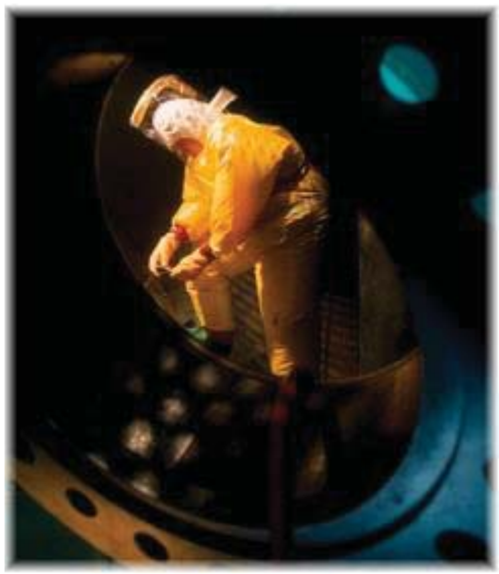
Generic Radiation Worker Training Lesson Plan

Revision 11
December 2017



Estimated Time to Complete: 2.0 Hours

This training is based on the objectives and material presented in ACAD 00-007 Rev 1, *Guidelines for Radiation Worker and Radiological Respiratory Protection Training*.

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 07-007 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

Use the scroll bar at the right to review all objectives.

All About Radiation Objectives

- State the basic structure of an atom including the three primary components and describe how radiation results from the nuclear process.
- List sources of radiation in the plant including the following:
  - reactor coolant
  - activation and corrosion products
  - plant components
  - reactor operation
- State the four types of radiation found in a commercial nuclear power plant.
- Characterize the four types of radiation by:
  - penetrating ability
  - methods of shielding
  - exposure hazard
  - source
- Define Total Effective Dose Equivalent (TEDE).
- Perform conversions from rem to millirem and from millirem to rem.
- State the effects of radiation on cells.
- Define "chronic radiation exposure" and the associated risks.
- Define "acute radiation exposure" and the associated risks.
- Define and compare "somatic" and "genetic" effects of radiation exposure.
- Compare the radiosensitivity of different age groups and identify the possible effects of radiation on an unborn child due to prenatal exposure.

Controlling Radiation at Work Objectives

- State the purpose of the NRC Form-4.
- State the federal dose limits for:
  - Total Effective Dose Equivalent (TEDE)
  - lens of the eye
  - skin
  - extremities
  - organs
- State the possible consequences if any federal radiation dose limit is exceeded.
- State the plant administrative guidelines for radiation dose.

- State the actions to be taken if administrative dose limits are being approached.
- State the federal and plant administrative guideline for an embryo/fetus.
- State the rights of a declared pregnant worker.
- Recognize the definition of a Planned Special Exposure (PSE).
- State the purpose of ALARA (As Low As Reasonably Achievable) and describe the ALARA program
- Explain how time, distance and shielding may be used to reduce dose, and state methods to implement these concepts.
- Calculate stay time given a dose rate, current exposure, and an exposure limit.
- State individual responsibilities regarding temporary shielding.
- State the purpose of dosimetry.
- List the types of radiation detected by the following devices:
    - Primary Dosimeter (dosimeter of legal record (DLR))
        - thermoluminescent dosimeters (TLDs)
        - optically stimulated luminescence (OSL)
    - self-reading dosimeters (SRD)
- Identify how to wear dosimetry devices properly including placement and orientation.
- Identify the modes, methods, and frequency for operating and reading SRD.
- Identify where and when the following dosimetry devices are issued and returned:
    - primary dosimetry (DLR)
    - SRDs
- State the actions to be taken if dosimetry is lost, damaged, off scale, or alarming.
- State the function of the Radiation Work Permit and the responsibility for complying with its requirements.
- State the required actions to be taken if the work scope or radiological conditions change such that they are not within the scope of the Radiation Work Permit.
- Extract information from a RWP (for example, protective clothing, dosimetry, special instructions)
- State the prerequisite requirements for access to overhead areas greater than 7 feet above the floor.
- Extract information from a survey map
- Define and recognize the following radiological areas and/or postings:
    - radiologically controlled area
    - radioactive materials area

    - radioactive materials storage area
    - radiation area
    - high radiation area
    - very high radiation area
    - locked high radiation area
    - radiography in progress
    - airborne radioactivity area
    - hot spot
    - low dose waiting area
    - discrete radioactive particle area
- State the potential consequences of violating, moving, or altering a radiological posting.
- Identify the radiological alarms used in the plant and state the proper response to these alarms including the potential consequences of ignoring them.
- Define "radioactive waste" and contrast the disposal costs of radioactive versus non-radioactive waste.
- State the methods for minimizing the generation of radioactive waste.
- Explain why it is important to keep the following separate: contaminated and non-contaminated waste, wet and dry contaminated material, and contaminated and hazardous waste.
- State the rights and responsibilities of a radiation worker regarding the following:
    - keeping dose ALARA
    - adhering to RP instructions (including stop work authority), written policies and procedures, RWPs, posted warnings and signs.

Contamination Objectives

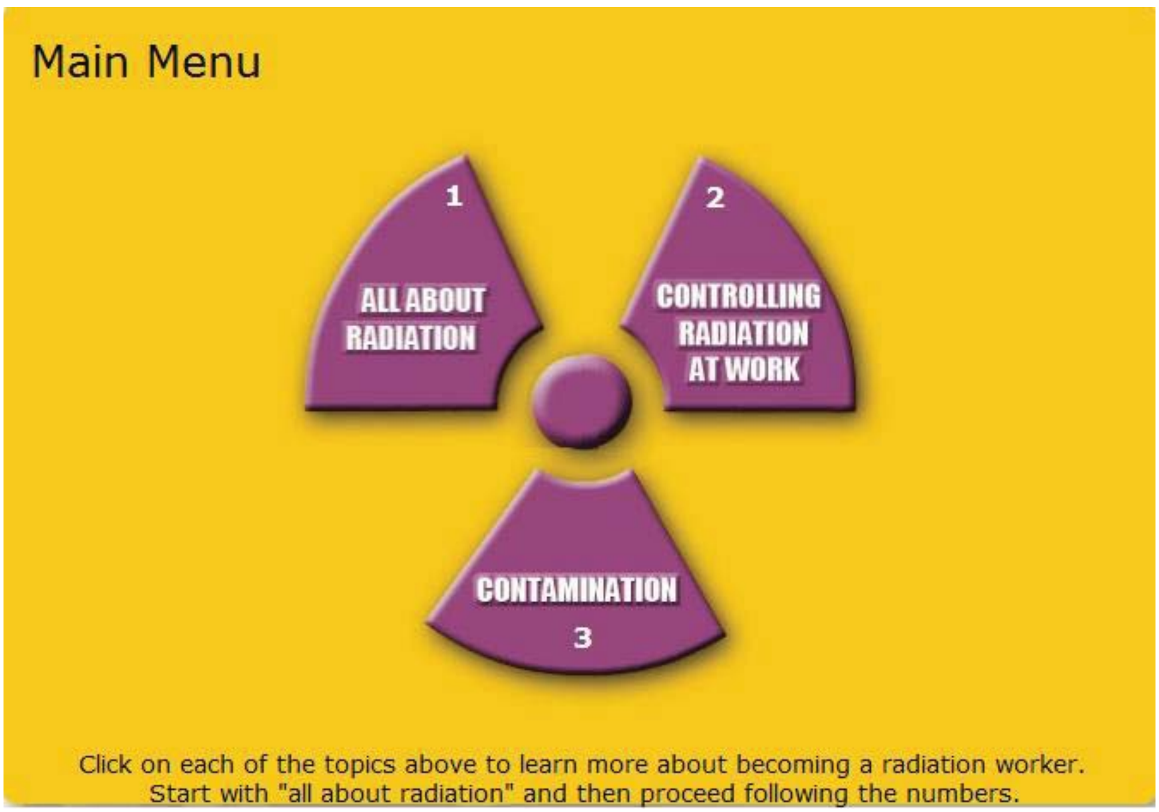
- Identify and compare the following types of contamination and state their units of measure:
    - fixed contamination
    - loose contamination
    - discrete radioactive particle contamination
- Explain why contamination is controlled.
- Describe sources and indications of contamination including: spills and leaks, opening contaminated systems and maintenance activities.
- Describe methods used to prevent contamination of personnel and areas including:
    - 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 access to non-routine surveyed areas (for example, overheads)
    - implementing engineering controls
- State the individual's actions for removing contaminated and non-contaminated materials from the RCA.
- Explain how to monitor personnel and personal items for contamination, including the use of friskers and personnel contamination monitors.
- State the actions to be taken upon indication of becoming contaminated.
- State the methods for control of contaminated tools, equipment, and materials, including minimizing contamination of materials and RCA tool issue.
- State the methods used to designate contaminated areas, including postings and step off pads.
- Regarding discrete radioactive particle be able to state:
    - 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
- Identify situations that require immediate exit from a contaminated area (for example, torn PCs, wounds, and wet PCs).
- State four pathways for radioactive materials to enter the body: inhalation - ingestion - absorption - open wounds/injuries.
- State the methods used to limit the internal deposition of radioactive materials, including respiratory protection and engineering controls.
- State the processes by which radioactive material is eliminated from the body (decay and biological).
- Recognize methods to determine the amount of radioactive material deposited in the body, including whole-body counters and bioassays.
- Define Derived Air Concentration (DAC), Annual Limit on Intake (ALI), Committed Effective Dose Equivalent (CEDE), and state the relationship among DAC, ALI, CEDE, and TEDE.
- Recognize plant conditions that may increase the potential for airborne radioactivity.

