U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

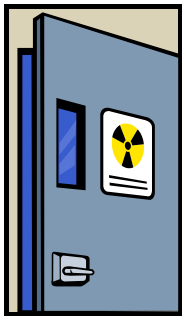
HRTD
Human Resources
Training & Development

Chapter 3:

Radiation Protection Standards & Guides

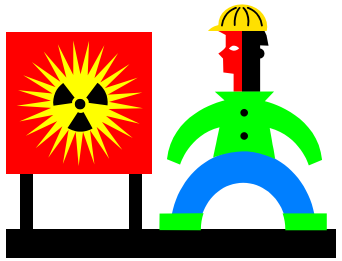
Objectives:

- Describe regulations governing occupational radiation exposure to personnel and minors, or dose limits to members of the general public.
- State the meaning of DDE, EDE, CDE, W_t, CEDE, SDE, TEDE, and TODE.
- Explain the requirements for Planned Special Exposures and associated annual and lifetime dose limits.
- Discuss the requirement to keep occupational radiation exposure As Low As Reasonably Achievable (ALARA).

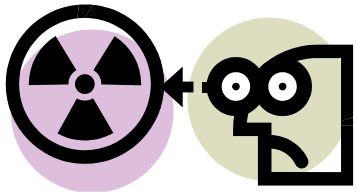


Objectives:

- Describe exposure control areas, corresponding warning signs and state the permissible radiation/radioactivity levels for radiation area, high radiation area, very high radiation area, airborne radioactivity area, and radioactive materials area.



- Discuss recommendations concerning emergency exposure.



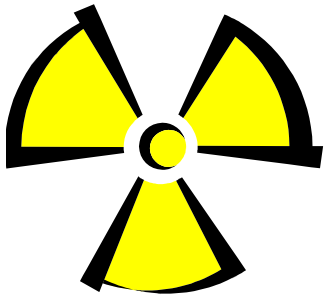
- Discuss regulations governing prenatal radiation exposure.

- Identify the purpose of NRC Forms 3, 4, & 5.

Dose Limit Requirements

The occupational dose limits are established in 10 CFR Part 20 for NRC licensees.

The occupational dose limits for NRC employees are established in Management Directive 10.131. The limits in this document are comparable to those in 10 CFR Part 20.

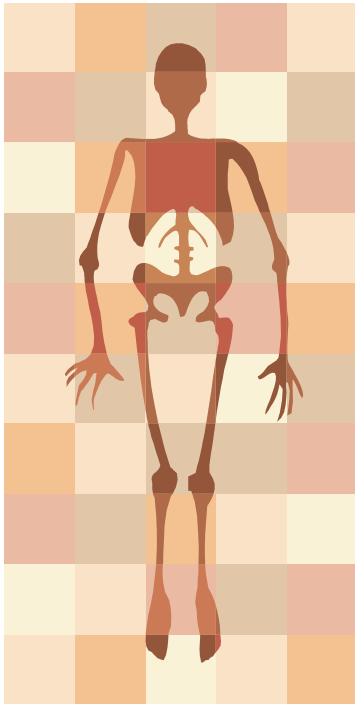


Dose Limits - General

Rad standards for workers are expressed as whole-body dose equivalents. In reality, the body is rarely uniformly irradiated; certain parts of the body/organs are often more affected than others. This is because activity taken into the body is distributed unequally among organs (e.g., radioactive iodine concentrates in the thyroid, inhaled plutonium mainly affects the lungs, and strontium goes to in bones). In addition, it is possible that only a portion of the body might be exposed to an external radiation source.

