Diagnostic X-Ray Shielding

Radiation Shielding Design: New Concepts and Methods Using NCRP 147 Methodology

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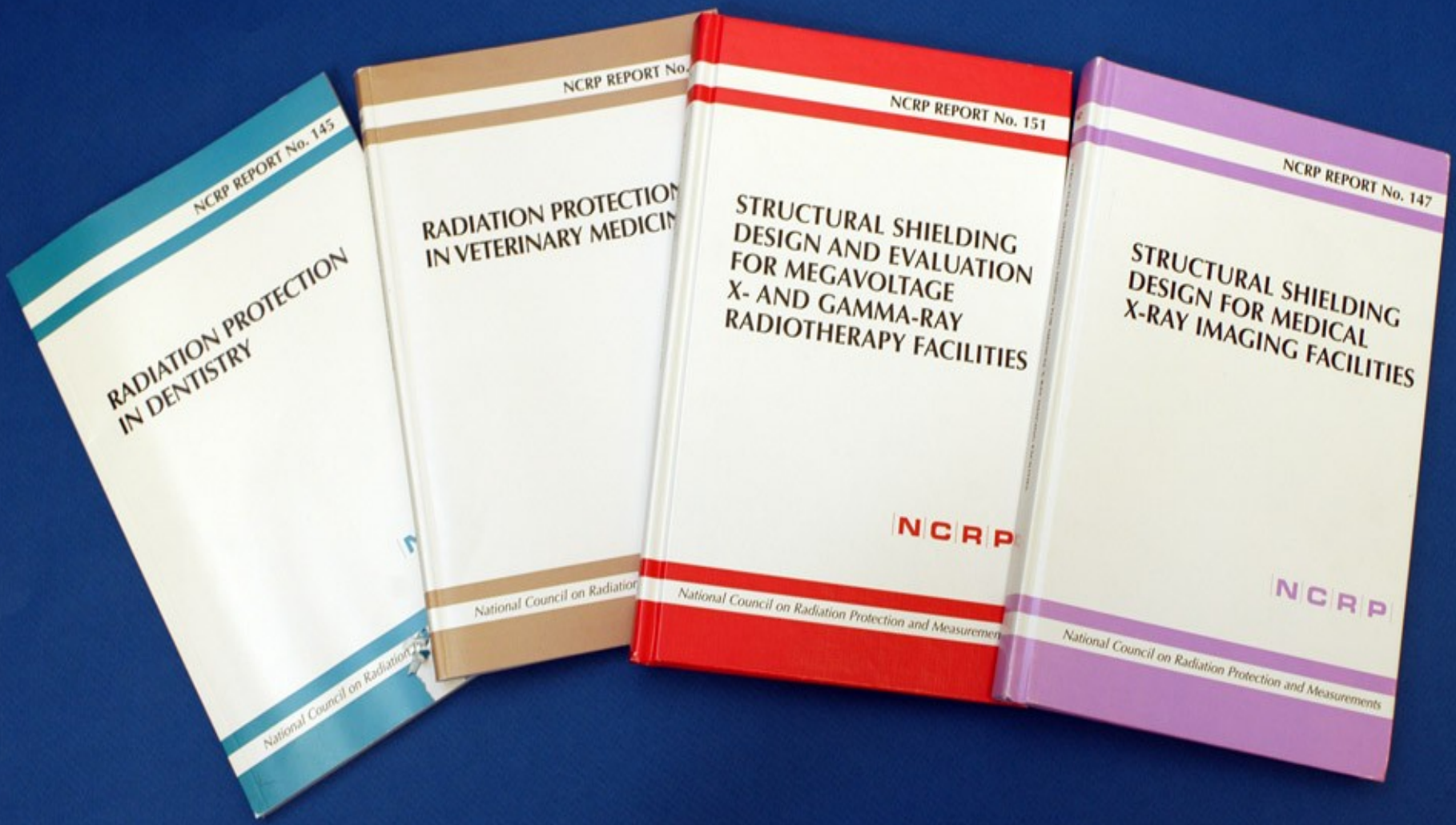
Recent NCRP report series for shielding medical x-ray sources



NCRP REPORT No. 147

Structural Shielding Design for Medical X-Ray Imaging Facilities

Recommendations of the
NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

Issued November 19, 2004

National Council on Radiation Protection and Measurement
7910 Woodmont Avenue, Suite 400 / Bethesda, MD 20814

Definitions of Occupied Areas

Controlled Area: A limited access area where the occupational exposure to personnel is under the supervision of an individual responsible for radiation protection.