Main Menu

Click on each of the topics above to learn more about becoming a radiation worker.

Start with "all about radiation" and then proceed following the numbers.



All About Radiation

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.

What Atoms Are Made of

To understand radiation you need to know a little 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.*

Part	**Where Found**	**Charge**
Proton	Nucleus (center)	Positive (+) charge
Neutron	Nucleus (center)	No charge
Electron	Orbit around nucleus	Negative (-) charge

The number of protons determines what the element is (for example, oxygen has 8 protons and iron has 26).

What is Radiation?

Even though atoms are very small they contain a very large amount of energy. An unstable atom is an atom that has excess energy. Such atoms will give off the extra energy to become stable. This energy can be in the form of particles or waves (similar to light waves).

The process that an atom goes through to become stable is called *radioactive decay* and the energy that is given off is called *radiation.* Radiation is simply a burst of energy (particles or waves) given off by an unstable (*radioactive*) atom. A large collection of radioactive atoms is called *radioactive material.*

Radioactive materials give off radiation. 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.

What is Contamination?

When radioactive material is in a place it is not supposed to be in, such as on the floor, it is called *radioactive contamination* or simply contamination.

Contamination is radioactive material in an unwanted location. If it is in the reactor it is radioactive material. If it is on the bottom of your shoe it is called contamination.

No matter where it is, radioactive material gives off radiation.

Can People Sense Radiation?

Radiation, just like light, is energy. When you compare the two, a light bulb is the source of light just like radioactive material (or contamination) is the source of radiation.

However, people cannot sense radiation. Even when radiation levels are very high the radiation cannot normally be seen, felt, smelled or heard.

In this course we will try to show visually how radiation travels but in reality radiation normally cannot be seen.

Fission - Fuel and Reactor Operations

Some very large atoms can split and become two atoms as they go through radioactive decay. The splitting of atoms is called *fission.* Both radiation and heat are given off during fission. 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.

These radioactive atoms are called *fission products.* By design they 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.

Radiation Sources – Activated Corrosion Products

The radiation inside a nuclear reactor is unique. It 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.

Radiation Sources - Where does it come from?

People don't normally go into a reactor so how do they become exposed to radiation?

Water in the reactor is called reactor coolant. The radioactive materials in the reactor are swept along by the coolant into other parts of the plant through the pipes.

These radioactive materials form a layer on the insides of pipes and can become trapped in small crevices, low points, filters, and similar areas. As they build up radiation levels increase. Personnel working around these areas can then be exposed to radiation.

If radioactive material leaks out of the pipes or other systems then radioactive contamination would be present. People could track the contamination around to other areas.

Types of Radiation

Now that you know where you are likely to find radiation while working at a power plant, you should know a little more about the types of radiation you may encounter.

Four main types of radiation are found at nuclear power plants. Each is different and has characteristics that are important to remember:

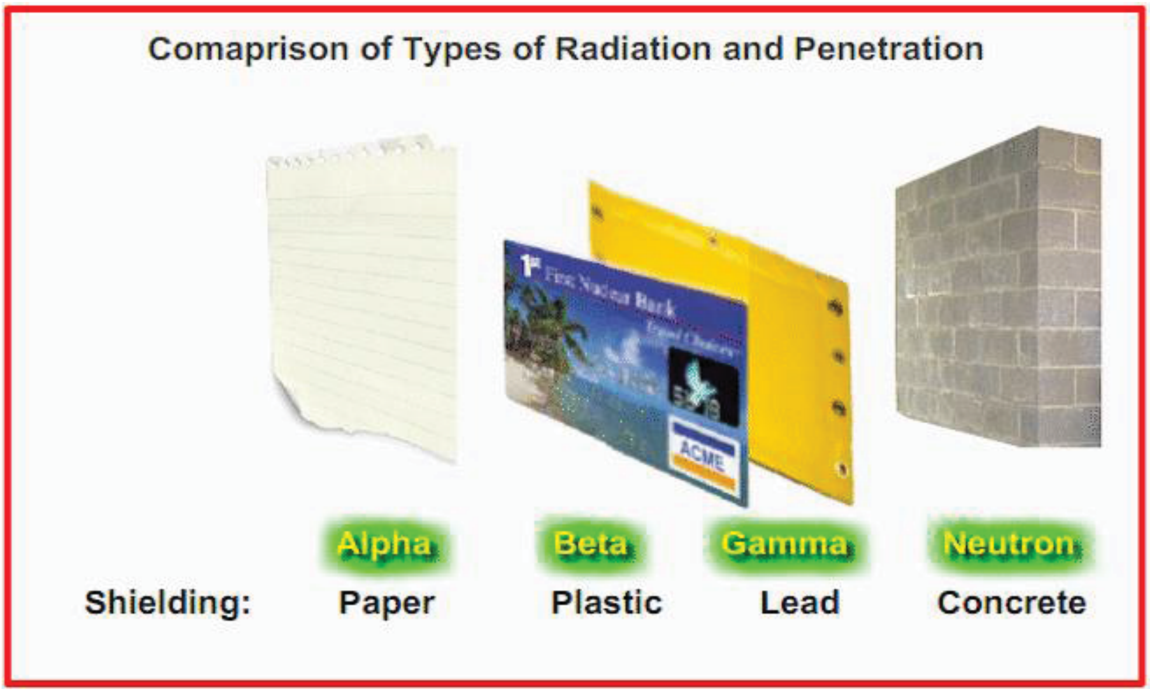
- penetrating ability (what can the radiation go through)
- shielding methods (what can stop or reduce the radiation)
- exposure hazard (for example what part of the body is exposed)
- major sources (what gives off the radiation)

To see the differences of these types of radiation, study the animations by clicking on each.

