Radiation Protection of Occupationally Exposed Personnel

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MI Program

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NCRP Occupational Exposure Limits Review

- Annual Effective Dose
  - 50 mSv (5 rem)
  - Does not include medical or background radiation exposure
- Cumulative Effective Dose
  - Age in years X 10 mSv (Age in years X 1 rem)

NCRP National Council on Radiation Protection & Measurements
Report #116

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ALARA

- Concept:
  - As Low As Reasonably Achievable
    - Collimate
    - Technique
    - Shielding
    - Minimize repeats

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Reduce Your Exposure

- Avoid repeats
- Collimation
- Cumulative Timer
- Highest exposures are in fluoro, portables and OR
- Stand 90 degrees from the patient
  - Patient is a source of scatter radiation
  - **3 feet from the patient (1 meter), the scatter radiation is approx. 1/1000 the intensity*
- Filtration
  - Non useful low energy photons are removed, less scatter

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Reduce Your Exposure

- Protective apparel
  - Lead aprons and barriers
- Exposure factors
  - Controls scatter
- Correct processing
  - Reduces repeats
- High speed image receptors
  - High speed systems use smaller exposures which causes less scatter
- Beam limiting devices
  - Reduces scatter

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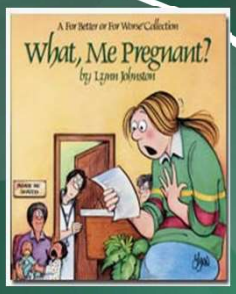
Protection of Pregnant Personnel

- Should be able to continue their duties without interruption of employment
- Voluntary declaring vs. not declaring
- After declaring
  - counseling
  - second "baby badge" is issued worn at waist level
- To reduce risk of leukemia or other malignancies
  - 0.5mSv (0.05rem) in one month
  - 5mSv (0.5rem) for the entire pregnancy
- Must read and sign a form acknowledging counseling
- If wearing a lead apron the badge is worn inside the apron at waist level
- Baby badge has a separate reading on the dose report
- Maternal tissue decreases fetus dose by 30%
- Work schedule rotation
  - Does not necessarily have to be done



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Types of Radiation

- Primary radiation- useful beam
  - Emerges directly from the tube collimator
- Scatter radiation- highest dose to technologist
  - Primary beam passes through matter and goes in various directions
- Leakage radiation
  - Escapes the tube housing

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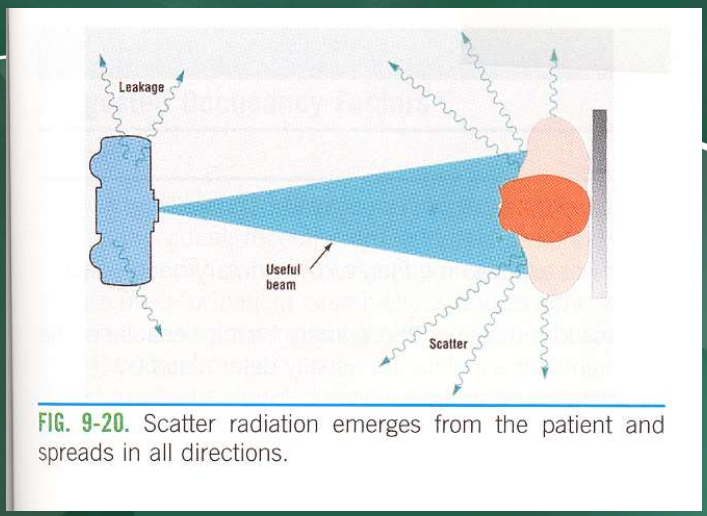

FIG. 9-20. Scatter radiation emerges from the patient and spreads in all directions.