This implies that occupancy, access, and working conditions are controlled for radiation protection purposes.

Definitions of Occupied Areas

Uncontrolled Areas: For radiation protection purposes, uncontrolled areas are ALL OTHER areas in the hospital or clinic and surrounding environs.

INVITED PAPER
ICRS-RPS

RADIATION PROTECTION STANDARDS: THEIR EVOLUTION FROM SCIENCE TO PHILOSOPHY

R. L. Dixon, Joel E. Gray, B. R. Archer, and D. J. Simpkin

Radiation Protection Dosimetry (2005), Vol. 115, No. 1–4, pp. 16–22

Exposure Limits in the NCRP report series for shielding medical x-ray sources

" NCRP has concluded that a suitable source control for shielding individuals in uncontrolled areas in or near medical radiation facilities is an effective dose of 1 mSv in any year. "

1 mSv per year to the maximally exposed individual in an uncontrolled area will provide adequate protection to the employees and the members of the public that access the uncontrolled areas.

Shielding Design Goals

Shielding Design Goals are levels of levels of air kerma used in the design calculations and evaluations of barriers constructed for the protection of employees and members of the public.

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

NCRP 147 Recommendation for Control Booths

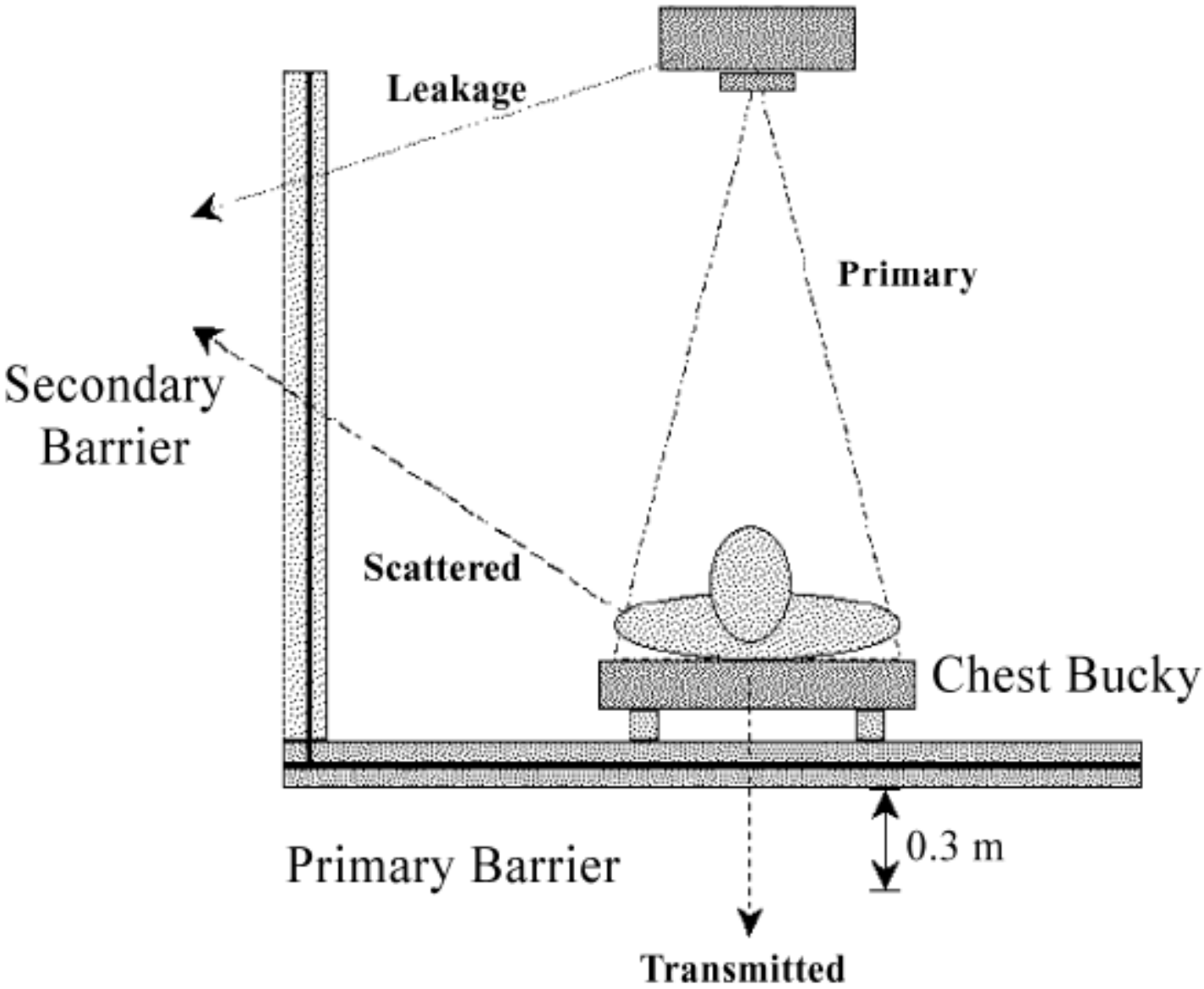
Unless specific information indicating that loaded cassettes will not be stored behind the control booth, the 0.5 mGy limitation per storage period *should* be assumed.