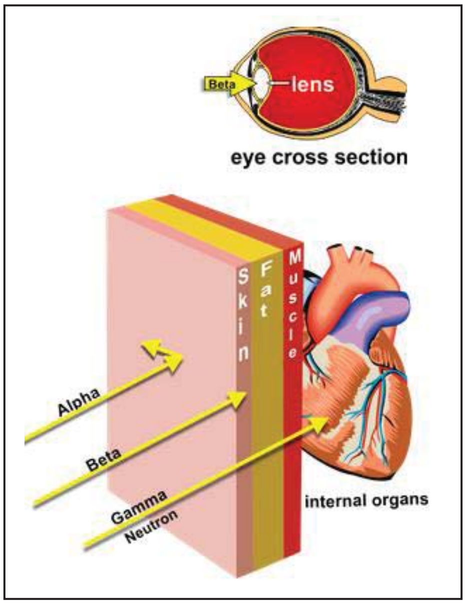
[Alpha](#)

[Beta](#)

[Gamma](#)
[Neutron](#)



Penetrating into the Human Body



Usually radioactive materials are outside the body and the amount of radiation received is from external radiation sources.

Each type of radiation differs in its ability to penetrate the human body.

Alpha radiation cannot penetrate into living skin cells. It is not a hazard unless the radioactive material gets inside the body. It would occur if the material is breathed in or swallowed.

Beta radiation can make it into the skin cells and cause damage but cannot penetrate further. At very high levels of beta some of it will make it to the lens of the eye but will be stopped there. It can easily be prevented with plastic goggles and other shielding materials.

Gamma and neutron radiation can penetrate through the skin and into the internal organs.

Where You Will Find Alpha Radiation

Alpha radiation originates in nuclear fuel assemblies. Remember that alpha radiation can't even penetrate paper. Since the fuel is contained in metal rods, the main hazard from alpha radiation exists only if the fuel assembly develops leaks. Very little dose received at nuclear plants comes from alpha radiation.

Alpha contamination introduced into plant systems by fuel leaks from past years will be present for many years because it stays radioactive much longer than other radioactive materials. This older alpha contamination found in abandoned systems and buried under layers of corrosion products can be present for many years.

Abrasive work like sanding, grinding, or sand blasting disturbs corrosion products and can uncover hidden alpha contamination, which can create a potentially high internal dose hazard.

In cases where the plant has operated with leaking fuel assemblies, alpha radiation may be found, especially under layers of corrosion products. 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 to alpha radiation. Your good work habits and protective equipment provided to you can prevent it.

Where You Will Find Neutron 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 basically 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.

Where You Will Find Beta and Gamma Radiation

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, if you recall, 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.

Gamma radiation is the primary dose concern in a nuclear plant. This is because gamma radiation has a high penetrating ability and can penetrate the piping walls. That's why gamma radiation can penetrate your skin and give you a whole-body dose.

Most of the exposure to radiation received by nuclear workers is from gamma radiation. Why? Because gamma is common inside the plant pipes, valves, tanks, etc. AND it can penetrate through thick materials. Remember normally shielding will reduce but NOT eliminate radiation

Measuring Radiation

The term *rem* is a measure of any type of radiation in terms of the estimated biological effects. Because measurements of radiation are frequently in very small fractions of rem, the prefix *milli*, meaning 1/1000, is generally used. One *millirem (mrem)* is one thousandth of a *rem*, therefore there are one thousand millirem in one rem. This unit is commonly abbreviated as *mrem* or *mr*.

Radiation Terms – Dose and Dose Rate

Two simple terms that you will want to become familiar with are *dose* and *dose rate.* If you understand the difference between these terms, you will better understand the rest of this lesson.

Dose is the amount of radiation absorbed by the body or a particular organ and is measured in units of *rem* or *millirem.*

Dose rate is the amount of dose you receive *in a certain period of time*. It is usually measured in terms of millirem per hour (unit of time) or simply *mr/hr.*

Remember, dose is *total* radiation exposure *received;* dose rate is how *fast* you receive it.

A Familiar Example

Because you work hard for your money, consider how much you earn on a paycheck before any deductions. That's your *total received*. By looking at your paycheck you can figure what your base pay is per hour.

- If you make $30/hr, how much do you earn in 8 hours (normal time)?
  - $30/hr X 8 hr = $240
- If you work in an area with a dose rate of 30 mr/hr, what is your dose in 8 hours?
  - 30 mr/hr X 8 hr = 240 millirem

That's how to calculate *dose*. It's the dose rate of an area multiplied by the hours spent there.

What is TEDE?

TEDE stands for *T*otal *E*ffective *D*ose *E*quivalent. This is the total of a person's external dose and internal dose.

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.

Remember TEDE. You'll use it later in this lesson.

How Does Radiation Affect Humans?

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. *Click on each of the links.*

Possible Effects

Nothing happens, *no damage to the cell* as a result of radiation exposure.

The cell is damaged by exposure to radiation but *repairs itself, before it reproduces.*

The damage to the cell from radiation exposure is extensive and may result in *cell mutation but not cell death.*

Damage to the cell from radiation exposure is so great that *the cell dies*.

Chronic Exposure

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

Scientific studies show an increased chance of health effects such as cancer from high doses, compared to occupational levels, delivered over a relatively short period of time.

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

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.

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 table compares the risk of receiving occupational dose to the following risks.

Estimated Days of Life Lost **Source: Reg Guide 8.29, Table 1**	
Activity/Condition	**Loss**
Smoking 20 cigarettes a day	6 years
Overweight by 15%	2 years
All accidents (home, auto, drowning)	1 year
Alcohol consumption (U.S. Average)	1 year
1rem/year for 30 years (Calculated)	51 days
All Catastrophes (earthquake, etc.)	7 days
Medical & diagnostic X-rays (Calculated)	6 days

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 next screen shows the effects from different levels of acute radiation exposure.

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.

Genetic Effects

Genetic effects from radiation exposure appear in future children of an individual who received the dose. The chances of their 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 regulatory guidance 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.

Somatic Effects

Somatic effects of radiation exposure occur in the individual who has received the radiation dose. Somatic simply means "something affecting the body". With somatic effects any cell damage would be to the cells of the person exposed to the radiation.

This damage could cause one of two effects:

- prompt effects
- delayed effects

Somatic effects occur JUST in the individual who was exposed to the radiation.

If a worker is exposed to radiation and later has a health issue from the exposure that would be considered a somatic effect.
somatic effect

Cell Division

Human body cells are constantly dividing and making copies of themselves to grow and to replace older cells. Some parts of the human body do this more rapidly than others. **The highest risk to a cell from radiation exposure is during cell division.** The more often cells are dividing the higher the risk of damage.

What Does Radiosensitivity Mean?

Cell reproduction slows as you age, so younger people are more sensitive to radiation than older people are. Therefore, unborn children are more sensitive than infants and infants are more sensitive than older children, and so on. It 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.

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 mental retardation 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.

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.
- 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.

Controlling Radiation at Work

Because of the radiation hazards you learned about in the “All About Radiation” section, a variety of regulations and site programs, policies, and procedures have been established to help ensure safe working conditions in areas where people could be exposed to radiation.

This section is quite lengthy. Summaries of the different topics are presented instead of one large section summary. Look for summaries on the following topics as you go through this section:

- Limits, Levels, and Guidelines
- ALARA
- Dosimetry
- Radiation Work Permits & Postings
- Alarms & Radioactive Waste

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.

Unplanned Radiation Exposure   Operating Experience

A worker was repairing a valve actuator when he received 110 mrem of radiation exposure because he did not respond to an alarm on his alarming dosimeter. 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 immediately upon receiving the alarm.

Worker received 110 mrem and ignored alarm

Limits, Levels, and Guidelines

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 by contacting the appropriate plant department.

Federal Dose Limits

Occupational radiation dose limits are set by the Nuclear Regulatory Commission (NRC). These legal limits are based on the current understanding of the biological effects of radiation.