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Protective Structural Shielding

- Usually lead or concrete
- Barriers
  - Primary Protective Barrier
  - Secondary Protective Barrier

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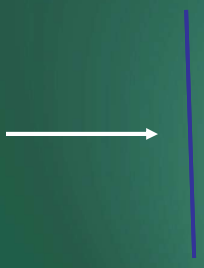
Primary Protective Barrier

- Located perpendicular to primary beam travel (beam can directly hit)
- Prevents direct or unscattered radiation from reaching personnel and general public
- For 130 kVp of peak energy a 1/16 inch (~1.6mm) of lead or lead equivalent and extends 7 feet (2.1 m) upward from the floor if the tube is 5-7 feet from the wall (1.5-2.1 m)



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Secondary Protective Barrier

- Any wall or barrier that is never hit by the primary beam
- Protects against scatter and leakage radiation
- 1/32 inch of lead or lead equivalent (~0.8mm)
- Overlaps the primary barrier by ½ inch (~1.3 mm) and extends to the ceiling
- The control booth is regarded as a secondary barrier
  - Technologist must remain behind the booth
  - The exposure cord length must be short enough that the technologist must remain behind the booth to take the exposure
  - Window is 1.5mm of lead equivalent

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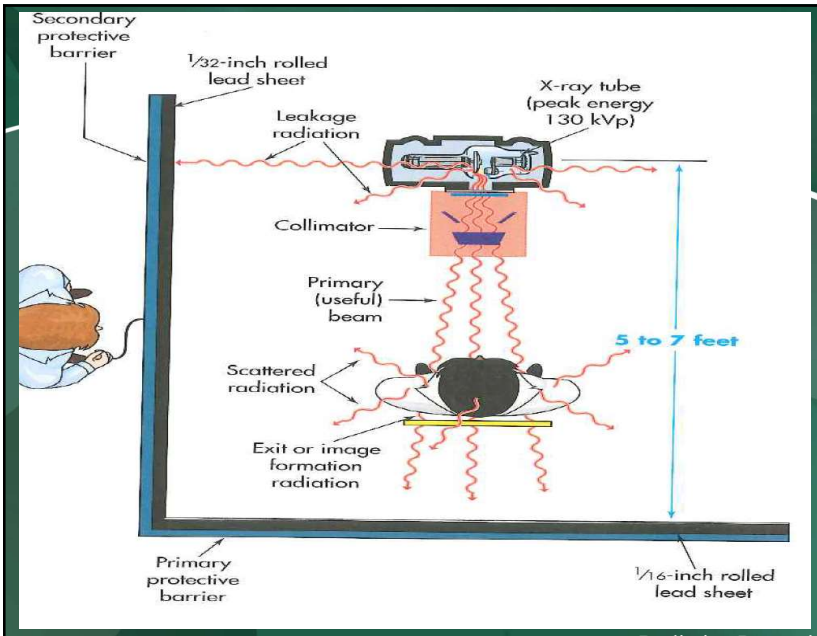

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Protective Device Requirements

- Lead Apron
  - Older guidelines state minimum of 0.25mm lead (Pb) (CFR20)
  - Newer guidelines state 0.5mm lead (Pb) for fluoroscopy, AIR, or operating systems above 100kVp (NCRP #102)
    - Protects from 95-99% of scattered radiation
- Gloves
  - 0.25mm lead (Pb)
- Neck & Thyroid
  - Must be at least 0.5mm lead (Pb)
- Protective Eyeglasses
  - Contains lead to protect the eyes (Pb)

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TABLE 13-1 Physical Attributes of Protective Lead Aprons

Percentage X-Ray Attenuation

Lead Equivalent Thickness (mm)	Weight (kg)	Kilovolts at Peak 50	75	100
0.25	1-5	97	66	51
0.50	3-7	99.9	88	75
1.00	5-12	99.9	99	94

At 100 kVp, x-ray attenuation for a 0.50-mm lead equivalent apron and a 1-mm lead equivalent apron is 75% and 94%, respectively.

Modified from Bushong SC: *Radiologic science for technologists: physics, biology and protection,* ed 10, St. Louis, 2013, Mosby.