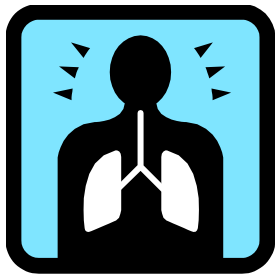
Dose Limits - Organs

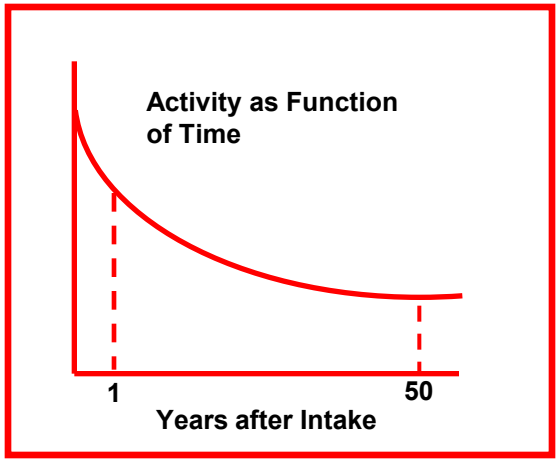
- Organ Dose Limits - objective is avoid harm to organs (deterministic) that would impair their function.
- Total Dose = External Dose + Internal Dose
- External - dose at 1 cm depth in tissue, called the DEEP DOSE EQUIVALENT (DDE).
- Internal – dose from internally-deposited radionuclides is called the COMMITTED DOSE EQUIVALENT. The CDE is determined for a 50-year interval and assigned to the year of intake.



The Committed Dose Concept

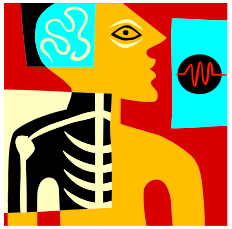
The dose from internally deposited radionuclides is based on the "Committed Dose" concept. This concept assigns the dose over a 50 year interval to the year of intake. For a short lived radionuclide, such as I-131 with an 8 day half-life, most likely all the dose will actually be received during the year of intake. For other radionuclides, such as Am-241 with a half-life of about 432 years, there may be dose received even after the 50 year interval.

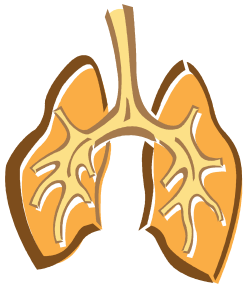




Dose Limits - Organs

- **Total Organ Dose Equivalent (TODE) limit is 50 rem per year to organs of the body from internal and external exposure (at a depth of 1 cm in tissue).**





- **TODE = DDE + CDE**

- **TODE $\leq$ 50 rem in a year**

Dose Limits – Whole Body

- **Total Effective Dose Equivalent (TEDE) limit is 5 rem per year to the whole body from internal and external exposure (at a depth of 1 cm in tissue).**
- **TEDE = EDEX + CEDE**
- **CEDE = CDE x W_T**
- **W_T is the "weighting factor" that relates the risk of dose to an individual organ to risk of dose to the whole body.**

Dose Limits - Whole Body

- 10CFR20 defines TEDE as “the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (CEDE) (for internal exposures).”
- However, EDEX cannot be directly measured.
- Use of DDE generally provides a conservative and best estimate of EDEX.
- In non-uniform fields (e.g., directional source), DDE can be overly conservative. Use of an approved method (e.g., 2-dosimeter) to calculate EDEX is allowed per RG 8.40. Part 20 also says that DDE be measured at the part of the body with the highest dose.

Weighting Factors (W_T) for Organs

A multiplier used to determine effective dose from equivalent dose in one/more organs/tissues. The factor takes account of the sensitivities of different organs/ tissues for induction of stochastic effects from exposure to ionizing radiation (principally induction of cancer).

Organ/Tissue	W_T*
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone Surfaces	0.03
Colon	-
Stomach	-
Bladder	-
Esophagus	-
Liver	-
Skin	-
Remainder**	0.30