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.

Limits are divided as follows:

- Extremities (elbow to finger tips, knees to toes)
- All internal organs (this is TEDE mentioned earlier), the portion of the body that does not include the extremities or the skin
- Organs - An (not all) internal organ (such as dose to the thyroid)
- Skin of the body (not the extremities)
- Lens of the eyes

Individual vital organs in the body have dose limits. This is based on one or a few organs getting dose and the rest of the body NOT receiving dose. This is very unusual in the nuclear industry. You will see that an organ by itself can have a much higher amount of dose than ALL the organs receiving dose (TEDE). For the commercial nuclear industry TEDE is the most restrictive so will be of most concern.

What Is Whole Body Dose?

"Whole body" refers to a part of the body. It is everything except the extremities (see graphic to the right).

Dose to the whole body can be divided into two categories:

- Whole body dose - TEDE, this is dose to all internal organs.
- Dose to the skin of the whole body

The "whole body" is marked in green. It includes all body parts above the knee and above the elbow.

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. So the upper arm and the upper leg that have vital blood forming organs are NOT part of the extremities.

Extremities are marked in green. Notice they do not include the upper arm and upper leg.

Dose Limits

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 specified below. The industry has adopted the administrative guidelines below to ensure that no Federal limits are reached:

Body Part	**Federal Limit (rem/yr)**	**Administrative Guidelines (rem/yr)**
Whole body (TEDE)	5	2
Lens of eye	15	12
Skin	50	40
Extremities	50	40
Internal organs	50	40

Important Note

If you are approaching one of the exposure guidelines above, **notify your supervisor and contact Radiation Protection** to authorize and process a dose extension.

Dose Limits for the General Public

The limits just described are for occupational exposure of *radiation workers* and do not apply to the general public. Generally, a *radiation worker* is any worker who is monitored for dose. The general public is anyone else.

The federal dose limit for members of the general public is 100 millirem/ year for exposure from plant activities. Recall that the average dose to people in the United States from natural radiation and medical procedures is about 620 millirem.

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

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.

Federal Dose Limits for Declared Pregnant Workers

Both NRC Reg. Guide 8.13 and 10 CFR 20.1208 contain a dose limit of *500 mrem (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 mrem for the duration of the pregnancy to provide fetal protection.

(The industry administrative guideline is 450 mrem for the entire term of the pregnancy, not to exceed 50 mrem 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.

Planned Special Exposures

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

An example of a Planned Special Exposure would be when only one person on site can complete an important job, but this person does not have enough available dose under federal limits.

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.

Summary: Limits, Levels, and Guidelines

- The NRC Form 4 contains your dose history for the year, and you have the right to review it at any time.
-

Federal Dose Limit	**Administrative Guide**
5 rem/year TEDE	2 rem/year TEDE
15 rem/year lens of the eye	12 rem/year lens of the eye
50 rem/year for the skin of the whole body	40 rem/year for the skin of the whole body
50 rem/year for internal organs	40 rem/year for internal organs
50 rem/year for extremities (hands and lower arms including the elbows; feet and lower legs including the knees)	40 rem/year for extremities (hands and lower arms including the elbows; feet and lower legs including the knees)
500 millirem for Declared Pregnant Worker for the term of the pregnancy	450 millirem for Declared Pregnant Worker for term of pregnancy, not to exceed 50 millirem per month

- If a woman does not declare pregnancy in writing, normal federal dose limits apply.
- A Planned Special Exposure (PSE) allows federal dose limits to be exceeded only with senior management approval.

ALARA

Because the nuclear industry assumes that all radiation exposure contains a risk, nuclear plants strive to keep dose *A*s *L*ow *A*s Reasonably *A*chievable (*ALARA*).

The purpose is to ensure that individuals and overall groups receive as little dose as reasonable while still accomplishing their work. This applies to internal as well as external dose.

ALARA Program

A formal ALARA Program indicates management is committed to minimizing dose. This program helps ensure that ALARA concerns are addressed systematically and makes everyone aware of ALARA in their daily work activities.

A station ALARA Committee provides management oversight and direction to the ALARA Program.

ALARA Program Components

Important components of the ALARA program include the following:

- prejob ALARA reviews and prejob briefings
- job planning to include worker experience and lessons learned
- training mockups (models of a structure or area that are used outside radiological areas for study, demonstration, and practice)
- good radiological work practices such as temporary shielding
- engineering controls such as ventilation and system cleanup

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.)

Reducing Dose – Time

Three of the most common ALARA tools are time, distance, and shielding. Let's take a look at how each of these can reduce your dose.

First is *time.* It makes sense that the more time you spend working around radiation, the more dose you receive (remember, Dose = Dose Rate X Time Spent). 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.

Reducing Dose – 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. For example, if you are working 1 foot from the source and move back to 2 feet away, the dose rate drops to 1/4. If you move to 3 feet away, the dose rate is 1/9.

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.

Reducing Dose – 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. Lead blankets are often used as shielding because they can shield alpha, beta, and gamma radiation.

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 doesn't 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 don't know what the radiation levels are in your work area, ask the radiation protection staff.

Shielding – Your Responsibilities

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.

ALARA Planning

Time, distance, and shielding are all ALARA tools that can assist you at the job site. However, there are some things you can do before going into the field that will also reduce dose:

- 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.

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.

Here is how to calculate stay time:

Stay time = (dose limit – current dose) ÷ dose rate in the work area

Summary: ALARA

- The purpose of the ALARA Program is to keep radiation dose to individuals and the site **A**s **L**ow **A**s **R**easonably **A**chievable.
- Common components of the ALARA Program are prejob 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 limit minus current dose divided by dose rate in the work area.

Dosimetry

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.

Dosimeter of Legal Record (DLR

Self-Reading Dosimeter (SRD)

Dosimeter of Legal Record (DLR)

There are two common DLR's used in the nuclear industry:

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

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, they cannot be read by the user. They are read in a laboratory with specialized equipment. These will be referred to as DLR's for the rest of the lesson. In some cases, a Self-Reading Dosimeter may be used as the DLR.

The DLR can measure gamma, beta, and neutron radiation exposure. 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. Commonly DLRs are stored with the security badge or key card when not in use. 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.

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

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.

The *Electronic alarming dosimeter* (EAD) is the most commonly used of self-reading dosimeters. The EAD shows your dose on a digital display and provides an audible alarm when it reaches a dose or dose rate limit. The EAD provides an approximate dose.

SRDs can measure gamma and beta radiation but are primarily used to measure gamma. This is more than 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 DLR's, the SRD's 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. DLR's on the other hand you will keep until the Dosimetry Group exchanges it for a new one.

SRD's are not normally 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 log-in your SRD. Upon Exiting the RCA, log-out utilizing the dose tracking system and return your SRD to the storage location.

SRD's will alarm if a preset dose or dose rate set point is exceeded. However, it is still important to track your on-the-job dose and use the alarms as a backup.

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. To avoid an accumulated dose alarm, a good practice is to 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.

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

DLR	SRD
Provides a permanent legal record of your occupational dose	Provides a real-time estimate of your occupational dose and is not the legal dose of record
Measures gamma, neutron, and beta radiation	Measures gamma radiation (some models also measure beta)

Can only be read by RP personnel using special equipment	Allows you to routinely check your own dose while you are working
Has *no* audible alarm	Has audible alarm
Note: In some cases, legal dose will be assigned based on SRD readings	

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.

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. Both are required for entry into areas where you must be monitored for radiation.

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 can be stopped by plastic. If the DLR is facing the wrong way, the plastic will shield the beta radiation and it won't be measured.

Nuclear worker wearing an SRD and a DLR (top).

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.

Dosimetry Terminology

Wow! That was a lot of new terms. Let's do a final review.

