Course Title: **Radiological Control Technician**
Module Title: **Dosimetry**
Module Number: **2.04**

Objectives:

2.04.01 Identify the DOE external exposure limits for general employees.

2.04.02 Identify the DOE limits established for the embryo/fetus of a declared pregnant female general employee.

☞ 2.04.03 Identify the administrative exposure control guidelines at your site, including those for the:
a. General Employee
b. Member of the Public/Minor
c. Incidents and emergencies
d. Embryo/Fetus

☞ 2.04.04 Identify the requirements for a female general employee who has notified her employer in writing that she is pregnant.

2.04.05 Determine the theory of operation of a thermoluminescent dosimeter (TLD).

2.04.06 Determine how a TLD reader measures the radiation dose from a TLD.

2.04.07 Identify the advantages and disadvantages of a TLD compared to a film badge.

☞ 2.04.08 Identify the types of beta-gamma TLDs used at your site.

☞ 2.04.09 Identify the types of neutron TLDs used at your site.

☞ 2.04.10 Determine the requirements for use of TLDs used at your site.

☞ 2.04.11 Determine the principle of operation, and the types used, for the personnel neutron dosimeters used at your site.

☞ 2.04.12 Determine the principle of operation of self-reading dosimetry (SRD) used at your site.

☞ 2.04.13 Determine the principle of operation, and guidelines for use, for the alarming dosimeters used at your site.

☞ 2.04.14 List the types of bioassay monitoring methods at your site.

2.04.15 List different uses of area monitoring dosimeters.

References:

1. "Basic Radiation Protection Technology"; Gollnick, Daniel; Pacific Radiation Press; 1994.
2. ANL-88-26 (1988) "Operational Health Physics Training"; Moe, Harold; Argonne National Laboratory, Chicago.
3. "DOE Radiological Control Standard" (reference TSP project number SAFT-0039).
4. 10 CFR Part 835 (1998) "Occupational Radiation Protection"

Instructional Aids:

1. Overheads
2. Overhead projector/screen
3. Chalkboard/whiteboard
4. Lessons learned

I. MODULE INTRODUCTION

A. Self Introduction

1. Name
2. Phone number
3. Background
4. Emergency procedure review

B. Motivation

This lesson will introduce the types of instruments used to measure external and internal radiation to people. Dosimetry is the quantitative assessment of radiation received by the human body. There are several types of dosimeters in use worldwide. This material is valuable to all radiological control personnel since dosimeters are the only direct method to measure and document personnel radiation exposure and ensure regulatory compliance with applicable limits.

C. Overview of Lesson

1. Dosimetry terms
2. DOE limits
3. Site administrative guidelines
4. TLDs
5. Site dosimetry
6. Bioassay assessment methods

D. Introduce Objectives

O.H.: Objectives

II. LESSON OUTLINE

A. DOSIMETRY TERMS

Majority from 835.2

Understanding the terminology used in discussing dosimetry and exposure to ionizing radiation is essential for RCTs to do their job.

Refer to the definitions provided in the Study Guide and review terms with class.

1. Absorbed Dose (D)
2. Dose Equivalent (H)
3. Deep Dose Equivalent (DDE)
4. Shallow Dose Equivalent (SDE)
5. Whole Body
6. Extremity
7. Committed Dose Equivalent (CDE)
8. Weighting Factor (W_t)
9. Committed Effective Dose Equivalent (CEDE)
10. Total Effective Dose Equivalent (TEDE)
11. Annual Limit on Intake (ALI)
12. Derived Air Concentration (DAC)
13. Bioassay
14. In Vivo
15. In Vitro
16. Background
17. Declared Pregnant Worker