Primary Radiation Barriers

- Radiation emitted by the x-ray tube used for patient imaging
- Primary barrier is any structure (floor, wall, ceiling) that intercepts the radiation emitted directly from the x-ray tube
- Function is to attenuate the useful beam to appropriate shielding design goals.

Secondary Radiation Barriers

- X-rays scattered from the patient and other objects
- Leakage from the protective housing of the x-ray tube
- Secondary barrier is any structure (floor, wall, ceiling) that will intercept and attenuate leakage and scattered radiation to the appropriate shielding design goal


Leakage
Primary
Secondary
Barrier
Scattered
Chest Bucky
0.3 m
Primary Barrier
Transmitted

Shielding Design Assumptions

- Patient attenuation factor of 10 to 100 is ignored
- Calculations of barrier attenuation assume perpendicular incidence of radiation
- Calculations ignore the presence of materials in the path of the x-ray beam other than the specified shielding material

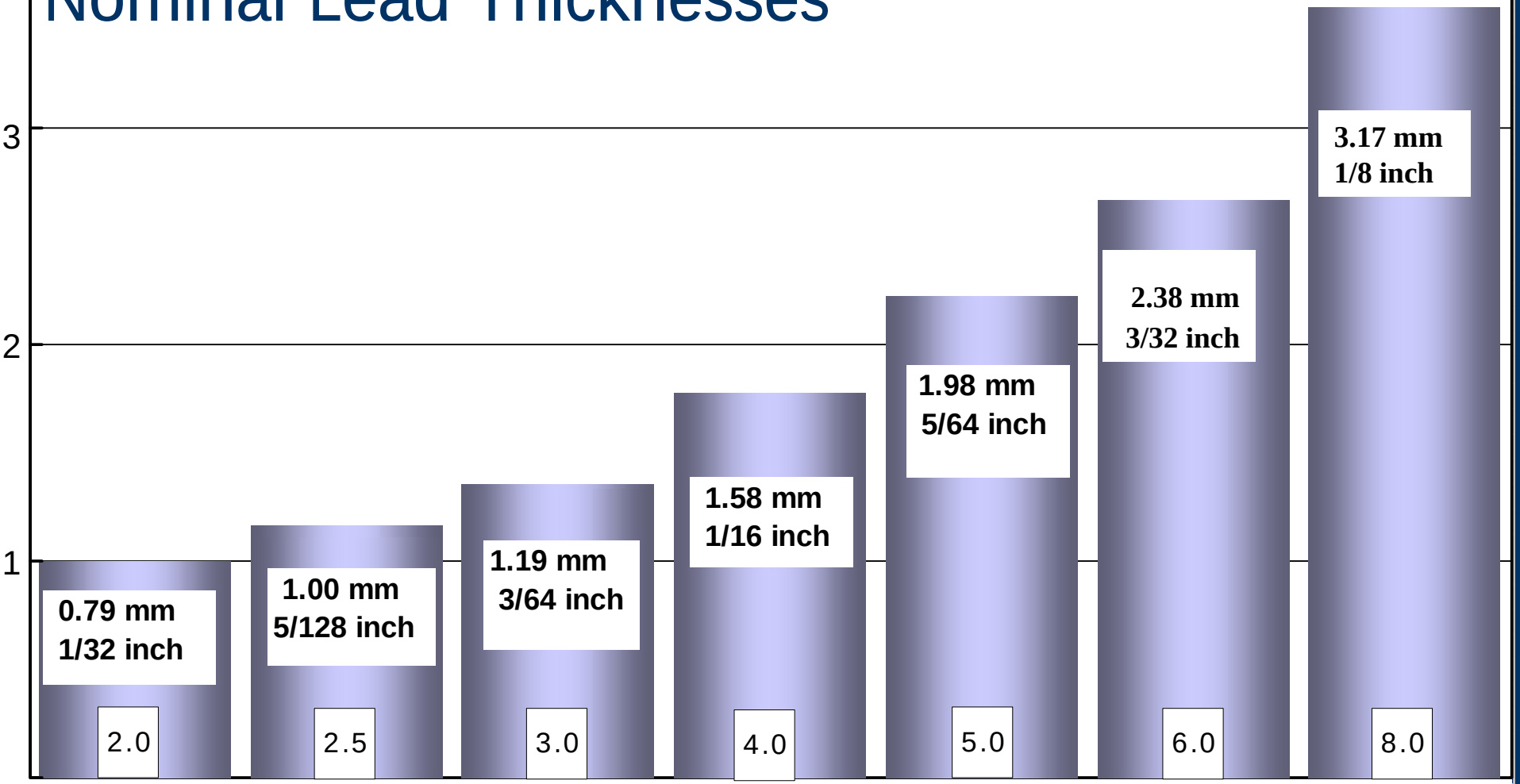
Shielding Design Assumptions

- Leakage radiation from x-ray equipment is assumed to be at the maximum value allowed by federal standards (0.876 mGy hr^{-1} air kerma or 0.100 mR hr^{-1} exposure)
- Field size and phantom used for scattered radiation calculations yield conservatively high values of scattered radiation.