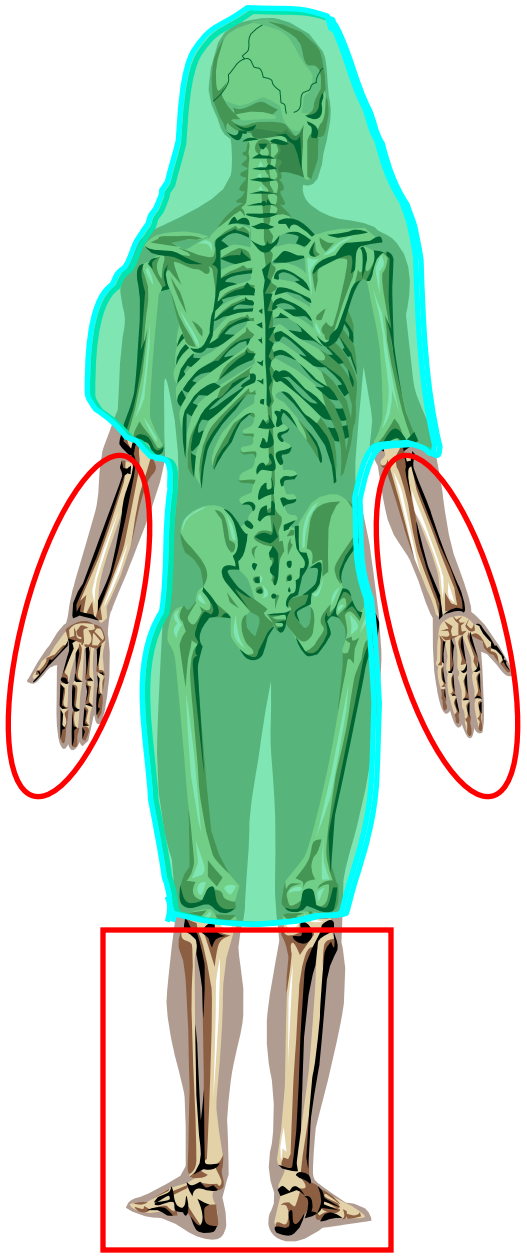
*From ICRP 26 **Five highest organs

Skin, Extremities & Whole Body

Whole Body -
everything except extremities

Skin of the Whole Body -
skin covering everything except the extremities

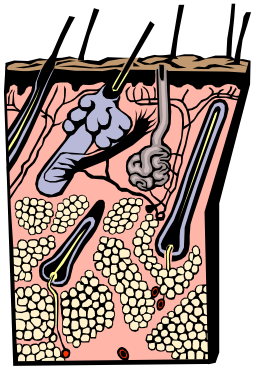
Extremities -
elbows and arms below elbows
knees and legs below knees



Dose Limits - Special Limits

- **Lens Dose Equivalent (LDE) - 15 rem per year to the lens of the eye from external radiation (measured as 0.3 cm depth in tissue).**

- **Shallow Dose Equivalent (SDE) - 50 rem per year (0.007 cm depth in tissue) to skin of the whole body or to the extremities (SDE_{ME}, SDE_{SKIN}) averaged over 10 cm^2.**



Occupational Dose Limits - Minors

- **The ANNUAL occupational dose limits for minors is 1/10th of the adult occupational dose limit:**
  - **TODE ≤ 5 rem**
  - **TEDE ≤ 0.5 rem**
  - **LDE ≤ 1.5 rem**
  - **SDE ≤ 5 rem**

Dose Limits – Members of the Public

- **The dose limits to members of the public (excluding dose from background radiation and medical exposure) are:**
  - **≤ 100 mrem TEDE in a year; and**
  - **≤ 2 mrem in <u>any one hour</u> in an unrestricted area from external sources.**

10CFR20.1301

There are other public limits out there for EPA, etc. that are different. For example:

40CFR190: 25 mr/yr

Dose Limits – Members of the Public

- If the dose rate is 12 mrem/hr, but the source is only "exposed" for 10 minutes, the dose in any one hour would be:

  (12 mrem/hr)(1 hr/60 min)(10 min) = 2 mrem

- The dose rate in this example is up to 12 mrem/hr. However, the time that the source is used which could result in a dose to the public is limited so that in any one hour the public dose would not exceed 2 mrem.

Planned Special Exposures (PSEs)

- **In addition to the annual adult occupational limits, planned special exposure (PSE) limits are established to allow additional dose in special situations. PSE's are doses that are in addition to annual occupational dose.**
- **The licensee must comply with the provisions of a PSE:**
  - **Must be a special situation with written plan in advance of the work**
  - **Must not be routine work**
  - **Person involved must be informed about radiological conditions & ways to maintain dose "as low as reasonably achievable" (ALARA)**
  - **Person must have their complete dose history**
  - **Must maintain records**
  - **Must inform people involved of their dose within 30 days**
  - **Must notify the NRC regional office**
  - **Doses must not exceed PSE dose limits.**

Planned Special Exposures (PSEs)

PSE dose limits are:

- **Equal to annual occupational dose limits in any year; &**
- **Not to exceed 5X the annual limits in person's lifetime.**

Organ	Annual	PSE-Ann	PSE- Life
TEDE	5 rem	5 rem	25 rem
TODE	50 rem	50 rem	250 rem
LDE	15 rem	15 rem	75 rem
SDE	50 rem	50 rem	250 rem

See Regulatory Guide 8.35 for more information on PSEs.