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Protective Tube Housing

- Lead lined metal that protects personnel and patients from leakage and off focus radiation
- Cannot exceed 1 mGy per hour at 1m away from housing
- No one should be touching the x-ray tube housing during an exposure

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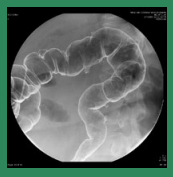
Protection During Fluoroscopy

- Proper position to be standing
  - Avoid high scatter areas
  - Try to stand behind the physician/ radiologist or RA
  - 90 degrees from the patient
- Wrap around lead
  - Have to move around the room to obtain supplies
- Should wear a thyroid shield
  - Unprotected areas are getting 10-20X more exposure
- Collimation
- Filtration
- Technical exposures
- High speed image receptors



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Protection During Fluoroscopy

- Correct processing
- Appropriate skin to source distance
- Cumulative timer
- Rotational scheduling of personnel
- Personnel must wear the badge on the outside of the lead apron at collar level
- Remote control fluoro units
  - Can perform the study from the control booth and enter room only when necessary
- Shielding (NCRP #102)
  - Apron- 0.25mm or 0.5mm (fluoro, AIR or above 100kVp)
  - Gloves- 0.25mm
  - Thyroid- minimum 0.5mm
  - Eyeglasses- 0.35mm

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Protective Curtain 0.25 mm lead equivalent

Scatter protection

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Bucky Slot Cover 0.25mm lead equivalent

Gonadal protection

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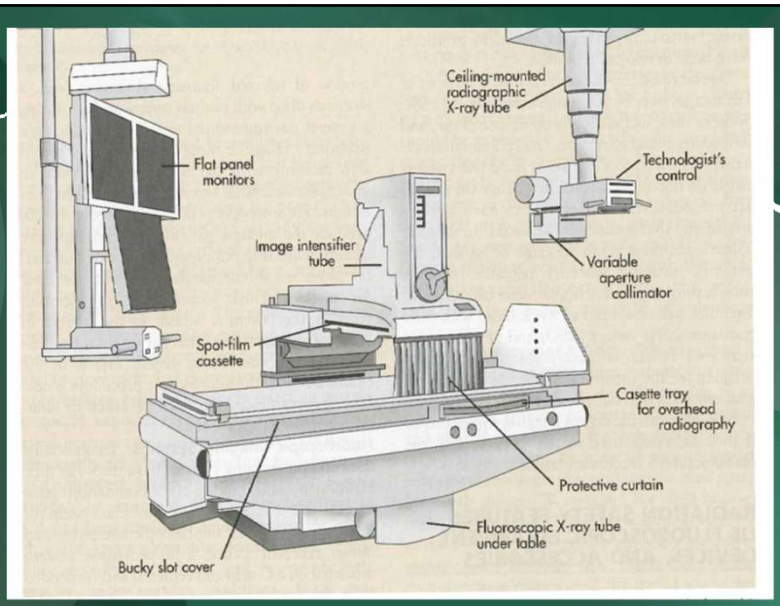

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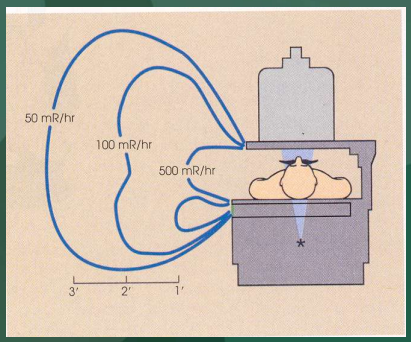
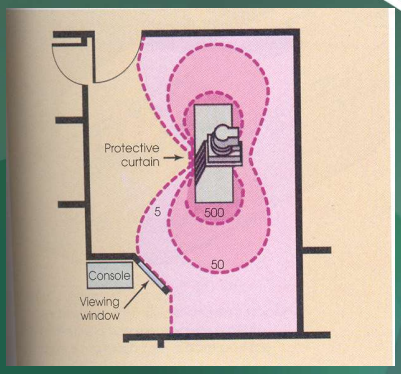
Isoexposure Curves in Radiation Protection





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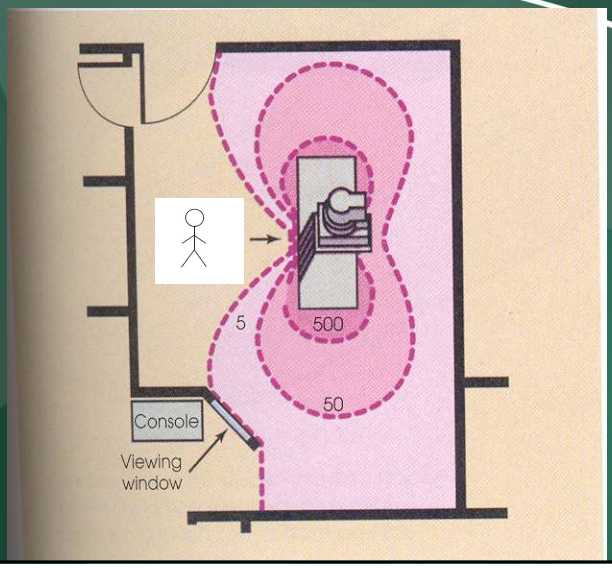
Dose from scatter radiation at 90 degrees and 1 meter (approx. 3 feet) away = dose X 0.001