- Recommended occupancy factors for uncontrolled areas are conservatively high.

Shielding Design Assumptions

- Lead shielding is fabricated in sheets of specific standard thicknesses. If shielding calculations require a value greater than a standard thickness, the next greater standard thickness will typically be specified.
- The minimum distance for an occupied area from a shielded wall is assumed to be 0.3 meters.

Nominal Lead Thicknesses



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

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

Radiation Shielding Design

- Radiation shielding SHALL be designed by a qualified expert to ensure that the required degree of protection is achieved.
- The term “qualified expert” is defined as a medical physicist or medical health physicist who is competent to design radiation shielding for medical imaging facilities. The criteria for compentency is certification by a recognized professional board.

Types of Imaging Facilities Covered in NCRP #147

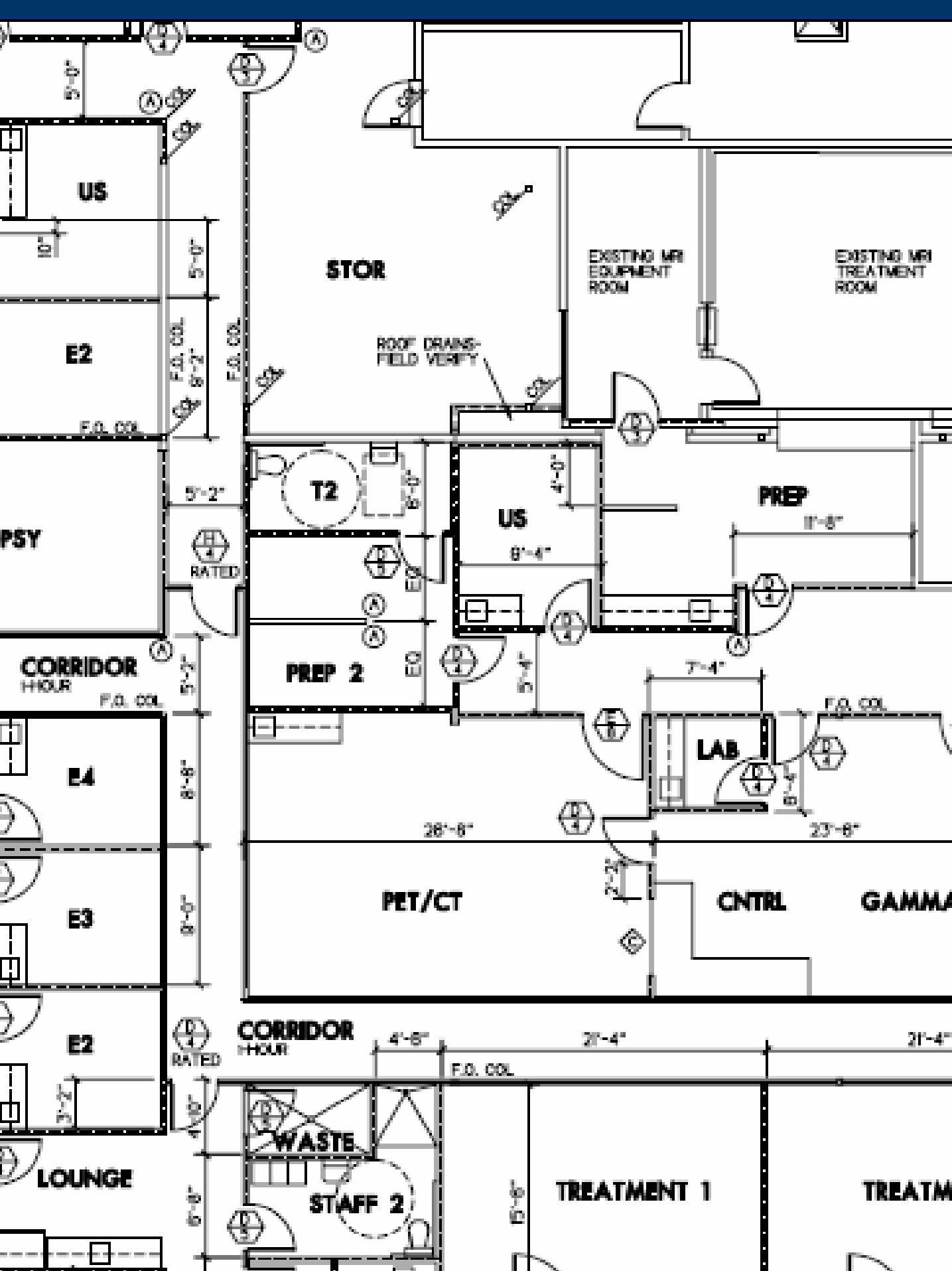
- Radiograpic Installations
- Fluoroscopic Installations
- Interventional Facilities
- Dedicated Chest Installations
- Mammographic Installations
- Computed Tomography Installations