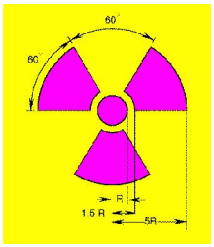
Dose History

- Dose is reported to worker if it exceeds 100 mrem TEDE or 100 mrem to any individual organ/tissue, or if it is requested (10CFR19.13).

- NRC Form 4 is "Cumulative Occupational Dose History" – you will find the terms you've learned in this chapter when you receive one of these reports, i.e., DDE, CDE, CEDE, LDE, SDE, TEDE, TODE. Note that these records include PSE doses as well as routine annual occupational dose information.

- NRC Form 5 is "Occupational Dose Record for a Monitoring Period." Typically a monitoring period is a year. It could be less if you were at a site and used dosimetry from the site. It has the same alphabet soup terminology above, plus some additional terms – the "intake," class and mode.

Signs and Posting



The licensee shall post the area with a conspicuous sign or signs bearing the radiation symbol and the words:

- Radiation Area > 5 mrem/hour @ 30 cm (from the source or any surface that it penetrates): "CAUTION, RADIATION AREA."
- High Radiation Area > 100 mrem/hour @ 30 cm: "CAUTION, HIGH RADIATION AREA" or "DANGER, HIGH RADIATION AREA."
- "Locked High Radiation Area," > 1,000 mrem/hr; this is a Technical Specification designation.
- Very High Radiation Area > 500 rads/hour @ 1 m: "GRAVE DANGER, VERY HIGH RADIATION AREA."

High and Very High Radiation Areas

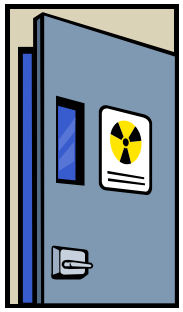
- **Access to High Radiation Areas and Very High Radiation Areas is required to be controlled. The controls must either:**

  (1) limit the dose rate to less than 100 mrem/hr;

  (2) provide a conspicuous visible or audible alarm so that the person entering the area and the supervisor of the operation are aware of the entry; or

  (3) entry ways are locked with positive access control over each individual entry.

- **Inadvertent or unauthorized access to Very High Radiation Areas is to be prohibited by licensee-instituted controls.**



Signs and Posting

- **Radioactive Material Area – where more than 10 times the activity in 10 CFR 20 Appendix C is stored, "CAUTION, RADIOACTIVE MATERIAL(S)," or "DANGER, RADIOACTIVE MATERIAL(S)."**

Nuclear Regulatory Commission

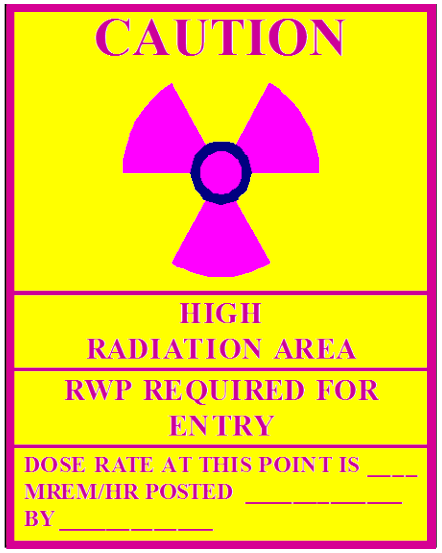
APPENDIX C TO PART 20—QUANTITIES[1] OF LICENSED MATERIAL REQUIRING LABELING

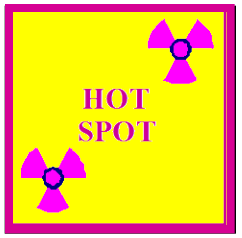
Radionuclide	Quantity (μCi)
Hydrogen-3	1,000
Beryllium-7	1,000
Beryllium-10	1
Carbon-11	1,000
Carbon-14	100
Fluorine-18	1,000
Sodium-22	10
Sodium-24	100
Magnesium-28	100
Aluminum-26	10
Silicon-31	1,000
Silicon-32	1
Phosphorus-32	10
Phosphorus-33	100
Sulfur-35	100
Chlorine-36	10
Chlorine-38	1,000
Chlorine-39	1,000
Argon-39	1,000
Argon-41	1,000
Potassium-40	100
Potassium-42	1,000
Potassium-43	1,000