Dosimeter of Legal Record - DLR

1. Thermoluminescent dosimeter - TLD
2. Optically stimulated luminescent dosimeter - OSLD

Self-Reading Dosimeter - SRD

1. Electronic Alarming Dosimeter – EAD

Summary: Dosimetry

- Dosimeters of legal record (DLR) and self-reading dosimeters (SRD, such as the EAD) monitor worker radiation dose.
- DLRs measure beta, gamma, and neutron radiation. SRDs can measure gamma and beta radiation but 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 approximate dose received.
- DLRs and SRDs are normally worn together on the front of the body between the neck and waist facing out. Don't relocate dosimetry unless directed otherwise by RP.
- Leave the area and notify RP, if your DLR/SRD is lost, is alarming for any reason, is damaged, or does not appear to be working.

Radiation Work Permits

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

Radiation Work Permits

A Radiation Work Permit (RWP) contains details about a Radiologically Controlled Area (RCA). The definition of an RCA is in an upcoming section but for now consider it any area where radiation or radioactive materials are present and monitoring is required. 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.

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

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 actions for the individual.

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.

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.

Also, 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.

Material Safety Data Sheet (MSDS) information for solvents being used

Work authorizations and clearances

Protective clothing requirements

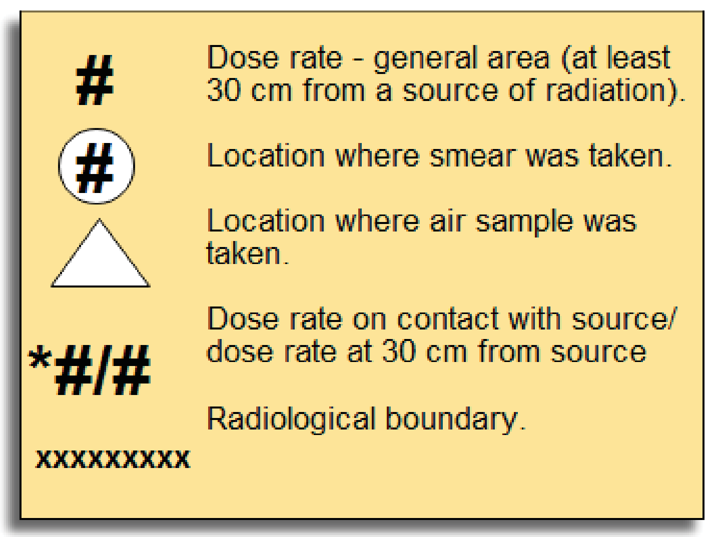
Dosimetry requirements

Outage schedule information

Torqueing requirements for valve assembly

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. *Click the map to the right for more information.*



Know the symbols above found on survey maps!

Radiological Survey Maps

Additional information you will find on survey maps are described here. Click the highlighted areas to see what each means.

"xxx" in succession for designating a radiological area boundary. Used in conjunction with RCA, RA, HRA, etc.

"N" for dose rates due to neutron radiation. Here 2.5N indicates 2.5 mrem/hr general area due to neutron radiation.

"KO" means "Keep Out" of the posted area, in this example, a High Contamination Area (HCA).

"β" or "B" for corrected dose rates due to beta radiation. In this example, the valve has a contact dose rate or 32 mrad/hour.

"NRP" means "Notify RP" prior to entry. Do not enter the area without first contacting Radiation Protection.

A rectangle with the letters "SOP" marks the entrance to a contaminated area to designate a step off pad.

"LDWA" for low dose waiting area which is the lowest dose rate in the area.

A Hot Spot is a localized source of radiation from components with contact readings of more than 100 millirem/hr and more than five times the general area dose rates). Contact and 30 cm dose rate of the hot spot may be placed adjacent to the HS. In this example, the contact dose rate is 150 millirem/hr and the 30 cm dose rate is 25 millirem/hr.

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! *Click on each picture for more information.*

Radiation Area: An accessible area in which a person could receive a whole-body dose greater than 5 millirem in one hour (**5 millirem/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 millirem/hr**) at 30 centimeters (about 12 inches) from the source.

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.*

Locked High Radiation Area: An area with greater than **1000 millirem/hr** dose rate at 30 cm (about 12 in.) from the source of the radiation. It is kept locked to prevent inadvertent exposure.

Radiological Postings

Click on each picture for more information.

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.

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. (More on DACs later.)

Radioactive Materials Area: An area in which radioactive material is used, stored, or transferred.

Radiography in Progress: An area or room where a special high intensity source is used to X-ray plant components.

Low Dose Area (Zone) Postings

Unlike the hazard warning signs you just saw, 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.

Contaminated Area Postings

The contaminated area sign indicates that there is loose contamination present in high enough quantities that the workers need to wear protective clothing. Personnel working in and around these areas need to be careful not to spread the contamination further. This will be further described in the contamination section.

Other Postings

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 Discrete Particle Area is an area established to control the spread of discrete particles. This will be further described in the contamination section.

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.

Self-Briefing for Low-Risk Radiological Work

This program 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 the following radiological area conditions and activity restrictions.

The following AREA restrictions apply to worker self-briefings:

- 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 *both the area and activity restrictions* listed may use the self-brief process.

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.

Self-Briefing for Low-Risk Radiological Work

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

Summary: Radiation Work Permits & Postings

- 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.

Summary: Radiation Work Permits & Postings

- **Radiation Area** is an accessible area in which a person could receive a whole-body dose in excess of 5 millirem in one hour (**5 millirem/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 millirem in one hour (**100 millirem/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 millirem/hr** dose rate. It is kept locked to prevent inadvertent exposure.

  RP may permit workers to use the self-briefing process if their work meets the

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.

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

Anyone who purposely ignores a radiological alarm will be subject to disciplinary action.

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.

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.

Radioactive Waste Reduction

If you put noncontaminated 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.

Contaminated 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.

If you mix contaminated waste with chemical or hazardous waste, you create “mixed” 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.

Summary: Alarms and Radioactive Waste

- 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.
- Keep contaminated waste separate from non-contaminated waste.
- Do not mix radioactive waste with wet materials or chemical waste.
- Before disposing of any chemical or hazardous waste, contact the appropriate station personnel.

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.

Organization of This Section

This section is quite lengthy. Summaries of the different topics are presented instead of one large section summary. Look for summaries on the following topics as you go through this section:

- Contamination
- Internal Exposure

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 prejob brief.

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.

Fixed Contamination

Fixed contamination is embedded in an object and cannot be removed by normal cleaning techniques. Click here for a non-nuclear example. 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 are marked with the color purple to identify them as having fixed contamination.

Remember: fixed contamination is attached to the surface and can't easily come off.

Loose Contamination

Loose contamination can be easily spread to clean areas. Click here for a non-nuclear example. Loose contamination can also become airborne, especially from activities such as sweeping or using a fan in a contaminated area.

Areas with a high enough amount of loose contamination have to be posted. These areas are called “contaminated areas”. Contaminated areas either 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.

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

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.

Monitoring for Discrete 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 as described on the next page.

Due to the small size of a discrete particle the frisker must be very close to the particle to detect it. Once found the discrete 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 particles. Make sure you use the equipment properly EVERY time you go through an exit equipped with these monitors.

Working Around Discrete Particles

Before entering a work area, make sure you understand the contamination and radiation levels as shown on the RWP and area survey map. Use the protective clothing required by the RWP and carefully monitor yourself when exiting the area.

Radiation Protection personnel post areas to help you do your job safely. Obey the postings. Read them every time you enter an area. The "discrete radioactive particle area" sign to the right lets you know that there will be some special requirements in this area. Check with RP, if you need help.

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.

Remember

Loose contamination is sampled by rubbing a "smear" over floors and other surfaces. Smears are simply round 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**.

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).

Why Contamination Must 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.

Also, 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.

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. Also, 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).