Types of Imaging Facilities Covered in NCRP #147

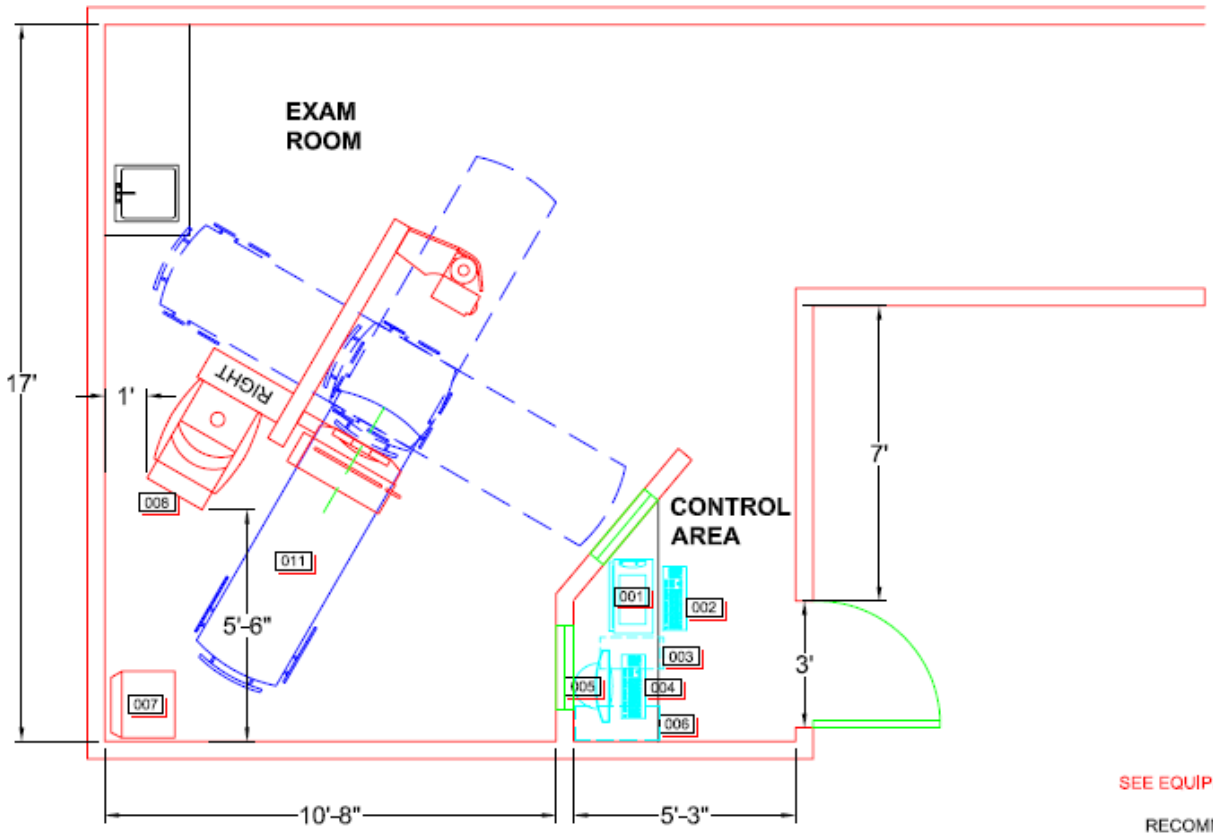
- Mobile Radiography and Fluoroscopy X-ray units
- Dental X-ray Facilities
- Bone Mineral Measurement Equipment
- Veterinary X-ray Facilities
- Other X-ray Imaging Facilities