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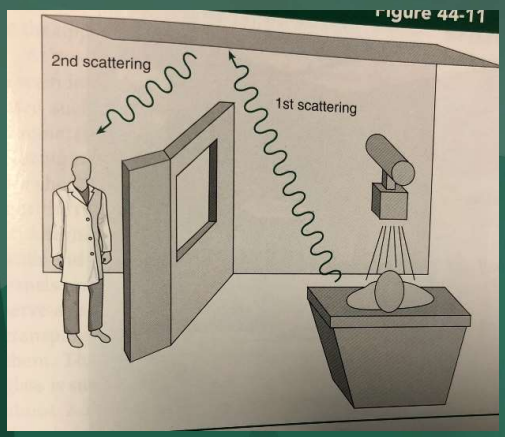
So radiation would have to scatter 2X to get behind the console



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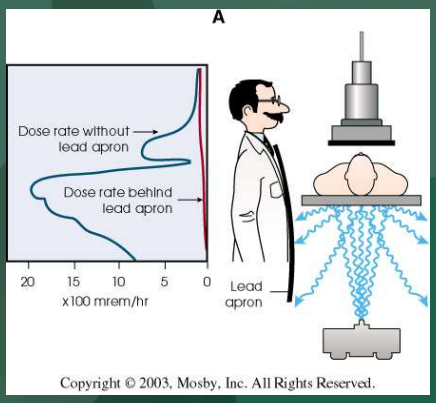
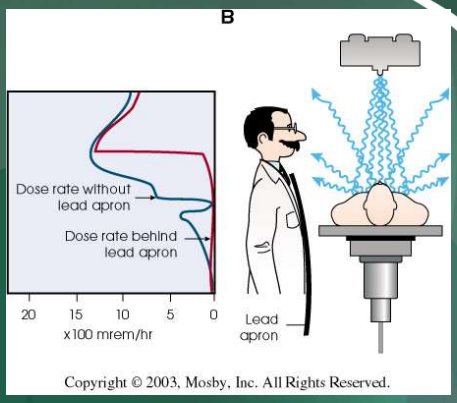
Fluoroscopy Orientation and its Effects on Exposures





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Protection in Mobile Radiography

- Cord length should be long enough to stand 6 feet (2m) from the patient
- Stand 90 degrees from the patient
- Use distance as a means of protection
- Wear protective shield
- Yell "x-ray" before taking exposure
- Do not hold the image receptor
  - Use cassette holders, pillows, sponges, or even a box of gloves

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Cassette Holder

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Portable Machines

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Protection in C-arm Fluoroscopy

- Proper position to be standing
  - In a lateral view, on the side of the patient away from the x-ray tube
- Protective shields and radiation monitors for all personnel
- Properly orient the c-arm with the II on top
- Minimize beam on time
- Position the II as close to the patient as possible to lower the beam intensity needed

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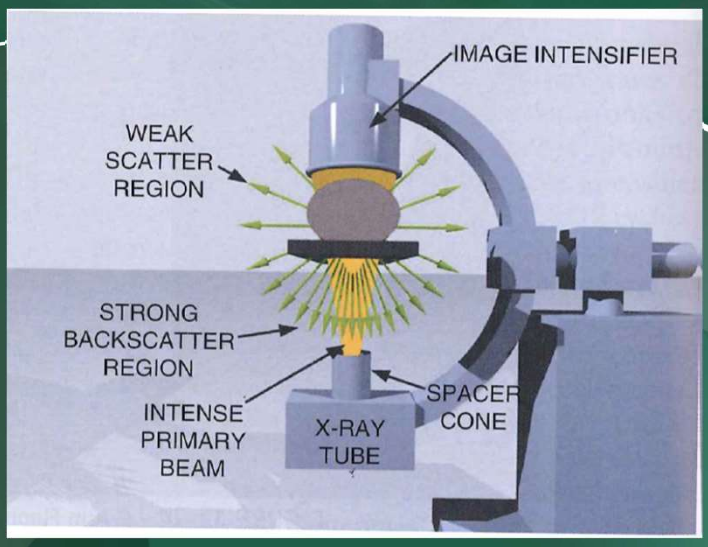