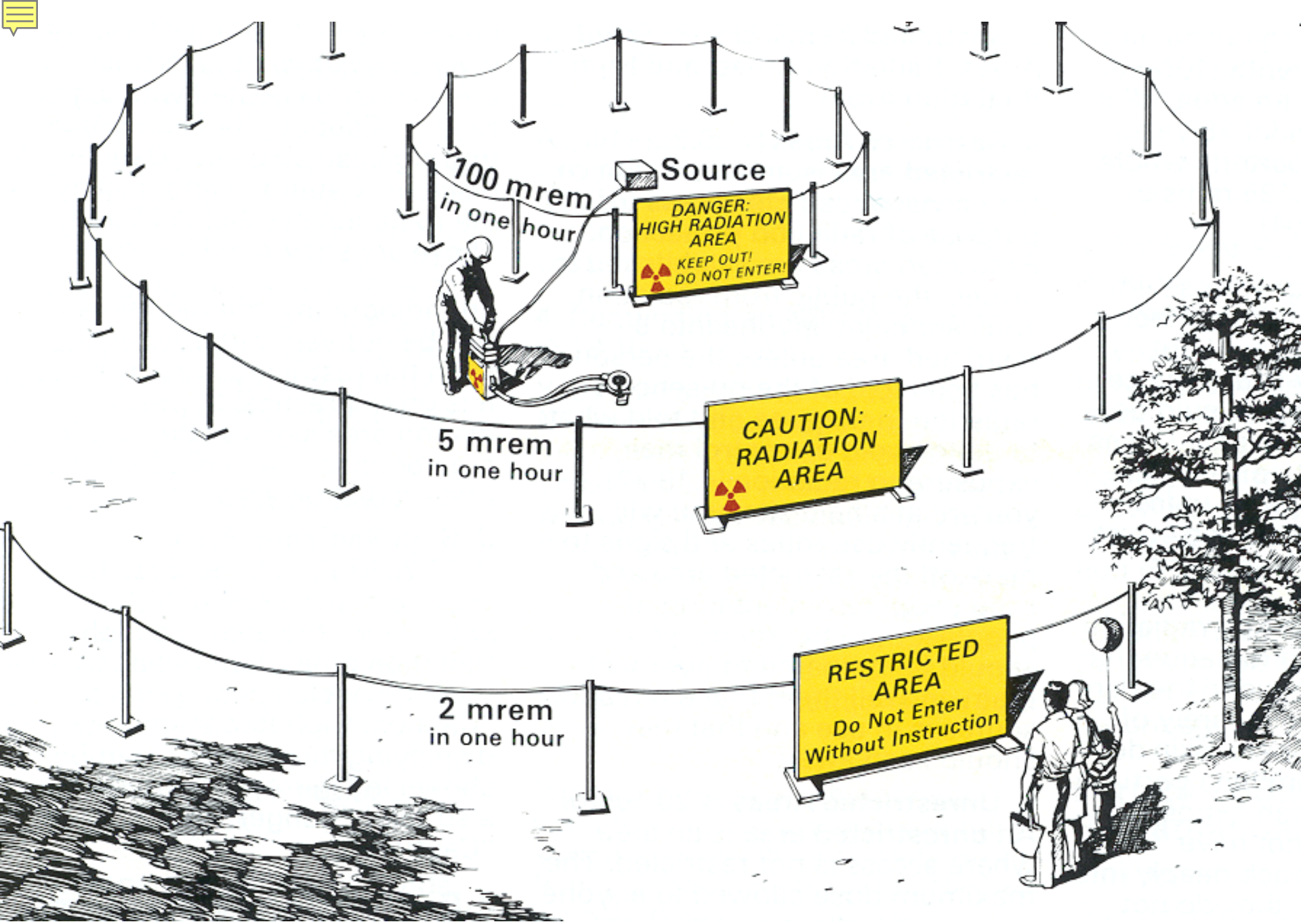
Signs and Posting

- **Airborne Radioactivity Area – the airborne concentration is more than 1 DAC or, where an individual present without respiratory protection equipment could exceed, during the hours an individual is present in a week, an intake of 0.6% ALI or 12 DAC-hours (30% of a DAC):**
- **"CAUTION, AIRBORNE RADIOACTIVITY AREA" or**
- **"DANGER, AIRBORNE RADIOACTIVITY AREA."**