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


US
STOR
EXISTING MRI EQUIPMENT ROOM
EXISTING MRI TREATMENT ROOM
E2
F.O. COL
ROOF DRAIN-FIELD VERIFY
T2
US
PREP
PSY
RATED
CORRIDOR
1-HOUR
PREP 2
LAB
E4
E3
E2
PET/CT
CNTRL
GAMMA
CORRIDOR
1-HOUR
WASTE
STAFF 2
LOUNGE
TREATMENT 1
TREATM

EQUIPMENT LAYOUT



SEE EQUIPMENT LEGEND FOR CODE DESCRIPTION

RECOMMENDED CEILING HEIGHT 10'-0" A.F.F.
MINIMUM CEILING HEIGHT 9'-3" A.F.F.
ACTUAL CEILING HEIGHT 9'-4" A.F.F.

Swissray
1160 McLester Street
Elizabeth, NJ 07201
1-800-903-5543

PRELIM ROOM PLANS
GLENDALE MEMORIAL HOSP. ER RM
1420 S. CENTRAL AVE.
GLENDALE, CA 91204

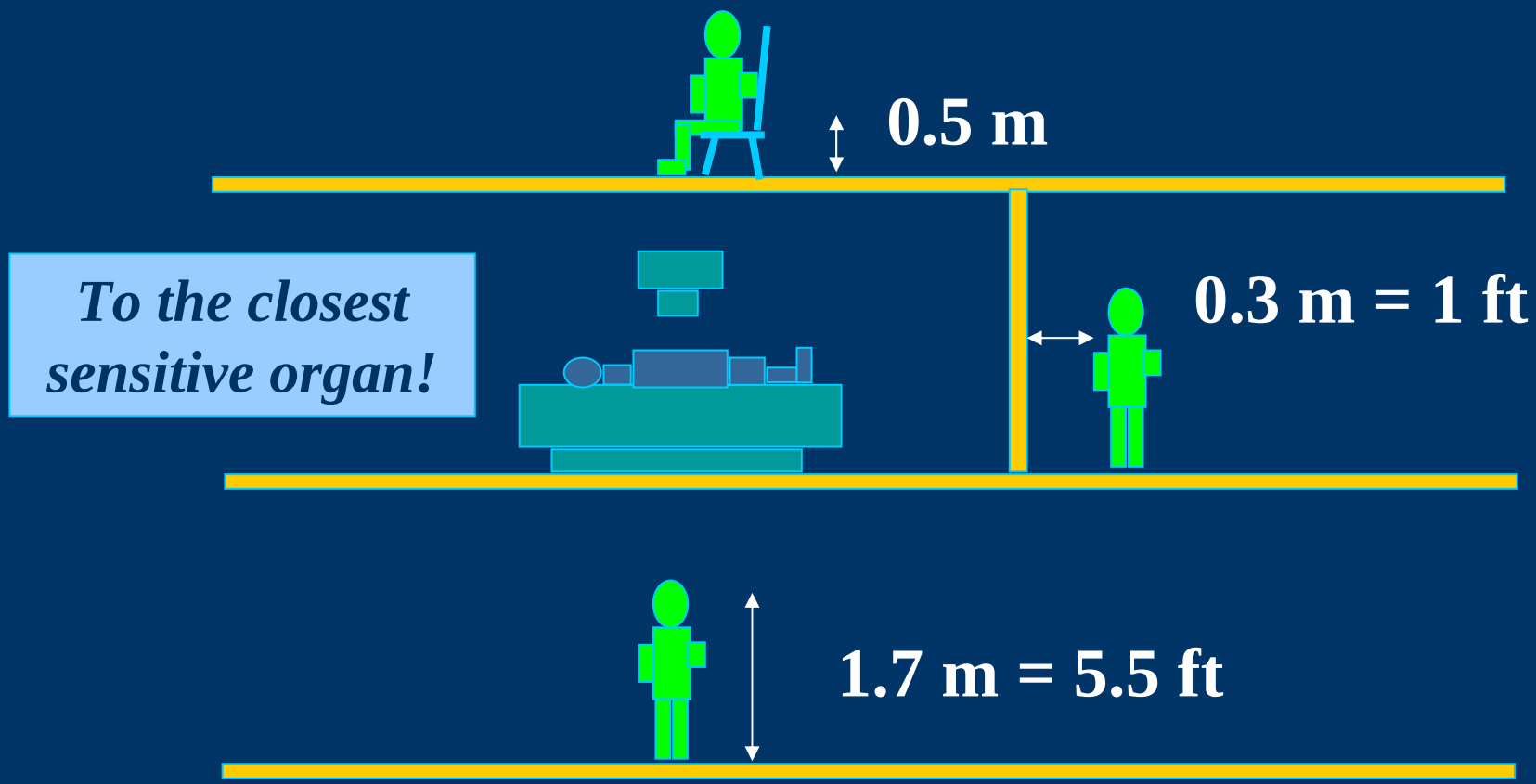
DRAWN BY: SR
SCALE: NTS
DATE: 5/23/06
PROJECT NO: SR0092-P3
SHEET NO: 3.1

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!

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)

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

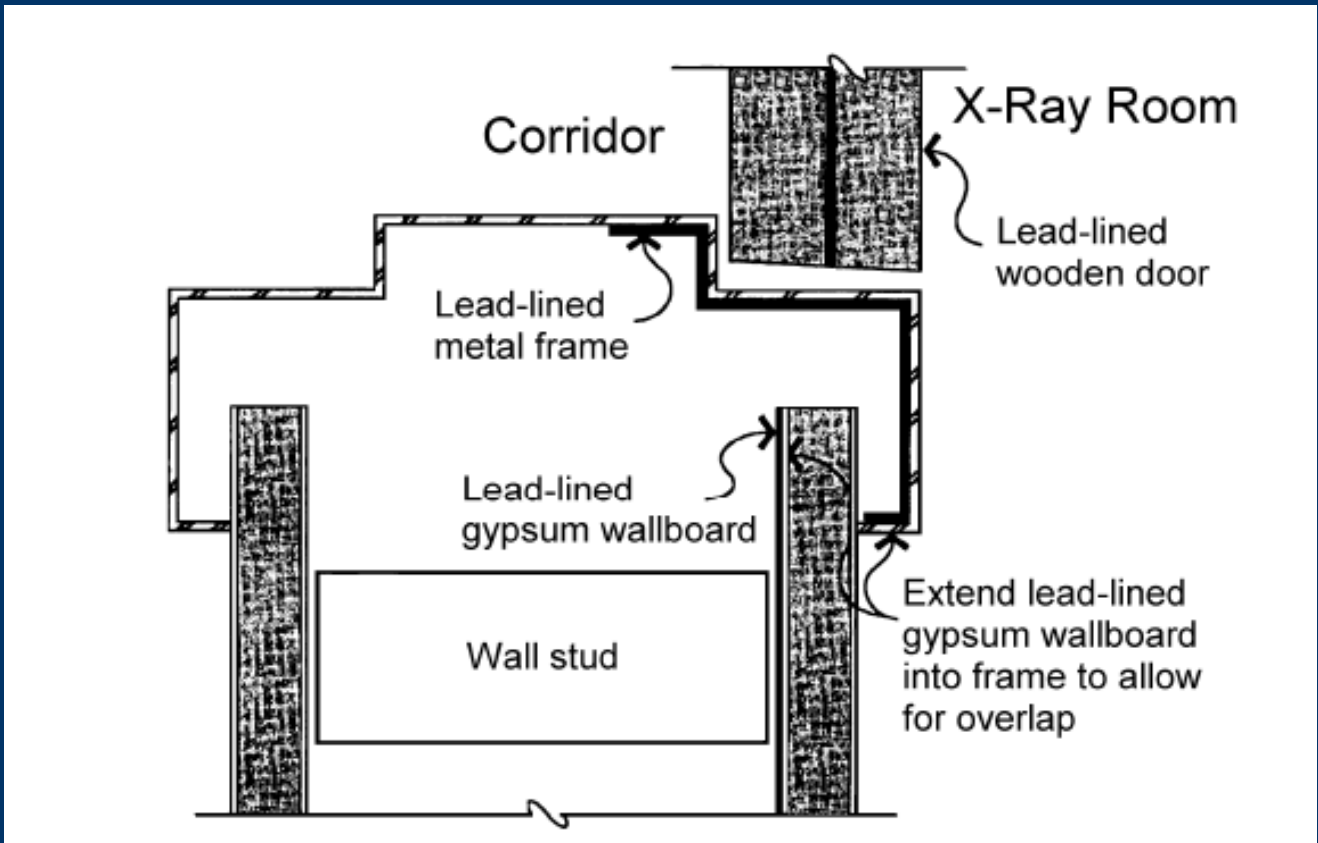
T=1/8 **corridor doors**

Recommended Occupancy Factors for Uncontrolled Areas:

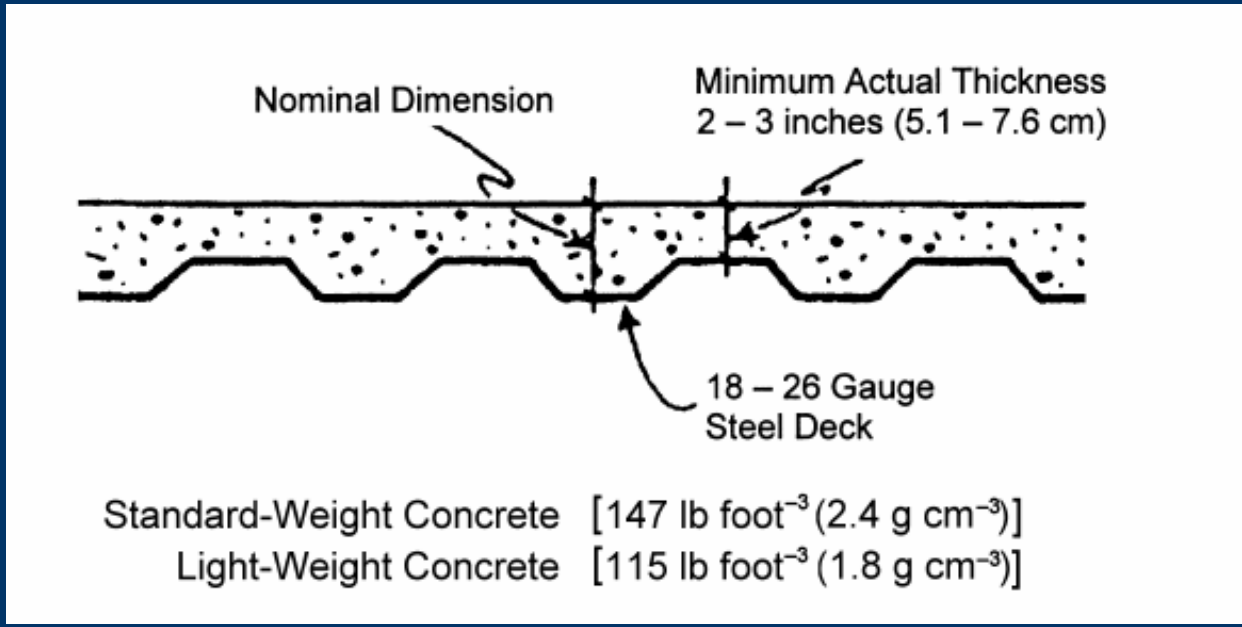
T=1/20 public toilets, vending areas, storage rooms, outdoor area with seating, unattended waiting rooms, patient holding areas

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

Lead Lined Doors



Concrete Floor Slab on Steel Deck



The minimum thickness should be used in calculating barrier thicknesses for all primary barriers

For secondary barriers, an average thickness may be used in barrier calculations

Penetrations in Protective Barriers

- Penetration openings in protective barriers SHOULD be located in secondary barriers whenever possible.
- Openings above 2.1 meters do not require shielding.
- Penetrations SHALL have supplementary shielding at least equivalent to the displaced material.

Shielding Design Strategy

- Effective and efficient use of shielding materials and the development of optimal design strategies require communication and cooperation between the architect, the qualified shielding expert, and the facility representative.
- Requires knowledge of the sources of radiation in a facility, the occupancy and usage of adjacent areas, and construction materials in floors, ceilings and walls

Post Construction Shielding Evaluation

- After construction, a performance evaluation (radiation safety survey) SHALL be performed by a qualified expert.
- Confirm that shielding provided will achieve the shielding design goal (P)
- Independent check that the assumptions used in the shielding design are conservatively safe.
- Recommend periodic monitoring of workload during actual operation

Documentation to be Maintained by the Operator of the Facility

- Shielding design data including assumptions and specifications
- Construction or as-built documents showing location and amounts of shielding materials installed.
- Post-construction survey reports
- More recent re-evaluations of room shielding relative to changes in utilization

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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