Design and Evaluation of Shielding for R/F Facilities

Using NCRP 147 Methodology

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Slides Courtesy of:

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Required Information for Shielding Designs

- Architectural drawings of equipment layout in room
- Architectural drawings of surrounding areas indicating usage of these areas - offices, restrooms, corridor, exterior, etc.
- Elevation view of room or construction of floor and ceiling and distance between floors

Nomenclature for Radiation Design Criteria

Required thickness = NT/Pd^2

where:

N = total no. of patients per week

T = Occupancy Factor

P = design goal (mGy/wk)

d = distance to occupied area (m)

Shielding Design Goal (Air Kerma):

Uncontrolled Areas

Annual: P = 1 mGy per year
Weekly: P = 0.02 mGy per week

Controlled Areas

Annual: P = 5 mGy per year
Weekly: P = 0.1 mGy per week

Distance (d)

The distance in meters from either the primary or secondary radiation source to the occupied area.

New recommendations in Report 147 for areas above and below source.

New Formalism for Radiation Design Criteria

Required thickness = NT/Pd^2

where:

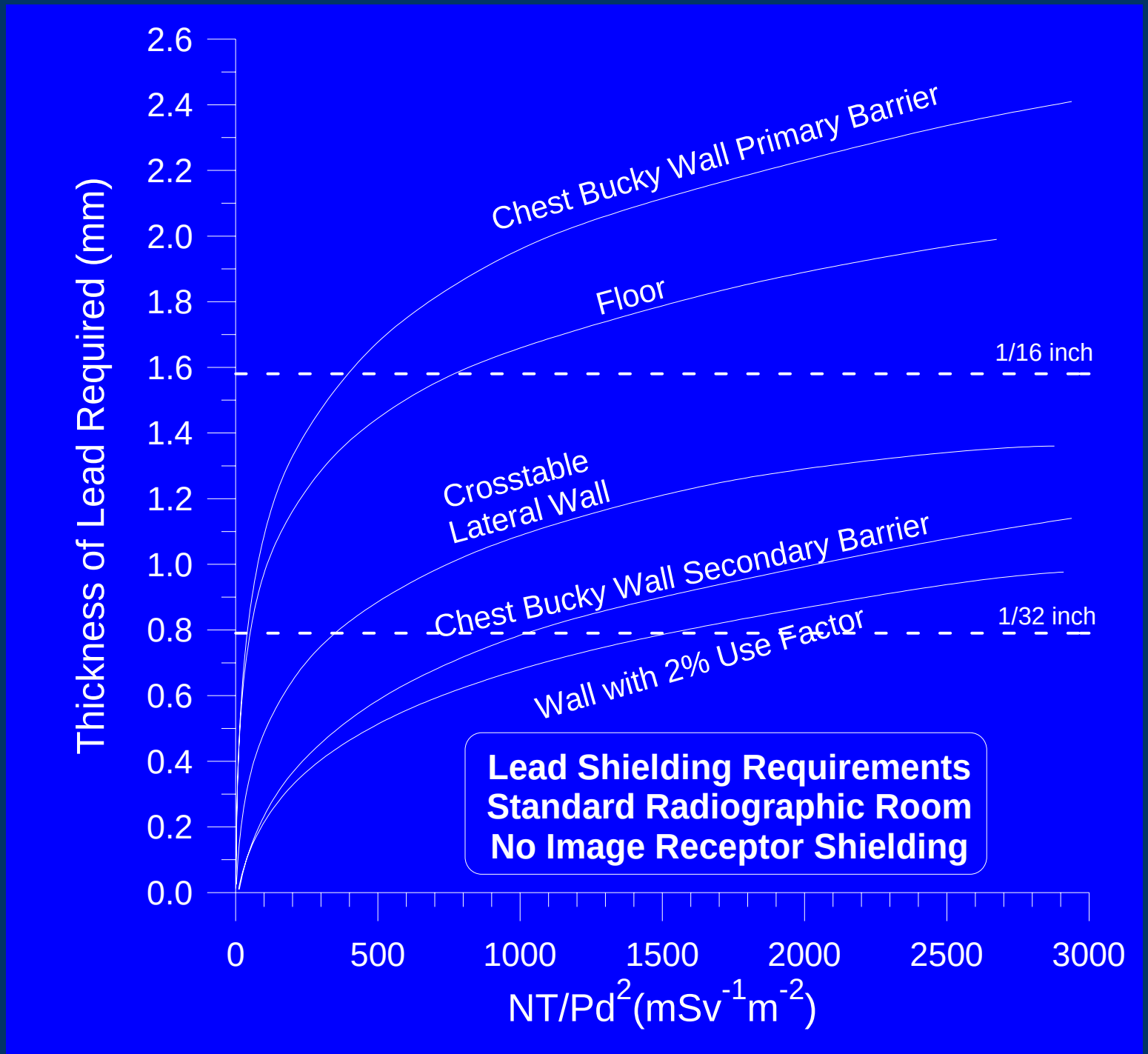
N = total no. of patients per week

T = Occupancy Factor

P = design goal (mGy/wk)

d = distance to occupied area (m)

Easy to use graphs for R and RF rooms developed by Simpkin are included in Report.


Thickness of Lead Required (mm)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Chest Bucky Wall Primary Barrier
Floor
1/16 inch
Crosstable
Lateral Wall
Chest Bucky Wall Secondary Barrier
Wall with 2% Use Factor
1/32 inch
Lead Shielding Requirements
Standard Radiographic Room
No Image Receptor Shielding
0
500
1000
1500
2000
2500
3000
NT/Pd2(mSv-1m-2)

Shielding Design Goal (Air Kerma):

