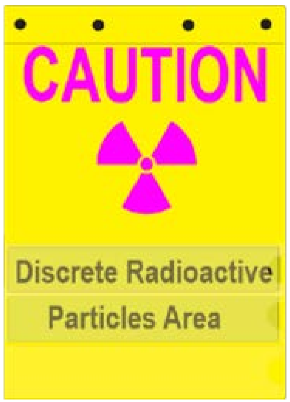
5.12 Radiological Posting - Informational

Objective 62 - Define and recognize the following radiological postings:
- *Hot spot*
- *Low-dose waiting area*
- *Discrete radioactive particle area*

Informational Postings

Radiation Protection uses a variety of signs to warn you about conditions you could encounter. Some provide valuable information on actions you should take. You will encounter others. If you do not know the meaning of a sign or other posting, ask the RP staff for assistance.

- A **Hot Spot** is a localized source of radiation that is much greater than the general background radiation level (components with contact readings of more than 100 millirem/hr. and more than five times the general area dose rates). Hot spots are typically found where corrosion products (crud) may accumulate, such as piping elbows, low-point drains, and others.
- A **Low Dose Area** posting is a notification to you of the lowest dose rate in the work area. If you have to remain in the area to support work but are not actively engaged at the time, find the low dose area to keep your dose ALARA.
- A **Discrete Radioactive Particle Area** is an area established to control the spread of discrete radioactive particles.



5.13 Radiological Posting Continued

Objective 63 - State the potential consequences of violating, moving or altering a radiological posting.

Obey the Postings

Postings serve an important purpose. They warn plant personnel of radiological hazards. Violation, movement, obstruction, or removal of any radiological posting will not be tolerated. It can result in:

- A radiological hazard,
- Increased dose to personnel,
- Regulatory fines, and
- Disciplinary actions up to and including termination.

Always be on the lookout for radiological postings and remember they can, and often do change as plant conditions and work activities change.

5.14 Summary – Radiation Work Permits and Postings

Summary: Radiation Work Permits

This lesson on Radiation Work Permits covered the following topics:

- **Radiation Work Permits (RWPs)** provide detailed work requirements for radiologically controlled areas.
- Before entering radiologically controlled areas, you must read and agree to follow all **RWP requirements**.
- If you encounter a **change in work conditions** or job scope, leave the radiologically controlled area and immediately notify Radiation Protection.
- **Radiologically Controlled Area (RCA)** is an area designated by Radiation Protection (RP) in which additional controls are prescribed due to increased risk from exposure to radiation or radioactive materials.

5.15 Summary – Radiation Work Permits and Postings

Summary: Postings

The lesson on postings covered:

- **Radiation Area** is an accessible area in which a person could receive a whole-body dose in excess of 5 mrem in one hour (5 mrem/hr.) at 30 centimeters (about 12 inches) from the source of radiation.
- **High Radiation Area** is an accessible area in which a person could receive a whole-body dose in excess of 100 mrem in one hour (100 mrem/hr.) at 30 centimeters (about 12 inches) from the source of radiation.
- **Very High Radiation** Area is an accessible area in which a person could receive a dose in excess of 500 rads in one hour (500 rad/hr.) at 1 meter from the source of radiation. VHRAs are posted with the words Grave Danger.
- **Locked High Radiation Area** is an area with greater than 1000 mrem/hr. dose rate. It is kept locked to prevent inadvertent exposure.

5.16 Radiological Alarms

Objective 64 - Identify the radiological alarms used in the plant

Objective 65 - State the proper response to a given radiological alarm.

Objective 66 - State the potential consequences of ignoring a radiological alarm.

Radiological Alarms

Many areas of the plant have equipment that monitors for changes in radiological conditions and will alarm if those conditions are higher than expected.

- **Continuous Air Monitors** sample the air at various locations in the plant.
- **Area Radiation Monitors** are located in areas where the potential exists for significant changes in radiation levels.