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).

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.)
- Determine which tools/equipment you will need, and see if they are available inside the radiologically controlled area.
- Use engineering controls as available.

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.

Preventing Contamination While Working

During the job (cont.):

- Tape down hoses, cords, etc., that pass into a contaminated area.
- Avoid skin contact with contaminated surfaces.
- Avoid water or white crystalline substances on the surfaces around radioactive systems. The white crystals may be boric acid an indication of a reactor coolant leak.

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.

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 normal 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.

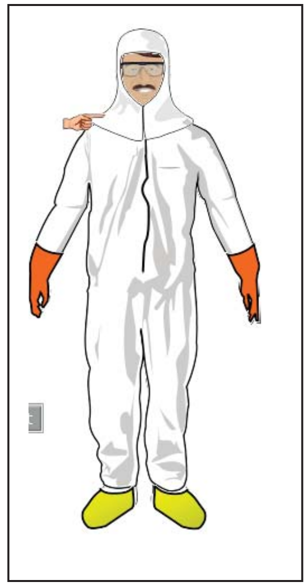
Protective Clothing

Protective clothing, or "PCs," must always be worn inside a contaminated area. Protective clothing requirements will be found on your Radiation Work Permit or will be specified by RP personnel.

A full set of protective clothing consists of the items below (Your RWP will define which ones apply to your work). *Click on each item to dress the worker.*

Lab coats or plastic suits may be used in special situations as authorized by RP.

Note: For FME purposes some work may require tape on your gloves and/or shoe covers.



1. Shoe covers/booties

2. Glove liners

3. Coveralls

4. Rubber overshoes

5. Rubber gloves

6. Hood or cap

For the purposes of this exercise, click on each item in sequence starting with number one.

Using Protective Clothing

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

Personal items (wallets, watches, keys, etc.) that could become contaminated should not be taken into the area.

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.

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.

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

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.

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).

Using a Personnel Contamination Monitor

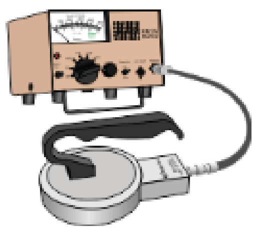
When preparing to leave the radiologically controlled area (RCA), you will be required to use a second type of contamination monitor, the personnel contamination monitor (PCM).

This monitor has several radiation detectors that monitor your entire body. It is more sensitive to radiation than a frisker and will detect very low levels of contamination.

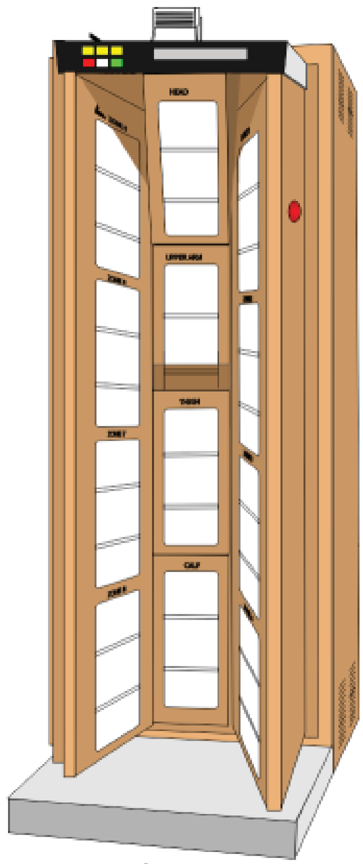
That coupled with very large detectors makes the PCM the best way to find contamination on your body. Friskers are good at pin pointing where the contamination is located but PCMs are the best at finding out if contamination is present. They should be the very last instrument used before leaving.

Don’t 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.



Hand-held frisker



Personnel contamination monitor

Removing Material from the RCA

The last barriers to stop radioactive contamination from leaving the RCA's are the main RCA control points. All personnel will exit through one of these control points.

PCM's and "Tool and Equipment Monitors" (TEM) are stationed at these exits to ensure that no radioactive material leaves the RCA's. Remember:

- Items that were in a contaminated area MUST be checked by Radiation Protection (RP) personnel.
- 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 PCM's. Some items must be checked for contamination by using a TEM. Follow the posted instructions OR contact the RP staff for assistance.

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. The PCM

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.

Don’t 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.

How to Recognize Contaminated Areas

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.

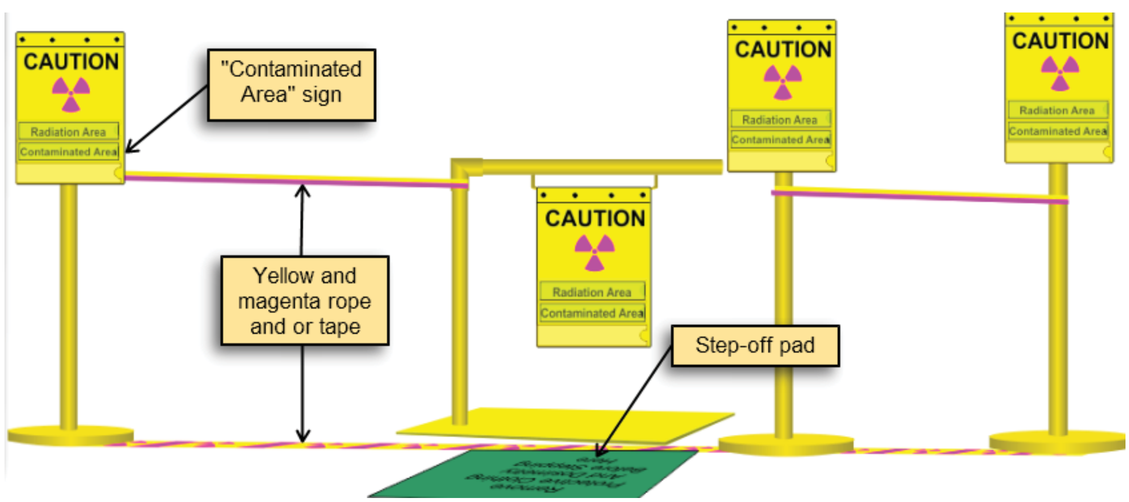
The entrance and exit to contaminated areas are usually designated by a step-off pad. Step-off pads are only used to reduce the spread of contamination. If you see a step-off pad, you know the area is definitely contaminated AND protective clothing will be required.

How can you tell if an area is contaminated? 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
- **Boundary tape** on the floor

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:



Alpha Contaminated Areas

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.

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.
- You are directed by RP personnel.

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

Summary: Contamination

- The three main types of surface contamination are loose contamination, fixed contamination, and discrete (hot) particles.
- Loose and fixed contamination may become airborne as a result 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.
- Contaminated areas are identified by 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.
- 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 any reason, 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.

Internal Exposure Pathways

Loose contamination can be an internal dose hazard, especially if it becomes airborne because you can *inhale it* (breathe it in). This is the most common way radioactive material enters the body. However, radioactive material can also enter your body through *ingestion* (eating, drinking, chewing), *absorption* (absorbing through the skin), or through *open wounds or sores.*

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.

Preventing Inhaled Contamination

To prevent 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.

As a last resort, respiratory equipment can be used to reduce the quantity of radioactive material inhaled. However, use of respirators can reduce efficiency and increase time in the contaminated area. This could actually increase total effective dose equivalent. You must be trained and qualified to wear respiratory protective equipment.

Preventing Ingested Contamination

Good radiological work practices can help reduce the possibility of ingesting radioactive material. Don’t 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.

Preventing Other Internal Contamination

Radioactive material can be absorbed through your skin, especially if your PCs get wet. When working with liquids, check your RWP 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.

Getting Rid of Internal Radioactive Material

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

1. Biological processes will naturally occur, causing many types of internal contamination to be eliminated from the body.