B. DOE LIMITS	Objective 2.04.01
1. Limits are the legal maximum values stated in 10 CFR 835. To exceed these values is to violate the law. Programs must be in place to ensure that exposures to ionizing radiation are kept below these levels. To accomplish this Administrative Control Levels are selected well below the regulatory limits. These control levels are usually multi-tiered with increasing levels of authority required to approve higher Administrative Control Levels.	
2. Annual dose equivalent limits are based on a calendar year (January 1st through December 31st). For assigning internal dose equivalent received from intakes (CDE and CEDE), the total 50-year committed dose received is assigned to the time of the intake even though the actual dose is proportionally received over the 50-year period.	See Table 2
a. General Employees	10 CFR 835.202
1) Whole body (internal + external) - 5 rems (0.05 sievert)	
2) Lens of the eye - 15 rems (0.15 sievert)	
3) Extremities - 50 rems (0.5 sievert)	
4) Organ or tissue and skin - 50 rems (0.5 sievert)	
b. Minors/Public - 0.1 rem (0.001 sievert)	10 CFR 835.207 & .208
c. Embryo/Fetus of Declared Pregnant Workers - 0.5 rems (0.005 sievert) per gestation period	10 CFR 835.206 Objective 2.04.02
d. Emergency Exposures	10 CFR 835.1302
e. Planned Special Exposures	10 CFR 835.204
C. SITE ADMINISTRATIVE GUIDELINES	
1. Radiological Workers	Objective 2.04.03.a
(Insert site specific information here)	

2. Non-Radiation Worker — Objective 2.04.03.b

   (Insert site specific information here)

3. Exposure from Incidents or Emergencies — Objective 2.04.03.c

   (Insert site specific information here)

4. Embryo/fetus — Objective 2.04.03.d

   (Insert site specific information here)

D. TYPES OF DOSIMETRY

1. As a result of irradiation, some solid substances undergo changes in some of their physical properties.

2. These changes amount to storage of the energy from the radiation.

3. Since the energy is stored, these materials can be used for dosimeters. The features that have been studied include:

   a. Optical density changes

      1) Optical density changes involve a change in the color of some types of plastics and glass.

      2) In glass, the dose range is 10^3 to 10^6 rads (10 to 10^4 gray). The range for plastics is 10^6 to 10^9 rads (10^4 to 10^7 gray).

      3) An example, film badges, provides low range, 10 mR to 10 R, for personnel and high range, 1 R to 1,000 R for accident readings.

   b. Thermoluminescence

      1) Thermoluminescence (TL) is the ability of some materials to convert the energy from radiation to a radiation of a different wavelength, normally in the visible light range.

      2) There are two categories of thermoluminescence.

a) Fluorescence - This is emission of light during or immediately after irradiation (within fractions of a second) of the phosphor. This is not a particularly useful reaction for TLD use.

Example - TV or computer monitor screen

b) Phosphorescence - This is the emission of light after the irradiation period. The delay time can be from a few seconds to weeks or months. This is the principle of operation used for thermoluminescent dosimeters.

3) The property of thermoluminescence of some materials is the main method used for personnel dosimeters at DOE facilities and will be discussed in further detail.

E. TLD OPERATION

1. TLD's use phosphorescence as their means of detection of radiation.

Objective 2.04.05

2. Electrons in some solids can exist in two energy states, called the valence band and the conduction band. The difference between the two bands is called the band gap.

3. Electrons in the conduction band or in the band gap have more energy than the valence band electrons.

4. Normally in a solid, no electrons exist in energy states contained in the band gap. This is a "forbidden region."

5. In some materials, or if impurities are added, defects in the material exist or are made that can trap electrons in the band gap and hold them there. These trapped electrons represent stored energy for the time that the electrons are held. This energy is given up if the electron returns to the valence band.

See figure 1 - "Electron Entrapment"

6. In most materials, this energy is given up as heat in the surrounding material, however, in some materials a portion of energy is emitted as light photons. This property is called luminescence.