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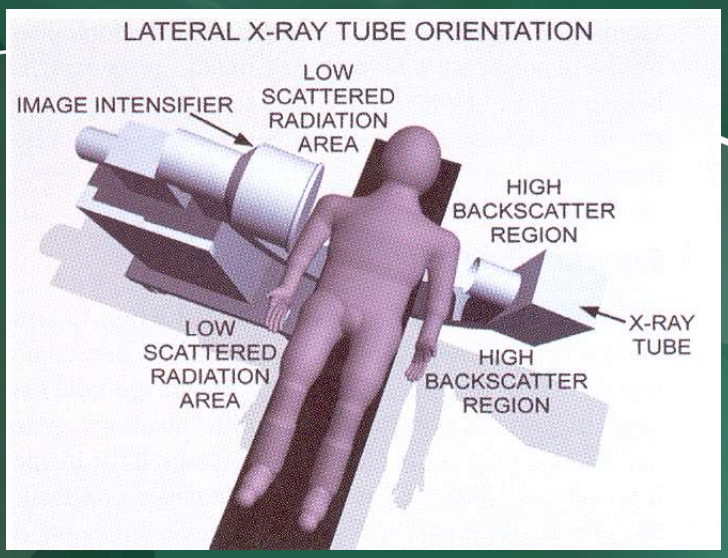

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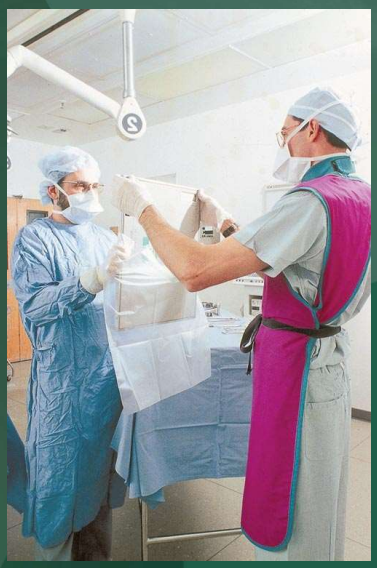
Portable Imaging in the OR



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Interventional Radiology (AIR) Protection

- Low dose fluoroscopy mode
- Pulsed beam operation
- Collimation
- Optimal beam filtration
- Optical apertures- like aperture diaphragm
- Last image hold
- Shortening duration of studies
- Extremity monitors
  - Rings- NCRP annual limits to 500 mSv

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Personnel Protection

- Technologist should never stand in the path of the primary beam
- If holding is necessary, try to utilize a non-occupationally exposed person or immobilization device
- Pregnant technologists are never to hold a patient for an exposure
- Exposures should never be made with the doors to the room open

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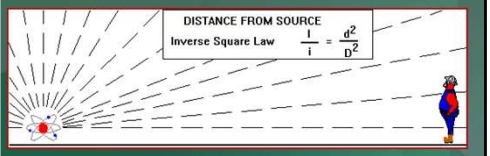
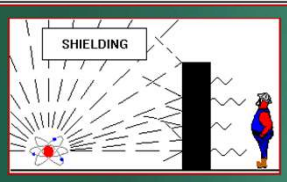
Cardinal Principles of Radiation Protection

- **Time**- amount of exposure is **directly proportional** to duration of the exposure
- **Distance**- most effective means of protection, it is **indirectly proportional**
- **Shielding**- absorbs most of the energy of scatter radiation
  - ~85% effectiveness