Uncontrolled Areas

Annual: P = 1 mGy per year
Weekly: P = 0.02 mGy per week

Controlled Areas

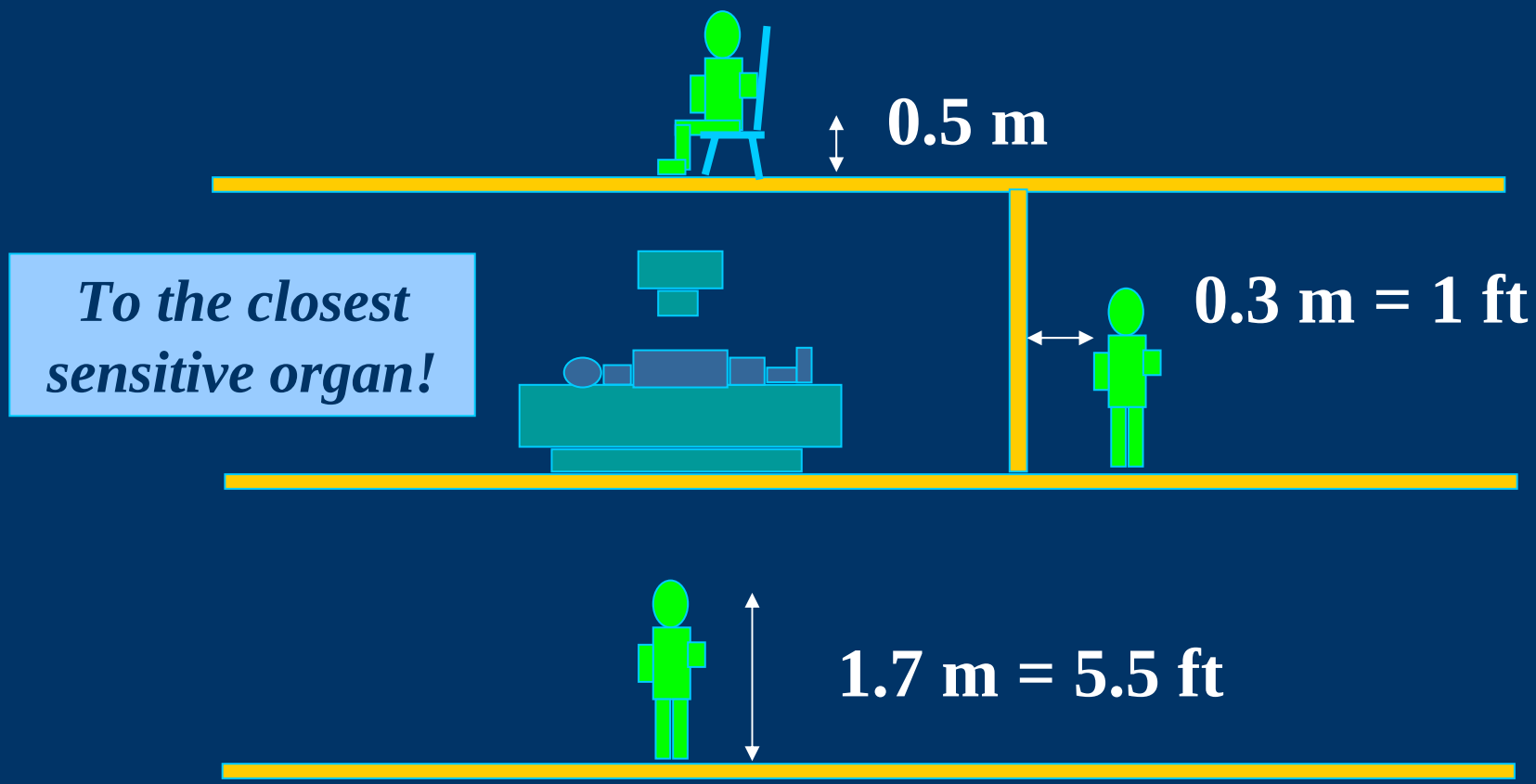
Annual: P = 5 mGy per year
Weekly: P = 0.1 mGy per week

Distance (d)

The distance in meters from either the primary or secondary radiation source to the occupied area.

New recommendations in Report 147 for areas above and below source.

Where in the occupied area do you calculate the dose?



To the closest sensitive organ!

Recommended Occupancy Factors for Uncontrolled Areas:

T=1 Clerical offices, labs, fully occupied work areas, kids' play areas, receptionist areas, film reading areas, attended waiting rooms, adjacent x-ray rooms, nurses' stations, x- ray control rooms

T=1/2 Rooms used for patient examinations and treatments

T=1/5 corridors, patient rooms, employee lounges, staff rest rooms

T=1/8 **corridor doors**

Recommended Occupancy Factors for Uncontrolled Areas:

T=1/20 public toilets, vending areas, storage rooms, outdoor area with seating, unattended waiting rooms, patient holding areas

T=1/40 minimal occupancy areas; transient traffic, attics, unattended parking lots, stairways, janitor's closets, unattended elevators

Pre-shielding (x_{pre}) for Radiographic Room Workload Distributions

(Dixon RL, Med Phys 1994)

Grid + cassette: (cross table)

Equivalent to: 0.3 mm Pb

or 3 cm concrete

Grid + cassette + table/chest bucky supports: (over table and chest)

Equivalent to: 0.85 mm Pb

or 7.2 cm concrete

Equivalency of Shielding Materials

Table 4.8 Page 67

Steel thickness requirement:

8 × Pb thickness requirement

Gypsum wallboard thickness requirement:

3.2 × concrete thickness requirement

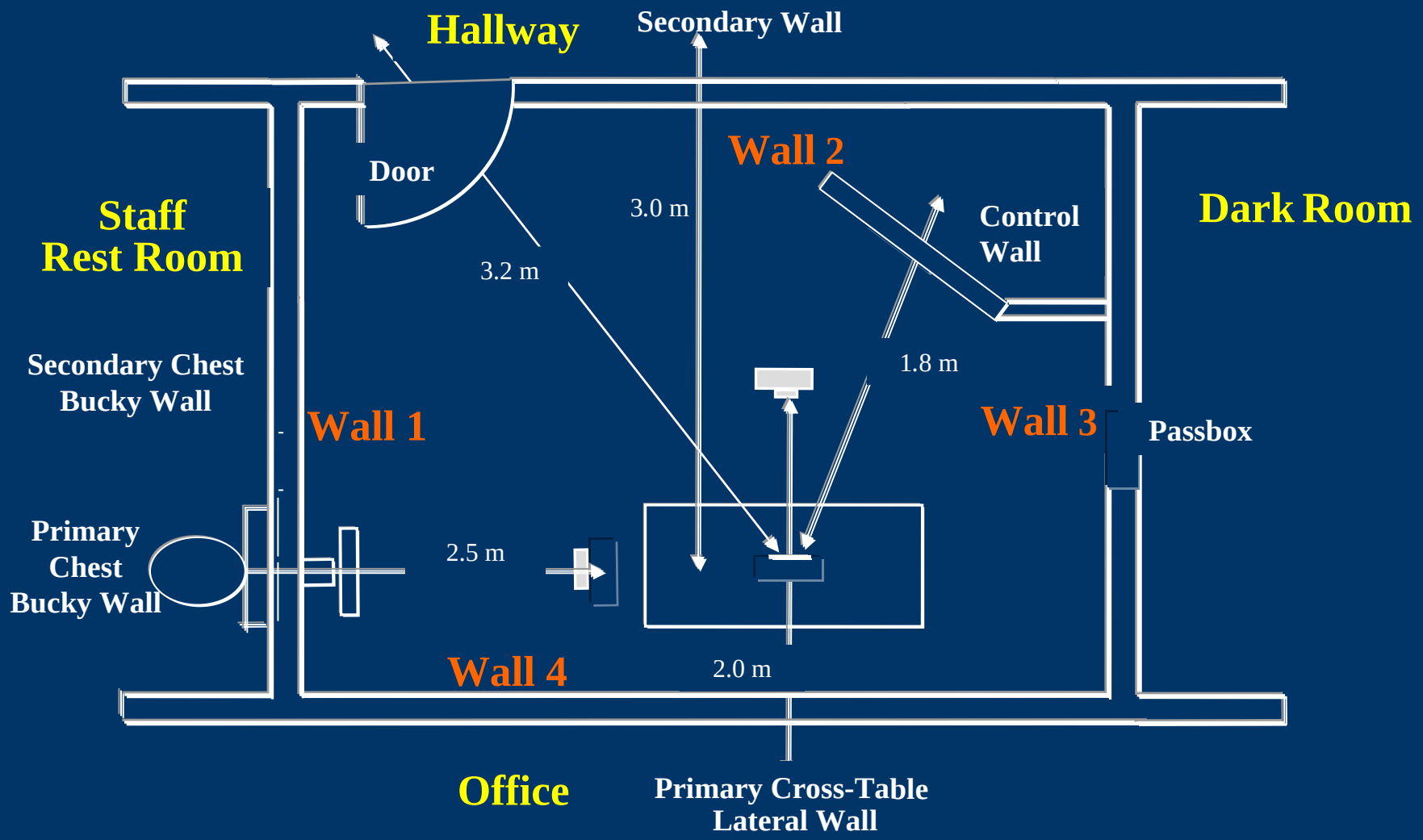
Plate Glass thickness requirement:

1.2 × concrete thickness requirement

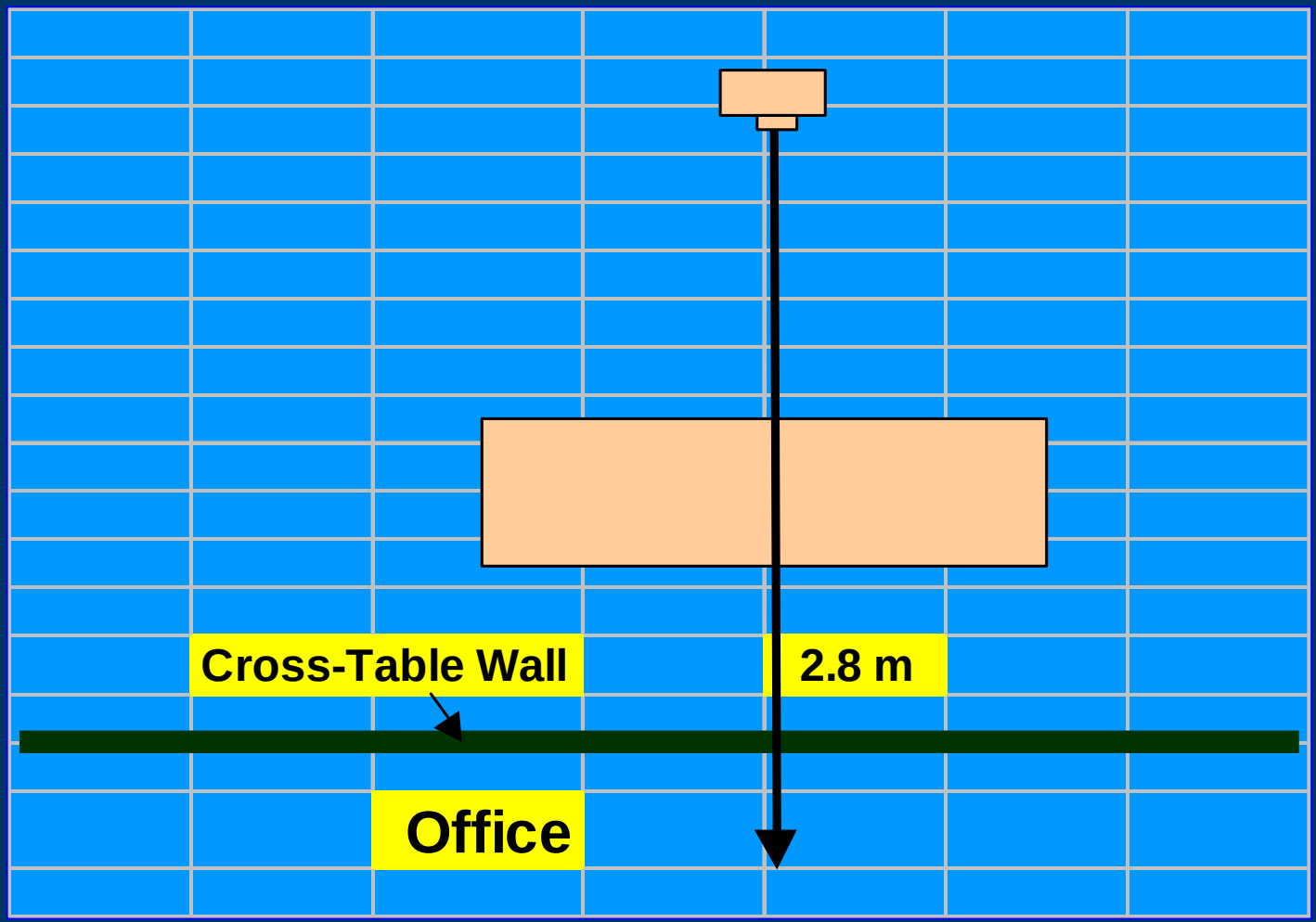
Light-weight concrete thickness requirement:

1.3 × std-weight concrete thickness requirement

Figure 5.2 Radiographic Room
page 75



PRIMARY BARRIER
Cross-Table Wall in Rad Room



Simplified Graphical Solution
Cross-Table Wall in Rad Room

Required thickness ► NT/Pd^2

where:

N = 125 patients/ week

T = 1

P = 0.02 mGy/wk

d = 2.8 m

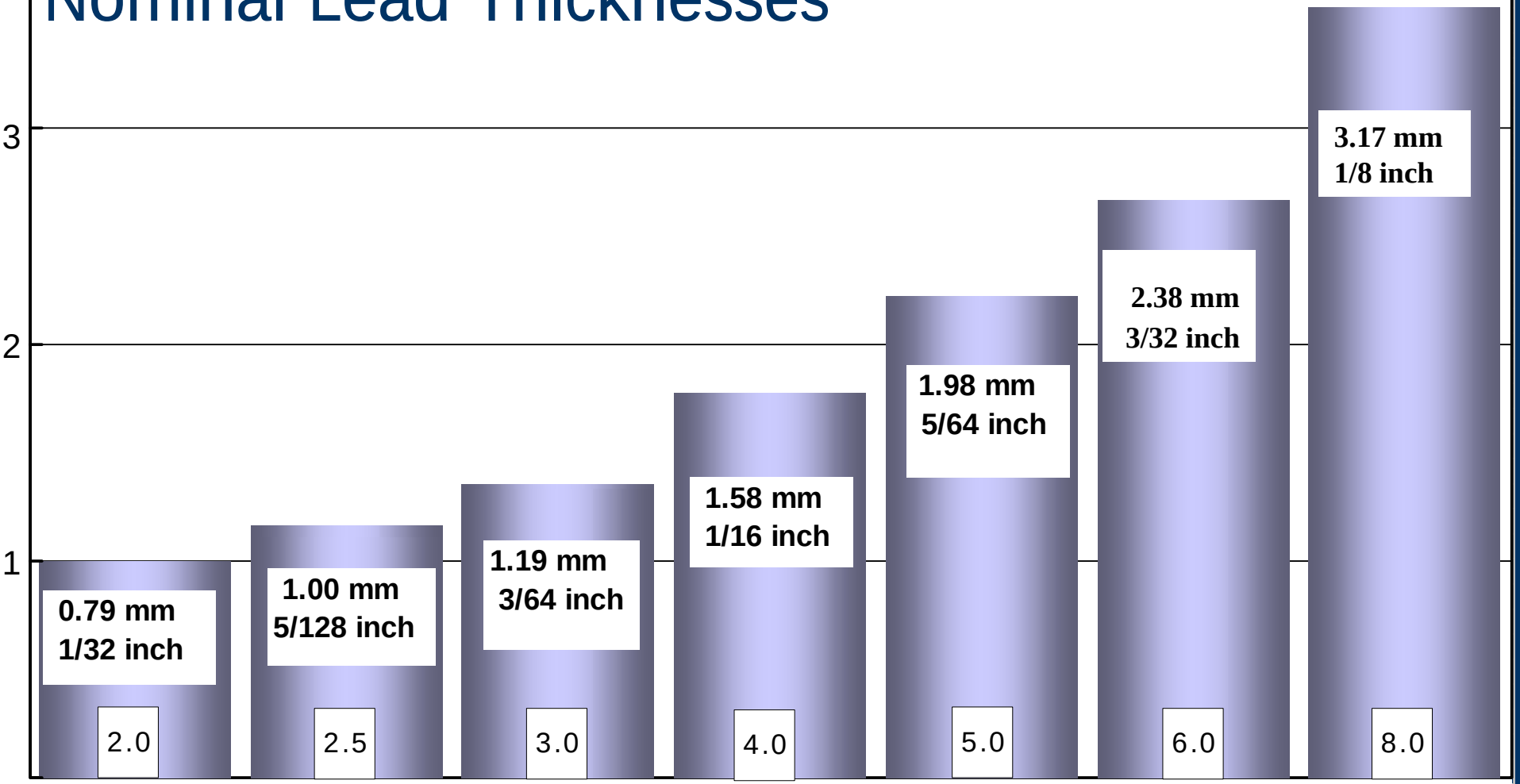
$NT/Pd^2 = 797\ mGy^{-1}\ m^{-2}$

Simplified Graphical Solution
Cross-Table Wall in Rad Room

1. Go to page 54, Fig. 4.5a
   (Primary, lead, with no pre-shielding)
2. Look up $NT/Pd^2 = 797$
   (Cross-table Wall)

Pb required = 1.03 mm
Specify: 3/64”; 3 lb/sqft

Nominal Lead Thicknesses



Nominal Thickness of Lead (mm and inches)
and Nominal Weight (lb ft^{-2}) at bottom of each bar

Simplified Graphical Solution
Cross-Table Wall in Rad Room

OR

1. **Go to page 55, Fig. 4.5b (Primary, lead, with pre-shielding)**
2. **Look up $NT/Pd^2 = 797$ (Cross-table Wall)**