See figure 2 - "Thermoluminescence"

F. TLD Reader — Objective 2.04.06

1. Basic principle of operation

   a. Heating of the TL material causes the trapped electrons to return to the valence band. When this happens, energy is emitted in the form of visible light.

   b. The light output is detected and measured by a photomultiplier tube and a dose equivalent is then calculated.

   c. A typical basic TLD reader contains the following components: — See figure 3 - "TLD Reader"

      1) Heater

      2) Photomultiplier tube

      3) Meter/recorder

2. Glow curve — See figure 4 - "Glow curve"

   a. Obtained from heating process.

   b. The light output from TL material is not easily interpreted. Multiple peaks result.

      1) As the material is heated, electrons trapped in "shallow" traps are released. This results in a peak as these traps are emptied. The light output drops off as these traps are depleted.

      2) As heating continues, the electrons in deeper traps are released. This results in additional peaks. Usually the highest peak is used for calculations. The area under the curve represents the radiation energy deposited.

   c. After the readout is complete, the TLD is annealed at a high temperature. This process essentially zeroes the TL material by releasing all trapped electrons. The TLD is then ready for reuse.

G. ADVANTAGES AND DISADVANTAGES OF TLDs	Objective 2.04.07
1. Advantages (primarily as compared to film badges)	
a. Able to measure a greater range of doses.	
b. Doses may be easily obtained.	
c. They can be read on site instead of being sent away for developing.	
d. Quicker turnaround time for readout.	
e. Reusable.	
2. Disadvantages	
a. Each dose cannot be read out more than once.	
b. The readout process effectively "zeroes" the TLD.	
H. SITE BETA/GAMMA TLDs	Objective 2.04.08
(Insert site specific information here)	
I. SITE NEUTRON TLDs	Objective 2.04.09
(Insert site specific information here)	
J. DOE EXTERNAL DOSIMETRY GENERAL PROVISIONS	10 CFR 835
1. Dosimetry shall be provided to and used by:	
a. General employee expected deep dose equivalent > 0.1 rem (0.001 sieverts); or > 10% of limits for extremities, organs, and other tissues.	
b. Declared pregnant worker expected to receive 0.05 rem (0.0005 sievert) or more during the gestation period.	
c. Minors likely to receive 50% of Occupational Dose Limits or more in a year.	

d. Public entering controlled areas likely to receive external deep dose equivalent of 0.05 rem (0.0005 sievert) or more in one year.

e. Individuals entering a high or very high radiation area.

2. Neutron dosimetry provided when applicable threshold is likely to exceeded due to neutron radiation.

3. Issued to individuals knowledgeable of proper use and worn only by assignee.

4. Issuance of dosimeters should be discouraged for individuals other than those where there is a likelihood of being occupationally exposed to levels above monitoring thresholds.

5. Dosimeters should be returned at required intervals. Individuals not returning dosimeters should be restricted.

6. Primary dosimeters should be worn on the chest area or between the waist and the neck.

7. Individuals should not be assigned multiple primary dosimeters during different periods of the dosimeter process year (exchange of primary dosimeter for multi-badging is acceptable); and avoid exposure of dosimeter to non-occupational sources.

8. When dosimeters are lost, damaged, or contaminated, the individual should place work in a safe condition, exit and notify the RCO. Reenter only after review and approval.

K. SITE REQUIREMENTS FOR USE OF TLDs — Objective 2.04.10

(Insert site specific information here)

L. SITE PERSONNEL NEUTRON DOSIMETERS — Objective 2.04.11

(Insert site specific information here)

M. POCKET AND ELECTRONIC DOSIMETERS

1. Provide real time dose indication.

2. Shall be issued for entry into High or Very High Radiation Area.

3. Should be issue when planned activity levels exceed 0.05 rem (0.0005 sievert) or 10% of control levels.

4. Should be issued when required by RWP.

5. Worn with primary dosimetry and located on chest area, on or between the waist and the neck.

6. Should be read periodically and should not exceed 75% of full scale.

7. Authorized work should cease when supplemental dosimeter indicates total dose or dose rate is > than expected.

8. When supplemental dosimeters differ by more than 50% from primary dosimeters and the primary result is >0.1 rem (0.001 sievert), an investigation should be initiated.