2. Radioactive decay will naturally occur, reducing the amount of radioactive material as time passes.

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.

Measuring Internal Radioactivity

Although the body contains naturally occurring radioactivity (potassium from bananas, for example), you should only be concerned about internal dose received from radioactive material deposited as a result 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:

1. A whole-body counter directly measures the level of radioactivity in your body and what type of radioactivity it is.

2. 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

Committed Effective Dose Equivalent

Federal law regulates the amount of internal exposure you can receive. (Remember the dose limits covered earlier?)

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. All the 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.

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 organ

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.

On the upcoming pages we will show you how this can be used. **Just remember that 1 DAC-Hr = 2.5 millirem.** So if you breath for an hour in an area with a concentration of 1 DAC you would receive 2.5 millirem.

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.

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 receive 2 DAC-hours internal dose because that's how long he will spend breathing in airborne contamination.

The Answer

By *not* wearing a respirator to perform this task, Chris will receive *less* total effective dose equivalent!

WITH a respirator

Dose from external radiation (24 millirem/hr)(3 hrs) = **72 millirem** total dose

(Because Chris used a respirator, he received no DAC-hours from airborne contamination but spent 60 minutes longer in the area.)

WITHOUT a respirator

	Dose from external radiation (24 millirem/hr)(2 hrs) =	**48 millirem**
+	Internal dose from airborne contamination	
	(2 DAC-hours)(2.5 millirem/DAC-hour) =	**+5 mrem**
	Total dose =	**53 mrem**

(Chris received 48 millirem external dose and 5 millirem internal dose by not using a respirator, but spent 60 minutes less time in the area.)

72 millirem – 53 millirem = 19 millirem dose savings

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.

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.

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.

Summary: Internal Exposure

- 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

Generic Radiation Worker Training

Release Date: November 19, 2017

This lesson provides general information that workers need to prepare for work in radiologically controlled areas of a nuclear power plant. It describes radiation and contamination, including their health effects, how they are created, how they are controlled and measured, and how to work safely in areas where they are found. The training material meets the National Academy for Nuclear Training's generic objectives for training of all radiation workers according to ACAD 00-007, Revision 1, "Guidelines for Radiation Worker and Radiological Respiratory Protection Training." Individual stations must supplement this generic training with additional site-specific training as required by ACAD 00-007. Use the information provided under the "Contact Us" link in the lesson "Help" menu if you have any content questions.

NANTeL Contact

If you need help using NANTeL, please contact the NANTeL administrator located at the facility for which you are taking training. This would most likely be the person who assigned you the training. This information is available on the NANTeL Web site.

Note: If you know your local administrator, it is best to direct your question to him or her before contacting the NANTeL Help Desk.

For general questions about NANTeL:

NANTeL Help Desk
INPO
Monday through Friday during normal working hours (Eastern Time)
Phone: 770-644-8900
E-mail: nantelhelpdesk@inpo.org

Reference Documents

ACAD 00-007,Rev.1, "Guidelines for Radiation Worker and Radiological Respiratory Protection Training"

NRC Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure"

NRC Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure"

Thanks!

This course was created in collaboration with the U.S. nuclear industry. Feedback and special reviews by the industry have been taken into account during this latest revision of Radiation Worker Training.

The following organizations contributed photographs, videos, and/or other developmental assets for this course:

Constellation Energy Group
Duke Energy Corporation
Exelon Corporation
FirstEnergy Nuclear Operating Company
FPL Group
Luminant
Omaha Public Power District
Progress Energy
Southern Nuclear Operating Company
STP Nuclear Operating Company
Union Electric Company
Wolf Creek Nuclear Operating Company
Xcel Energy

Questions or comments about this course can be addressed to nantelhelpdesk@inpo.org.

Glossary

10 CFR 20

Volume 10, Part 20 of the Code of Federal Regulations.

Activation Products

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

Acute Radiation Exposure

A large radiation dose received in a short period of time, usually less than 24 hours.

Administrative Guidelines

Dose administrative guidelines set by utilities. These guidelines are lower than the federal limits and are used to help control dose increase and prevent exceeding federal limits.

Airborne Contamination

Radioactive material (contamination) can become suspended in air. Work activities can stir up loose surface contamination. In some cases grinding, sanding and other abrasive techniques can dislodge fixed contamination and cause it to get into the air.

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.

Annual Limit on Intake (ALI)

The amount of airborne radioactive material air 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 breath in to reach the federal limit for either TEDE or CEDE.

ALARA

ALARA is an acronym, meaning As Low As Reasonably Achievable. The purpose of ALARA is to keep the dose of both the individual and group involved with the performance of a task as low as reasonably achievable and still get the task accomplished. This includes internal as well as external dose.

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.

Beta Window

An opening or window used on instruments that detect radiation to allow beta radiation to be measured.

Since beta radiation can easily be stopped by plastic materials, common housings can prevent beta from being measured.

Instruments can then distinguish between the amount of beta and gamma radiation.

Bioassay

Determine the amount of radioactive material by analyzing samples such as fecal material or urine.

Biological Effects

Relating to damage associated with radiation exposure to the human body. Tissue damage, cell death, and mutation are examples of biological effects.

Biological Process

Natural processes of the human body such as elimination of waste products through urination or defecation.

Committed Effective Dose Equivalent (CEDE)

The amount of internal dose that relates organ dose to the whole-body dose.

Chronic Radiation Exposure

A series of small doses spread out over a long period of time, even months or years.

Contamination

Occurs when radioactive *material* gets outside the place it is intended to be. When this happens, the radiation it releases is no longer controlled.

Contamination Control

Preventing the spread of radioactive contamination.

Contamination control programs result in minimal spread of contamination through the facility.

No contamination should leave the radiologically controlled areas.

Contamination Monitor

Various equipment and techniques are used to detect (monitor) contamination. Friskers, tool monitors, and personnel contamination monitors are examples.

Loose contamination must also be monitored. Typically technicians sample for loose surface contamination by rubbing a piece of cloth across the surface being checked and then checking to see how much contamination is on the cloth.

Corrosion Products

Bits of metal and other debris that are carried into the reactor by the flow of water to and around the reactor. When bombarded by high levels of neutron radiation this material becomes "activated" which makes it radioactive.

Counts per Minute

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).

Covered Work

Work activities that are subject to government regulations under 10 CFR 26.

Derived Air Concentration (DAC)

The concentration of radioactive material in air that would result in one ALI if breathed for 2000 hours.

Declared Pregnant

Women who are pregnant have an option for a lower dose limit. To get the lower limit they must declare their pregnancy.

A declared pregnant woman is a women who has stated in writing that she is pregnant.

Discrete Radioactive Particle

Tiny specks of highly radioactive material. These are not thermally "hot" as the term might imply.

A fairly 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.

Delayed Effects

Occur months or years after exposure and may result from acute or chronic radiation exposure.

Example of delayed effects:

Cancer and cataracts are possible delayed effects. The delay in time creates a problem in linking the exposure with the outcome.

Disintegrations per Minute

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).

Dose

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

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.

Dosimeter/Dosimetry

A device used to measure radiation exposure. There are two categories:

- The dosimeter of legal record (DLR)
- The self-reading dosimeter (SRD)

These are normally both used together. The DLR can't be read by the user and has to be sent off to be read. The SRD can be read by the user.

DLRs include the TLD and OSLD
The most commonly used SRD is the electronic alarming dosimeter (EAD).

Dose Limits

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.

Body Part	Dose Limit Rem/Yr.
Whole body (TEDE)	5
Lens of eye	15
Skin	50
Extremities	50
Internal organs	50

Electronic Alarming Dosimeter (EAD)

The Electronic Alarming Dosimeter (EAD) is the most commonly used self-reading dosimeter.