Pb required = 0.83 mm

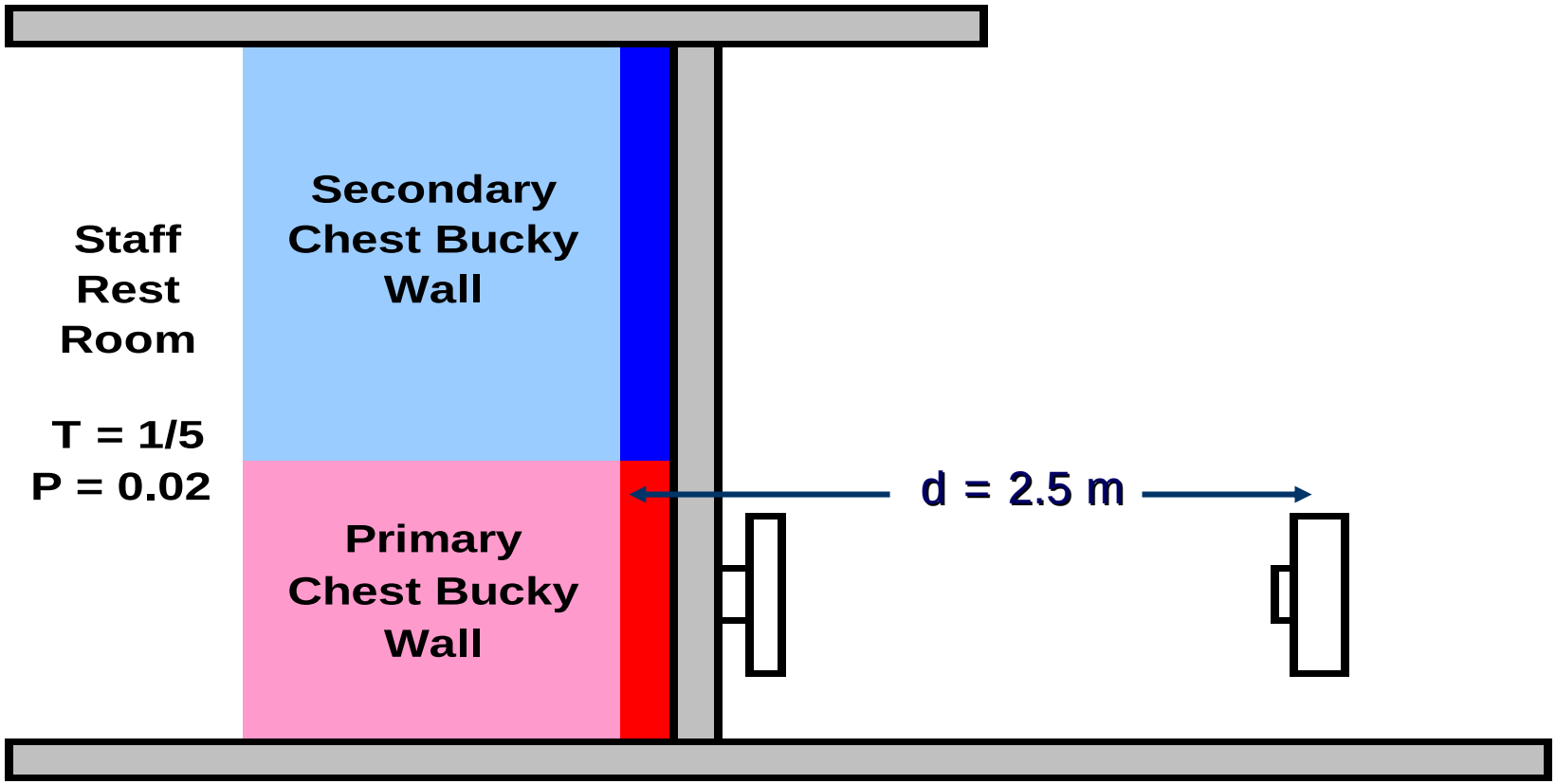
Specify: 5/128”; 2.5 lb/sqft

NCRP 49– Calculated Requirements for Cross-Table Lateral Wall in Radiographic Room

Using the NCRP 49 attenuation data and recommendations of W = 1000 mA-min per wk, U = ¼, T=1, the new dose limit of P = 0.02 mGy (0.002 R) per wk, and assuming all exposures are made at 100 kVp, the required barrier thickness is 2.6 mm Pb (1/8 in. or 8 lbs per sq ft).

Wall Containing Chest Image Receptor

Rad Room



Wall Containing Chest Image Receptor

Chest Receptor Wall

- Required thickness ⇨ NT/Pd^2

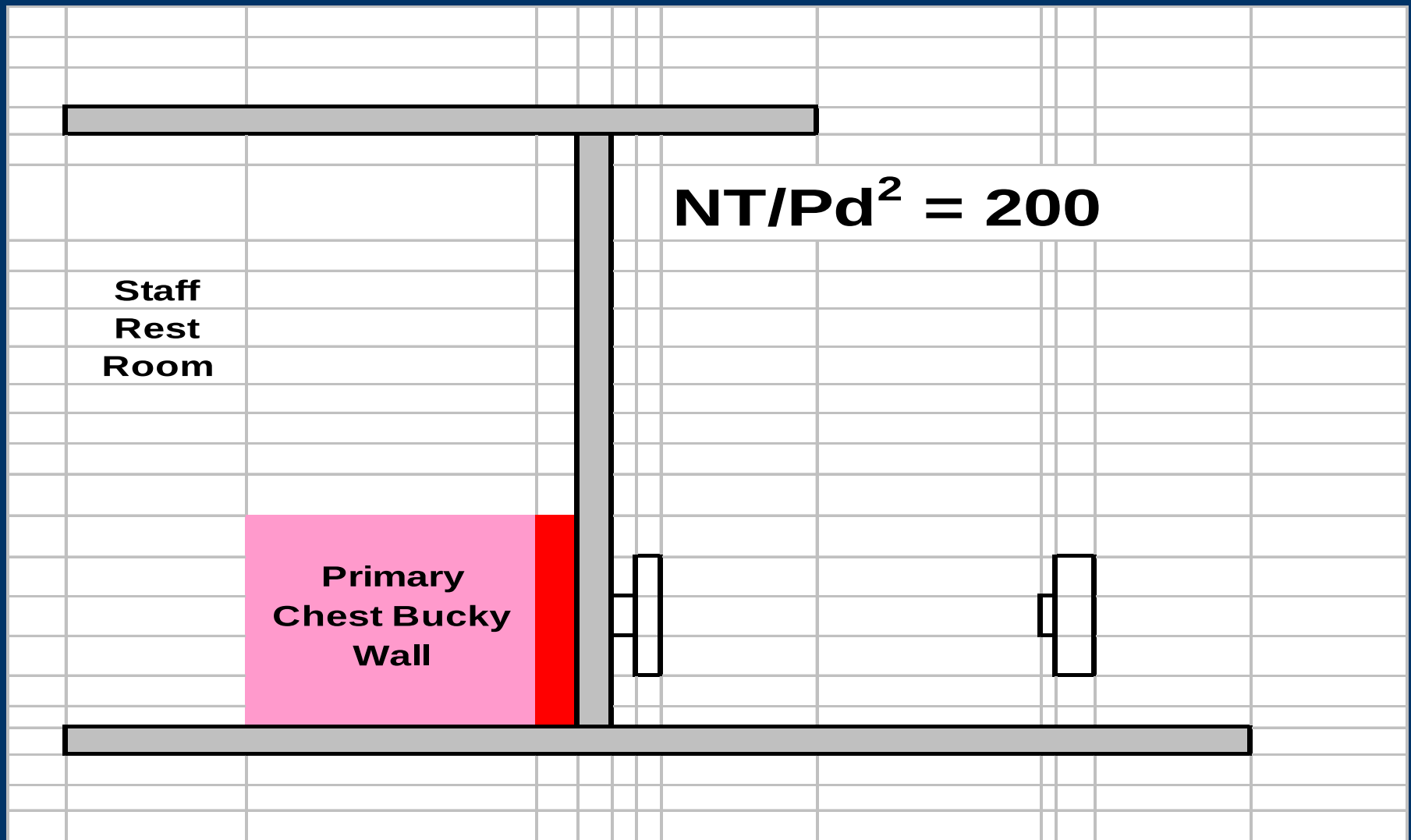
  where:

- N = 125 patients/ week
- T = 1/5 (staff rest room)
- P = 0.02 mGy/wk
- d = 2.5 m

- $NT/Pd^2 = 200\ mGy^{-1}\ m^{-2}$

Wall Containing Chest Image Receptor

Primary Barrier- Chest Receptor Area



Wall Containing Chest Image Receptor

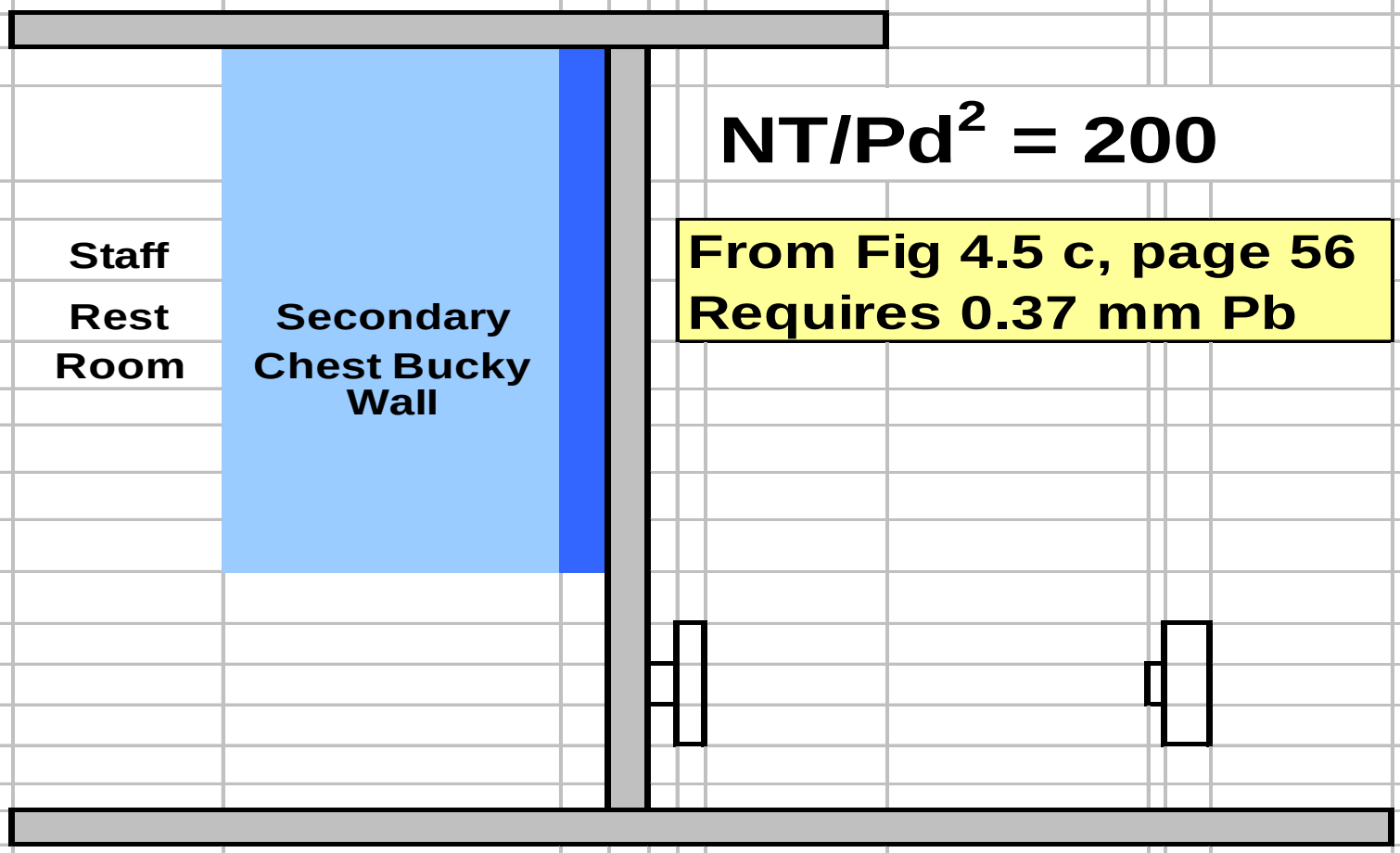
Primary Barrier- Chest Receptor Area

- From Fig 4.5 a, page 54
- (no pre-shielding)
- Requires 1.32 mm Pb

- From Fig 4.5 b, page 55
- (with pre-shielding)
- Requires 0.50 mm Pb

Wall Containing Chest Image Receptor

Secondary Barrier- Chest Receptor Wall



Wall Containing Chest Image Receptor

Shielding Required for Entire Wall

Since the primary shielding is greater than the secondary wall requirements, the entire wall can be shielded with the minimum primary requirement.