N. SITE SELF-READING DOSIMETERS

(Insert site specific information here)

Objective 2.04.12

1. Self Reading Pocket Dosimeters (SRPD)

See figure 5 - "SRPD"

a. Direct reading ion chamber.

Note: SRPDs with steel walls are usually insensitive to beta and low energy gamma

b. Utilizes two electrodes:

1) Fiber electrometer (fixed and moveable components)

2) Metal frame

c. As chamber is ionized the charge is decreased on the movable and fixed fiber.

d. The movement of the fiber is proportional to the dose received.

See figure 6 -"SRPD Reading"

O. SITE ALARMING DOSIMETRY

(Insert site specific information here)

Objective 2.04.13

P. INTERNAL DOSIMETRY REQUIREMENTS

Re-enforce difference between "internal" and "external" dose

1. Internal dose evaluation programs shall be conducted for:

10 CFR 835.402

   a. General employees - likely to receive 0.1 rem (0.001 sievert) or more CEDE.

   b. Declared pregnant workers - likely to receive an intake resulting in dose equivalent of 10% of the limit (or 0.05 rem [0.0005 sievert]).

   c. Minors - likely to receive a CEDE in excess of 50% of limit (or 0.05 rem [0.0005 sievert]).

   d. Public - likely to receive a CEDE in excess of 50% of limit (or 0.05 rem [0.0005 sievert]).

2. Estimation shall be based on bioassay results rather than air concentration values unless air concentration values are more reliable or bioassay results are unavailable.

3. Follow-up bioassay monitoring is typically required when results indicate a committed effective dose equivalent of 0.1 rem (0.001 sievert) or more.

4. A bioassay program should be considered for personnel routinely exposed to surface or airborne contamination or to radionuclides readily absorbed through the skin.

5. Personnel are required to submit bioassay samples.

6. Personnel shall be notified of positive bioassay results.

Q. BIOASSAY ASSESSMENT METHODS

1. General

a. Today's technology has not produced a device that allows accurate determination of internal exposure following the entry of radioactive materials into the body.

b. The method that is used to determine internal dose contributions relies on calculation of dose to affected portions of the body based on the quantities of radioactive materials in the body. Thus, the real problem becomes one of quantifying the amount of material present.

c. Bioassay is the term that is used to describe the assessment of the quantity of radioactive material present in the body. There are currently two types of bioassay measurements employed in nuclear industries:

1) In vivo - analysis of living tissue.

2) In vitro - analysis of excreted samples.

d. Bioassay programs are designed to fulfill two needs:

1) Evaluate effectiveness of contamination control practices.

a) Routine bioassay programs utilize submission and analysis of samples from workers in facilities where the likelihood of intake exists.

b) Primarily limited to urinalysis due to ease of sample collection.

c) Also includes initial, routine, and termination whole body counts.

2) Evaluate potential consequences of accidental inhalation or ingestion of large quantities of radioactive materials.

a) Can involve all types of bioassay measurements with collection and analysis of nasal, urine, and fecal samples.

b) Whole body counts provide immediate indications for given radionuclides if individual(s) involved are free of external contamination.

2. In vivo measurements

a. The amount of materials is estimated by counting radiation emitted by radioactive materials in the body.

b. Only good for radioactive materials which emit gamma radiation of sufficient abundance and energy to be detected and statistically measured.

c. With use of expensive, sophisticated spectroscopy, most contributors (radionuclides present) can be identified.

d. Site In vivo methods

(Insert site specific information here) Objective 2.04.14

e. Advantages

1) No sample required.

2) Results obtained quickly.

3) Some equipment design allows field use.

4) Time and manpower requirements minimized.

f. Disadvantages

1) Limited to detection and measurement of gamma emitters.