Signs & Posting





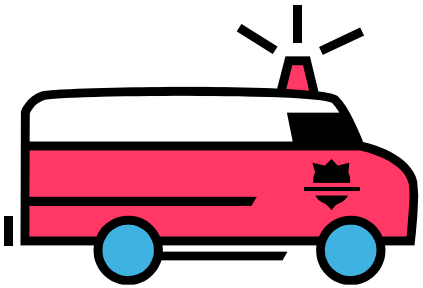

100 mrem
in one hour
Source
DANGER:
HIGH RADIATION
AREA
KEEP OUT!
DO NOT ENTER!
5 mrem
in one hour
CAUTION:
RADIATION
AREA
2 mrem
in one hour
RESTRICTED
AREA
Do Not Enter
Without Instruction

Dosimetry

- Regulations require that you wear dosimetry, that is a device that measures your dose, if you enter either a:
  - High Radiation Area, or a
  - Very High Radiation Area.
- If you are not going to enter either of these areas and your dose in a year is not likely to exceed 10% of the dose limits, then you are not required to wear dosimetry BY REGULATION.
- It is a common practice, though, for plants to issue dosimetry to personnel for entry into ALL radiation areas.

Guidance on Dose Limits for Workers Performing Emergency Services

Lifesaving or protect large population: if > 25 Rem; only on a voluntary basis to persons informed of risk, select health individuals, preferably age > 45.



Lifesaving or protect large populations: up to 25 Rem (without informed consent) when lower dose not practicable.

Protection Valuable Property: up to 10 Rem when lower dose not practicable or by PSE if time permits.

Recovery of Deceased Victims – 5 Rem or by PSE.

Ref: Handbook 10.131; EPA 400-R-92-001, May 1992

Review

- The annual adult occupational dose limits are: 5 rem TEDE; 15 rem LDE; 50 rem SDE(skin, ME); 50 rem TODE. Limits for minors are 1/10th the adult limits. The limit for a DPW is 0.5 rem @ 50 mrem/month.

- TODE = DDE + CDE
- TEDE = EDEX + CEDE
  - CEDE = CDE x Wt

- PSE limits are:
  - Annually – equal to annual dose limits per requirements;
  - Lifetime – equal to 5 times the annual dose limits.
- NRC dose limits for NRC personnel are in MD 10.131.
- Dose limits for licensees and NRC contract personnel are in 10 CFR Part 20 (and other places such as 40CFR190).

Review

- Area designations are:
  - Radiation Area, > 5 mrem/h @ 30 cm;
  - High Radiation Area, > 100 mrem/h @ 30 cm;
  - Very High Radiation Area > 500 rads/h @ 1 m;
  - Radioactive Materials Area > 10 times Appendix C levels;
  - Airborne Radioactivity Area – more than 12 DAC-hours in 40 hr. work week (0.3 DAC), or concentration > 1 DAC.
- Access is controlled for High Radiation Areas and VHRAs. In plants LHRA is > 1 rem/hr per Techical Specifications.
- BY REGULATION, dosimetry is required:
  - For entry into High Radiation or VHRA's, or
  - If it is likely you will exceed 10% of the limits in a year (500 mrem).

Population	Annual Dose Limit
Adult Worker	5 REM TEDE 50 REM TODE 15 REM LDE (lens of eye) 50 REM SDE (extremities/skin)
Minor Worker	0.5 REM TEDE 5.0 REM TODE 1.5 REM LDE (lens of eye) 5.0 REM SDE (extremities/skin)
Member of Public	100 mREM (only 10 mR airborne)
Embryo/Fetus of DPW	500 mREM during entire gestation