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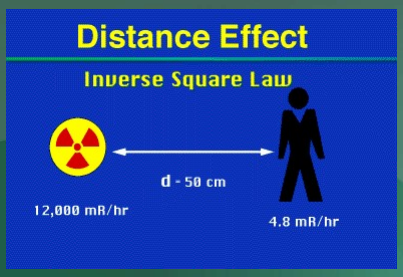
Inverse Square Law (ISL)

$$\frac{I_1}{I_2} = \frac{(D_2)^2}{(D_1)^2}$$

OR

$$\frac{E_o}{E_n} = \frac{(D_n)^2}{(D_o)^2}$$



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Inverse Square Law Example

old: 1 m
new: 2 m

old: 2 mGy
new:___mGy

$\frac{2}{\_\_} = \frac{(2)^2}{\_\_}$

$\frac{}{X} = \frac{}{(1)^2}$

Answer is 0.5 mGy

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More distance	=	Less intensity (quantity of radiation)
2 × d	=	¼ intensity
3 × d	=	⅑ intensity
4 × d	=	1⁄16 intensity

FIGURE 13-3 As the distance between the source of radiation and any given measurement point increases, radiation intensity (quantity) measured at that point decreases by the square of the relative change in distance between the new location and the old.

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Diagnostic Protection Design

- Workload (W)
  - Radiation on time during a week
  - mAs/week or mA-minute/week
- Use (U)
  - Amount of time the beam is directed at the structure
  - Takes into account primary or secondary radiation
- Occupancy (T)
  - Time that the area is occupied behind a barrier
    - Waiting room
    - Empty courtyard
- Distance (D)
  - Distance from the source to the structure

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Calculating Barrier Requirements

- Needs to be calculated for every barrier in an x-ray room

W x U x T

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HVL- Half Value Layer

- Insufficient HVL test could mean improper filtration
- Example
  - Exposure in a room is 350mGy What will be the exposure for:
    - 1 HVL
      - 175mGy
    - 2 HVL
      - 87.5mGy
    - 4 HVL
      - 21.88mGy

* Another term
TVL- tenth value layer- thickness that will decrease the intensity of the beam by 1/10th

TABLE 8-1

HVL Required by the Radiation Control for Health and Safety Act of 1968 and Detailed by the Bureau of Radiological Health* in 1980

Peak Kilovoltage	Minimum Required HVL in Millimeters of Aluminum
30	0.3
40	0.4
50	1.2
60	1.3
70	1.5
80	2.3
90	2.5
100	2.7
110	3.0
120	3.2

*The Bureau of Radiological Health changed its name to the Center for Devices and Radiological Health in 1982.

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Areas of the Department

- **Controlled**- occupied by workers who are trained and wearing monitoring devices; Maximum permitted equivalent dose is 0.1 mGy per week
- **Uncontrolled**- occupied by the general public; Maximum permitted equivalent dose is 0.02 mGy per week
  - Waiting rooms
  - Hallways
  - Bathrooms
  - Stairways

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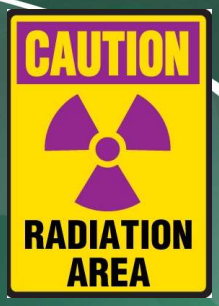
Radiation Area Sign Posting

- Radiation symbol that is magenta, purple or black on a yellow background
- Radiation hazard
  - Radiation area
  - High radiation area
  - Very high radiation area



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BOX 13-4 | Posting Sign Requirements

1. A permanent sign bearing the words "Caution Radiation Area" must be conspicuously posted in any area accessible to individuals in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.05 mSv in 1 hour at 30 cm from the radiation source or from any surface that the radiation penetrates.[8]
2. A permanent sign bearing the words "Caution High Radiation Area" must be conspicuously posted in any area accessible to individuals in which radiation levels could result in an individual receiving a dose equivalent in excess of 1 mSv in 1 hour at 30 cm from the radiation source or from any surface that the radiation penetrates.[8]
3. A permanent sign bearing the words "Grave Danger, Very High Radiation Area" must be conspicuously posted in any area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in excess of 5 Gy_t in 1 hour at 1 m from a radiation source or from any surface that the radiation penetrates.[8]

From *Radiation safety manual,* section 10: *Area classification and posting,* 1999, UW Environmental Health and Safety.

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Warning Signs

- Signs that indicate the room is in use

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Radiation Protection in 1918

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The End

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