No Pre-shielding

Pb required = 1.32 mm

Specify: 1/16”; 4 lb/sqft

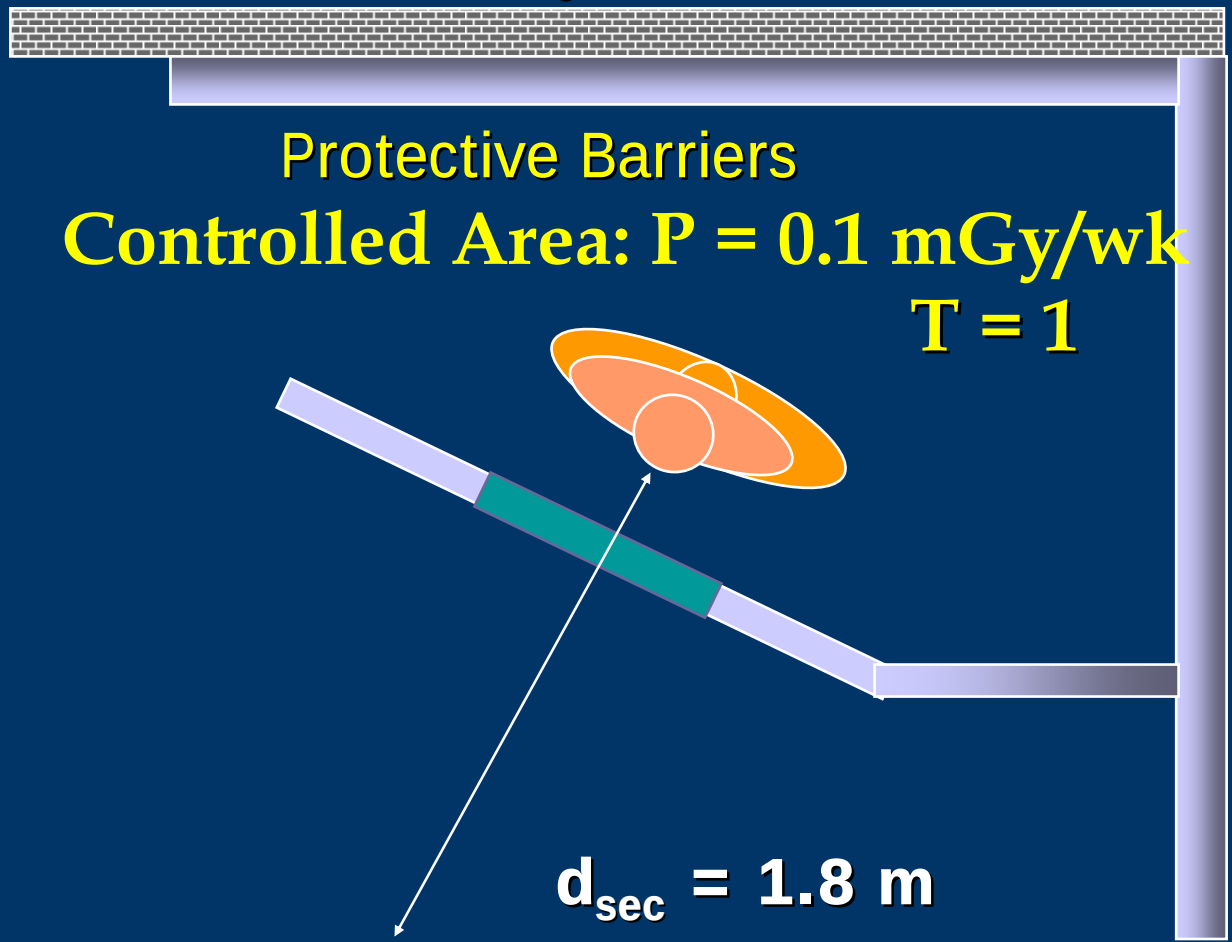
With Pre-shielding

Pb required = 0.50 mm

Specify: 1/32”; 2 lb/sqft

Control Wall in the Radiographic Room

Secondary Barrier



Simplified Graphical Solution
Control Wall in the Radiographic Room

$NT/Pd^2 = 125x1 / 0.1x(1.8)^2 = 386$

1. Go to page 56, Figure 4.5c
   "Secondary Wall" curve
2. Look up $NT/Pd^2 = 386$

- Pb required = 0.27 mm
- Specify: 1/32"; 2 lb/sqft
- Specify: similar equivalent lead thickness of lead glass for the view window in this wall.

Instructional (Longer) Method

Control Wall in the Radiographic Room

N = 125 patients per week

Leakage + 90^0 side-scatter (Table 4.7 page 46)

Rad Room (all barriers) = 3.4×10^{-2} mGy patient^{-1}

Unshielded secondary air kerma:

$$K_{sec}(0) = \frac{3.4 \times 10^{-2} \text{ mGy patient}^{-1} \times 125 \text{ patients week}^{-1}}{(1.8\text{m})^2}$$

$$K_{sec}(0) = 1.3 \text{ mGy wk}^{-1}$$

Instructional (Longer) Method
Control Wall in the Radiographic Room

To reduce this to the design goal for a controlled area, 0.1 mGy week^{-1}, the secondary barrier transmission is:

$$B_{sec}(x_{barrier}) = \frac{0.1 \text{ mGy week}^{-1}}{1.3 \text{ mGy week}^{-1}} = 7.7 \times 10^{-2}$$

Figure C.2; page 141, Rad Room (all barriers):

0.27 mm Pb is required

Caveat for Shielding a Control Booth

- Suleiman et al (1995): fogging of x-ray film in a cassette will occur if it is exposed to 0.5 μGy or more.
- Many facilities typically store loaded cassettes behind the control barrier in radiographic and R/F rooms.
- Assuming a recycling time of 1 d, during which time an average of 25 patients will be radiographed (1/5 the weekly workload), the control wall shielding required is calculated as follows:

Caveat for Shielding a Control Booth

$K_{sec}(0) = 3.4 \times 10^{-2}$ mGy patient^{-1} x 25 patients / (1.8m)^2

$$K_{sec}(0) = 0.26 \text{ mGy}$$

To reduce this to 5×10^{-4} mGy, requires a secondary barrier transmission of:

$$B_{sec}(x_{barrier}) = 5 \times 10^{-4} \text{ mGy} / 0.26 \text{mGy}$$

$$B_{sec}(x_{barrier}) = 1.9 \times 10^{-3}$$

Caveat for Shielding a Control Booth

$$B_{sec}(x_{barrier}) = 1.9 \times 10^{-3}$$

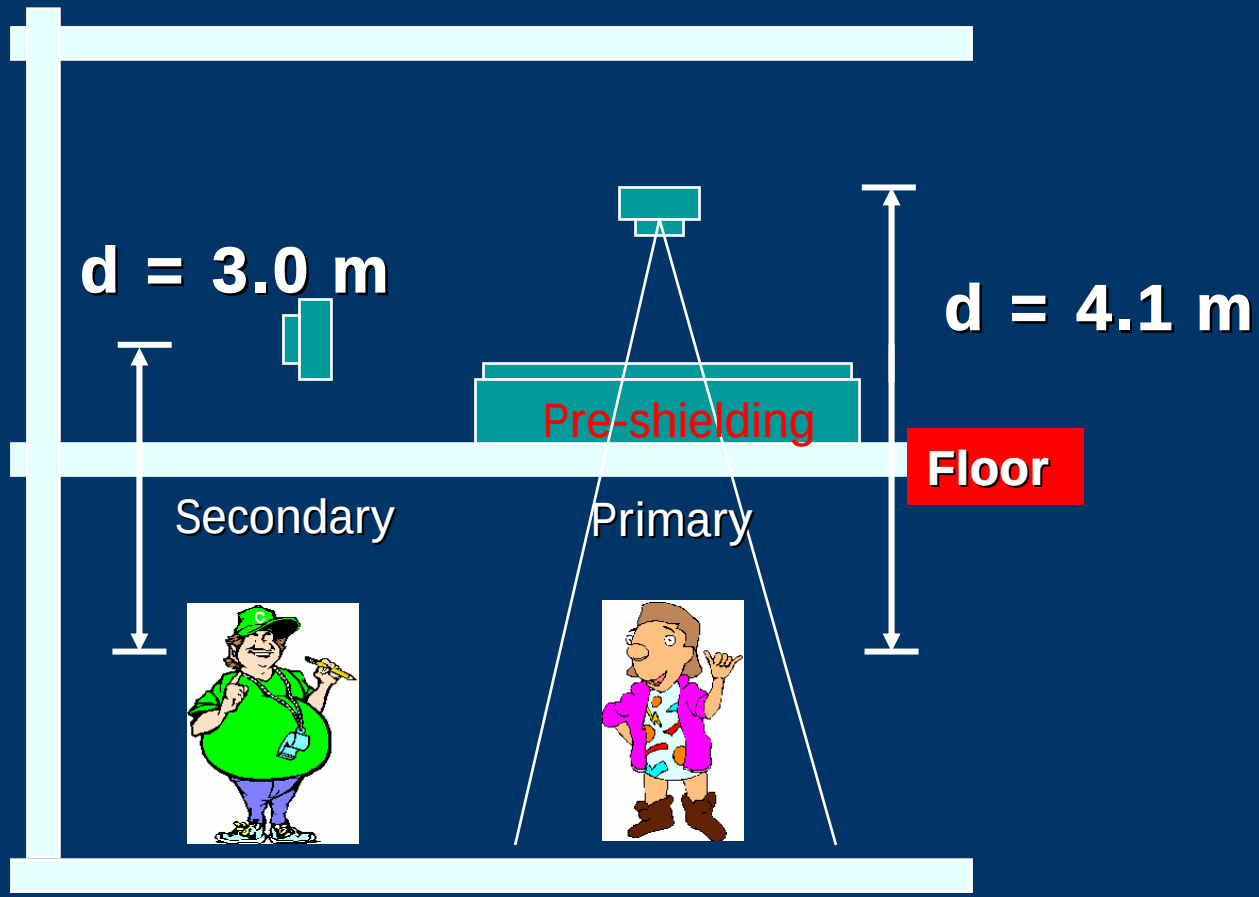
1. Go to page 141, Fig. C.2;
   Rad Room (all barriers)

Control Booth Wall=1.3 mm Pb.
Specify: 1/16 in. (4 lb/sqft)

NCRP 147 Recommendation for Control Booths

Unless specific information indicating that loaded cassettes will not be stored behind the control booth, the 0.5 μGy limitation per storage period *should* be assumed.

Floor of the Rad Room



Floor of the Rad Room

Primary Barrier Beneath the Rad Table

- Required thickness ⇨ NT/Pd^2

  ` where:

- N = 125 patients/ week
- T = 1
- P = 0.02 mGy/wk
- d = 4.1 m

- $NT/Pd^2 = 372\ mGy^{-1}\ m^{-2}$

Floor of the Rad Room

Primary Barrier Beneath the Rad Table

1. Go to page 58, Fig. 4.6b
   (Primary, concrete, with pre-shielding)
2. Look up $NT/Pd^2 = 372$

If Specifying: Standard-Weight Concrete:
Minimum Concrete required = 37 mm = 1.5 in.

If Specifying: Light-Weight Concrete:
Minimum Concrete required = 37 mm x 1.3 =
48.1 mm = 1.9 in.

Floor of the Rad Room

Secondary Barrier Calculation for Floor

- Required thickness ⇨ NT/Pd^2

  ` where:

- N = 125 patients/ week
- T = 1
- P = 0.02 mGy/wk
- d = 3.0 m

- $NT/Pd^2 = 694\ mGy^{-1}\ m^{-2}$

Floor of the Rad Room

Secondary Barrier Calculation for Floor

1. Go to page 59, Fig. 4.6c (Secondary, concrete)
2. Look up $NT/Pd^2 = 694$

Minimum Concrete required = 33 mm = 1.3 in.

This is less than the 37 mm thickness required for the primary barrier. Thus 37 mm of standard-weight concrete will suffice for the entire floor.

Darkroom Wall in Rad Room

Secondary Barrier

- Limiting factor = stored film not T
- Recommended Limit = 0.1 mGy/ storage period (Suleiman et al, 1995)
- Assuming 1 month storage:

  Limit = 0.025 mGy/wk
- Assume darkroom is secondary barrier

Darkroom Wall in Rad Room

Secondary Barrier

- Required thickness ⇨ NT/Pd^2

  where:

- N = 125 patients/ week
- T = 1
- P = 0.025 mGy/wk
- d = 2.0 m

- $NT/Pd^2 = 1250\ mGy^{-1}\ m^{-2}$

Darkroom Wall in Rad Room

Secondary Barrier

1. Go to page 56, Fig. 4.5c (Secondary, lead)
2. Look up $NT/Pd^2 = 1250$ (Secondary Wall)

Pb required = 0.53 mm
Specify: 1/32”; 2 lb/sqft


Celotex

Shielding References

- Simpkin, DJ, Transmission of scatter radiation from computed tomography (CT) scanners determined by a Monte Carlo calculation. Health Physics 58(3):363-367, 1990.
- Dixon, RL and Simpkin, DJ. New Concepts for Radiation Shielding of Medical Diagnostic X-ray Facilities. In Proceedings of the 1997 AAPM Summer School.
- NCRP (2005), National Council on Radiation Protection and Measurements. *Structural Shielding Design for Medical X-Ray Imaging Facilities*, NCRP Report #147 (National Council on Radiation Protection and Measurements, Bethesda, Maryland)

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