The EAD uses a digital display to indicate your dose and provides an audible alarm when a predetermined dose rate or dose limit is reached.

The EAD provides an approximate dose and is not the legal dose of record (remember, that comes from your TLD or OSLD). EADs measure gamma radiation, but some models also measure beta radiation.

Embryo

The first stage of human development from fertilization of the egg through the 8th week of pregnancy.

NOTE: This is provided to help you understand radiation exposure but is not an objective that you will be tested on.

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).

Fetus

The stage of human development from the eighth week up till the time of birth.

NOTE: This is provided to help you understand radiation exposure but is not an objective that you will be tested on.

Fission

The process of splitting an atom.

Fission Products

Radioactive materials that were created through the fission process. Some radioactive materials in a nuclear plant were created when nuclear fuel fissioned in the reactor. Others are created through activation.

Fixed 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.

Frisker

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

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

Genetic Effects

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

General Public

In this course the term "general public" refers to people who are not nuclear workers. There are limits on how much radiation the general public can be exposed to. This does not include the dose they normally get from nature and other sources.

High Radiation Area

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.

Hiroshima and Nagasaki

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.

Internal Dose

Radiation exposure due to radioactive materials that are inside a person's body.

The source of radiation is inside rather than outside the body. Almost all dose to nuclear workers comes from external sources. Small amounts do result from the inhalation or ingestion of radioactive materials.

Lead Blanket

Lead is used as temporary shielding. Typically it is used to reduce exposure to gamma radiation.

Lead is a hazardous material and difficult to handle and hard to clean up. Most of the time lead blankets are used instead of raw sheet lead.

A lead blanket is lead wool inside of a heavy duty synthetic cover. These are easier to move and can be molded around pipes and other components. They can also easily be cleaned.

Loose 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.

Millirem

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).

Monitor

Measuring and tracking Radiation and contamination levels. A variety of specialized equipment is used for this purpose such as:

- friskers
- tool monitors
- personnel contamination monitors
- dose rate instruments

Millirem

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).

mrem is an abbreviation for millirem.

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.

Nuclear Regulatory Commission (NRC)

The government agency that oversees the nuclear industry. Also referred to as the NRC.

Occupational Dose

Radiation exposure received while working in the nuclear industry. The federal dose limits covered in this training are for occupational exposure.

Protective Clothing (PCs)

Clothing made of cloth, plastic, or paper that is designed to keep radioactive contamination off of people and their own belongings.

Protective clothing is commonly referred to as PC's. 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.

Posting

Signs used to warn or advice personnel of radiological conditions.

Probes

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.

Prompt Effects

Are observed as the result of a large acute dose usually shortly after the exposure.

Nuclear workers do not receive radiation levels that are this high. Plants are designed to keep workers away from areas where this could happen.

Dose limits set by the federal government are also used to ensure this does not occur.

Protective Clothing

Clothing made of cloth, plastic, or paper that is designed to keep radioactive contamination off of people and their own belongings.

Protective clothing is commonly referred to as PC's. 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.

Planned Special Exposure (PSE)

PSEs is an option that could be used in extreme circumstances. These must be planned and have the approval of Sr. Management.

They allow a worker, once in a lifetime, to exceed the federal limits.

Rad

Stands for Radiation Absorbed Dose, and for the purposes of this training is equal to a REM as a measure of radiation.

Radiation

The *energy* that is released when an atom splits is called *radiation*.

Radiation Worker

Any worker who is monitored for dose.

Radiation Work Permit

A permit used to gain access to areas which contain radiation or radioactive material at a high enough level to be monitored and/or controlled.

Radiation work permits are commonly referred to as RWPs. They typically contain information for the worker on protective clothing and other job requirements. Some will also include a summary of the radiological conditions in the area.

Radiation Exposure

Dose. Usually expressed in millirem or rem.

Radiation Area

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.

Radioactive Decay

Process by which unstable atoms give off excess energy by emitting radiation.

Radioactive Material

Anything that contains decaying atoms and is releasing radiation is called *radioactive material.*

Radioactive Materials Area

Is an area in which radioactive material is used, stored, or transferred.

Radioactive Waste

Any materials that must be disposed of and are radioactive. This can include fluids, paper trash, resins and other by products of the nuclear industry.

Radiation Sources

Anything that gives off radiation is said to be the "source" of radiation. That includes pipes, pumps, tanks and other equipment that contains radioactive material.

Radiological Work Practices

Techniques used by nuclear workers to reduce radiation exposure and prevent the spread 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.

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. Sensitivity to radiation is called Radiosensitivity.

Reactor Coolant System (RCS)

Reactor Coolant System

Reactor coolant is simply the water that circulates around the reactor.

Reactor Coolant

The water that flows in and around the reactor.

Rem

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).

Regulatory Controls

The nuclear industry is regulated by the federal government. The government agency that regulates the nuclear industry is the Nuclear Regulatory Commission.

Each utility has written procedures used to implement the government regulations.

Regulatory controls are in place to ensure that the public and nuclear workers are safe.

Respirator

A device used to reduce (not eliminate) the material breathed by the worker. There are many types of respirators. Personnel who wear respirators must successfully complete training on respiratory protection. The training in this module is NOT sufficient.

Radiation Protection (RP) 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.

Some plants will refer to RP as Health Physics (HP).

Radiation Work Permit (RWP)

All work in areas where radiation is a concern is governed by RWPs. Make sure you are signed in to an RWP when entering the plant. Each plant will have its own procedures on use of RWPs.

A Radiation Work Permit contains details concerning a radiologically controlled area.

As a radiation worker, the RWP is one of the most important tools you have available in achieving your ALARA goals.

Shielding

Materials used to reduce or eliminate radiation levels. Typical materials used include lead, water, concrete and steel.

Temporary shielding is often used to reduce gamma radiation levels. The most common type used is the lead blanket.

While gamma radiation can only be reduced it is possible to eliminate beta radiation. Common shielding material for beta includes plastics.

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

Somatic Effects

Occur in the individual who has received the radiation dose.

Stochastic Effects

Effects that occur by chance, generally occurring without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose. In the context of radiation protection, the main stochastic effects are cancer and genetic effects.

TEDE

Stands for "**T**otal **E**ffective **D**ose **E**quivalent". This the total of a person's external dose and internal dose.

Temporary Shielding

Materials used to reduce or eliminate radiation levels. Typical materials used include lead, water, concrete and steel.

Temporary shielding is often used to reduce gamma radiation levels. The most common type used is the lead blanket.

While gamma radiation can only be reduced it is possible to eliminate beta radiation. Common shielding material for beta includes plastics.

Thermoluminescent Dosimeter (TLD)

Thermoluminescent Dosimeters (TLD) are used to provide a permanent record of your occupational radiation dose, but require use of special machines by Radiation Protection to read the radiation dose. TLDs detect and measure dose from beta, gamma, and neutron radiation. The TLD has a window that allows measurement of skin dose from beta radiation.
Other portions of the TLD may be used to measure gamma, neutron, and some penetrating forms of beta radiation.

Ventilation

Air flow in the work area. Permanent and temporary equipment in the plant is used to control ventilation.

This is a powerful tool to reduce or eliminate airborne radioactive materials.

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.

(Note: RAD stands for Radiation Absorbed Dose, and for the purposes of this training is equal to a REM as a measure of radiation)

Whole Body

Whole body dose (NOT whole body counter) for purposes of external exposure does not mean your entire body.

In fact, *whole body* only refers to the head, trunk, gonads, arms above elbows, and legs above knees and does not include internal organs or skin.

Whole Body Counter

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.

Typically workers are given a whole body count at the beginning of employment and at the end. Other reasons may arise while working.

In the following scenario, you will identify 6 potential indications of contamination.

Click on each item you believe indicates an issue with loose surface contamination. If you are using a mobile device, double tap the item.