Area Radiation Monitor

If either of these alarms is activated, place work in a safe condition, leave the area and notify radiation protection personnel.

Responding to Radiological Alarms - Radiological alarms can be one of the first indications of a serious radiological problem.

Improper response or ignoring a radiological alarm can increase your radiation dose and health risk to you and your co-workers.

Anyone who purposely ignores a radiological alarm will be subject to disciplinary action up to and including termination.

5.17 Radioactive Waste

Objective 67 - Define "radioactive waste."

Radioactive Waste

What is Radioactive Waste?

Radioactive waste is any radioactive material that must be disposed. Examples include the following:

- Damaged protective clothing
- Plastic bags used to carry contaminated tools or equipment
- Packing material taken into a contaminated area
- Consumable materials like pens, notebooks, and cleaning materials

Anything that has been in contact with radioactive material may be contaminated and is disposed of as radioactive waste.

Remember: If you don't take it in it won't get contaminated! Minimizing the amount of materials (such as those mentioned above) that are taken into radiologically controlled areas can help reduce the amount of radioactive waste generated.

5.18 Radioactive Waste – Additional Information

Objective 68 - Contrast the disposal costs of radioactive waste versus nonradioactive waste.
Objective 69 - State the methods for minimizing the generation of radioactive waste.
Objective 70 - Explain why it is important to keep contaminated and non-contaminated waste separate.
Objective 71 - Explain why it is important to keep wet and dry contaminated material separate.
Objective 72 - Explain why it is important to keep contaminated and hazardous waste separate.

Radioactive Waste - Additional Information

Handling Radioactive Waste - Because of the regulatory controls required for handling and processing radioactive material, the cost of disposal is quite high. Another factor that increases cost is the *limited options* for disposal and burial of radioactive waste. Because wet waste is not allowed at any of the burial sites, it is important to keep dry and wet waste separate. It includes cleaning items such as mops and towels. Reducing the amount of radioactive waste we create reduces the disposal costs.

Do not add clean materials in with contaminated items - If you put non-contaminated waste into a contaminated waste receptacle (or vice versa), then all the waste must be handled as radioactive. This is because loose contamination can spread easily from one item to another. It takes time and effort for someone to separate the trash, monitor each item, and dispose of it properly.

Put only contaminated trash in appropriately marked trash containers.

Do not mix wet and dry waste - Wet and dry contaminated waste that has been mixed must be separated and allowed to dry before it can be packaged for burial. It takes time and resources as well as increases the chance of spreading contamination.

Do not mix hazardous waste with other contaminated materials - If you mix contaminated waste with chemical or hazardous waste, you create “mixed” hazardous waste, which is even more difficult to dispose of due to the restrictions on both radioactive waste and the chemical/hazardous waste. If you have to dispose of chemicals or hazardous waste, contact the Chemistry or Environmental group for direction.

5.19 Summary – Alarms and Radioactive Waste

Summary: Alarms and Radioactive Waste

In this lesson, you learned about:

- Continuous air monitors sample air in the work area for airborne contamination.
- Area radiation monitors, at fixed locations in the plant, monitor radiation dose rates in the area.
- If either of these monitors alarm, leave immediately and notify appropriate plant personnel.
- Improper response to or ignoring radiological alarms can increase your dose. It can also subject you to disciplinary action.
- Minimize the amount of radioactive material brought into the RCA.
- Do not mix radioactive waste with wet materials or chemical waste.
- Before disposing of any chemical or hazardous waste, contact the appropriate station personnel.

5.20 Summary - RWPs, Posting, Maps, Alarms, Waste

Section Summary

Topics covered in this section include:

- Radiation Dose Limits and Guidelines
- ALARA
- Dosimetry

6. End of Generic Radiation Worker Training Lesson Plan

You have completed this course. You must pass an exam on this material to be qualified. Your company NANTeL administrator will be able help you get started with the exam.