2) Individual must be free of external contamination.

3) Long count times for identification.

4) Effects of background.

5) Complex calibration procedure and calibration equipment.

6) Expense.

7) Quantification error due to differences in tissue structure from one person to another as compared to calibration phantom.

3. In Vitro Measurements

a. The amount of material present in the body is estimated using the amount of materials present in excretions or secretions from the body.

b. Samples include urine, feces, blood, sputum, saliva, hair and nasal discharges.

c. Calculation requires knowledge of and use of metabolic models which allow use of activity in samples to be related to activity present in the body.

d. Resulting dose calculations to quantify committed and effective dose equivalents are estimates.

1) This is due partly to use of default values for measurements that cannot be readily made such as mass of particular organs, volumes of particular fluids, etc., in lieu of actual values for individual involved. Remember that reference man is an average.

2) Another contributing factor is different metabolism from one individual to another.

e. Types of analysis

1) Urinalysis - indicates intake of primarily soluble material.

2) Fecal analysis - primarily indicates intake of insoluble material. Provides relatively rapid indication.

3) Sputum - may contain insoluble material initially deposited in the lung and later eliminated by ciliary action.

4) Saliva - may be use to estimate uptake of tritium oxide.

5) Nasal discharge - indication of the deposition of the coarsest inhaled particles in the nose.

f. Site in vitro methods

(Insert site specific information here) Objective 2.04.14

g. Advantages of in vitro measurements

1) Can be used for estimation of neutron doses using activation product concentration in hair and blood (^{32}P and ^{24}Na).

2) Can be used to quantify presence of materials which decay by alpha and beta emission to allow detection and measurement with external detector systems.

h. Disadvantages

1) Requires sample submission and analysis.

2) Time and manpower requirements.

3. Bioassay Scheduling Program

a. Contamination found at a given site will depend on the materials that are used and produced at the site. Thus, the materials that internal dosimetrists are primarily concerned with will change from one site to another as well.

b. Baseline/Routine/Exit Evaluations

(Insert site specific information here)

c. Special Evaluations

(Insert site specific information here)

d. Investigation Levels

(Insert site specific information here)

e. Medical Uses

(Insert site specific information here)

R. AREA MONITORING DOSIMETERS

Objective 2.04.15

1. Area monitoring dosimeters are often used to record and document radiation levels in routinely occupied areas adjacent to areas where radiation or radiological operations exist.

   Note: This type of monitoring does not apply when the radiation hazard of concern arises from low-energy beta sources (e.g., 14C, 3H).

2. Establishment and maintenance of a comprehensive area monitoring program can demonstrate that doses outside Radiological Buffer Areas are negligible, and help to minimize the number of areas requiring the issuance/use of personnel dosimeters.

   Minimizing the number of personnel dosimeters issued saves in the costs of operating the dosimetry program and reduces costs associated with maintaining personnel with enhanced training and qualifications.

3. Area monitoring dosimeters are also used to help characterize workplace conditions to verify the effectiveness of physical design features, engineering controls, and administrative controls. In addition, area monitoring dosimeter results can be used to support dosimetry investigations where personnel express concerns about their work environments and exposure to ionizing radiation.

4. Finally, area (and equipment) monitoring dosimeters are useful for the determination of dose rates and/or integrated doses for:

a. equipment and/or areas with suspected high dose rates;

b. devices emitting pulsed radiation not accurately measured with portable survey instruments;

c. highly collimated beams of radiation; and

d. radiological incidents.

III. SUMMARY

A. Review major topics

1. Dosimetry terms

2. DOE limits

3. Site administrative guidelines

4. TLDs

5. Site dosimetry

6. Bioassay assessment methods

B. Review learning objectives

IV. EVALUATION

Evaluation shall consist of a written examination comprised of multiple choice, fill-in the blank, matching and/or short answer questions. 80% shall be the minimum passing criteria for examinations.