SKYSHINE AND ADJACENT STRUCTURES

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- Skyshine is important when a vault roof is essentially unshielded, i.e. the roof is designed to protect from the elements only.

NCRP 51 Approach

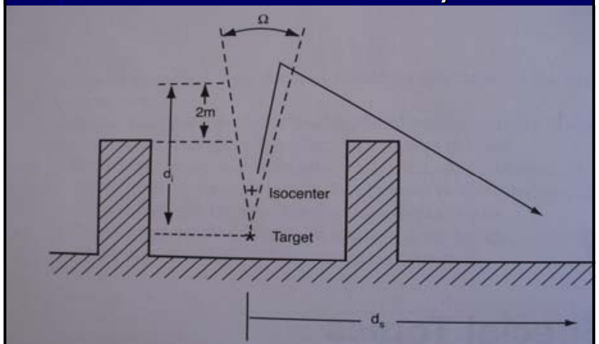
- McGinley, pp 93-99
- NCRP Report 51, pp 68-71

SKYSHINE:

- Two components for high energy installations:
  - Photon
  - Neutron

PHOTONS

Photon Geometry



From McGinley, page 94

Where:

d_s = horizontal distance in meters from isocenter to point of measurement.

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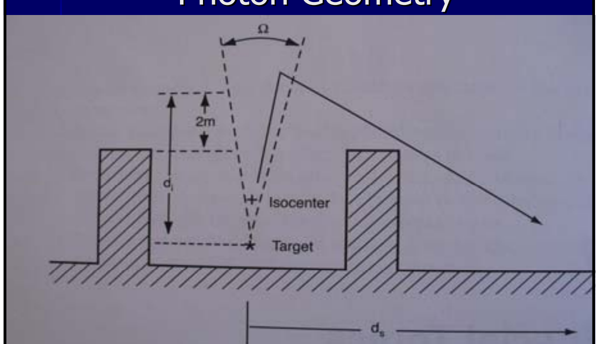
Ω = solid angle of maximum radiation field size

Photon Geometry



From McGinley, page 94

To Add a Level of Shielding:

$B_{XS} = 4.02 \times 10^{-6} D(d_i d_s)^2/(D_{io}\Omega^{1.3})$ (eq. 1)

Where:
B_{XS} = roof material transmission ratio
D = photon dose equivalent rate (nSv s^{-1}) at point of measurement.
D_{io} = linac output (cGy/s) at isocenter (1 m).

NCRP 51, p 69

Solving Eqn. 1 for D:

$$D = 2.49 \times 10^5 B_{xs} D_{io} \Omega^{1.3}/(d_i d_s)^2$$

(eq. 2)

Determination of Solid Angle

- For a beam with a circular cross section:

$$\Omega = 2\pi(1-\cos\theta)$$

Where: Ω = solid angle in steradians

π = pi

θ = angle between CAX and beam edge.

Determination of Solid Angle

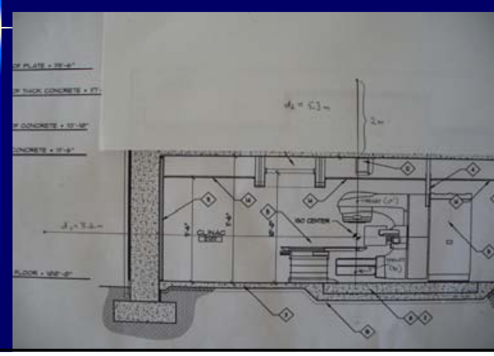
For a 40 cm x 40 cm field at 100 cm:

$$\theta = \tan^{-1}(20\text{ cm}/100\text{ cm}) = 11.3^{o}$$

So:

$$\Omega = 6.28\ (1 - \cos 11.3) = 0.122 \text{ ster}$$

A Photon Calculation



A Photon Calculation

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Assume:

- D_{io} = 600 cGy/min = 10 cGy/s at isocenter (100 cm)
- Roof provides no photon shielding, i.e. B_{xs} = 1.00
- Calculation of solid angle adequately approximates square beam geometry.

A Photon Calculation

Then:

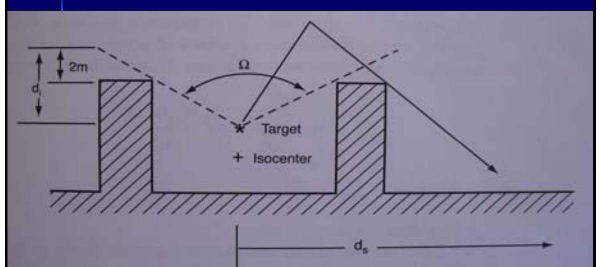
$D = 2.49 \times 10^5 B_{xs} D_{io} \Omega^{1.3}/(d_i d_s)^2$

$= 2.49 \times 10^5 (1)(10)(0.122^{1.3})/(8.2 \times 5.3)^2$

=85.6 nSv/sec

NEUTRONS

Neutron Geometry



- From McGinley, page 95

Where:

- Ω = solid angle defined by target and vault walls.

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- Ω = solid angle defined by target and vault walls.
- d_i and d_s are as previously defined.

To calculate shielding:

$$B_{ns} = 1.19 \times 10^{-5} H (d_i)^2/\Phi_o\Omega \qquad \text{(eq. 3)}$$

Where:
B_{ns} = roof neutron shielding ratio.
H = neutron dose equivalent at ground (nSv/s).
d_i = distance from target to roof + 2 m.
Φ_o = neutron fluence rate ($cm^{-2}s^{-1}$) at isocenter.
Ω = solid angle defined by target and vault walls.
NCRP 51 p 71

To calculate shielding:

- Note absence of d_s in equation 3.

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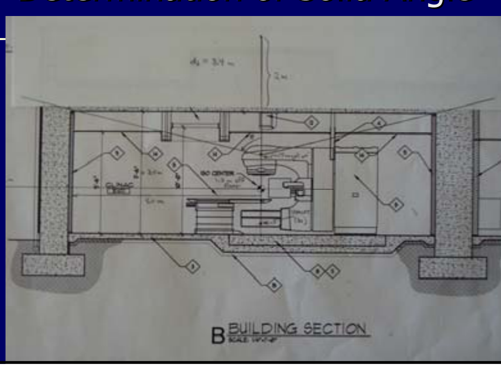
- Note absence of d_s in equation 3.
- Equation 3 is intended for use at all distances d_s < 20 meters.

Solving Eqn. 3 for H:

$$H = 8.4 \times 10^5 B_{ns}\Phi_o\Omega/d_i^2 \qquad \text{(eq. 4)}$$

To predict dose equivalent rates within 20 feet of an outside wall.

Determination of Solid Angle

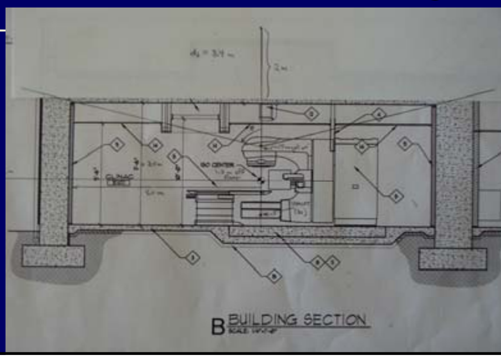


Determination of Solid Angle

- Floor to isocenter = 1.3 m
- Target to isocenter distance = 1.0 m
- Wall height = 3.5 m

So, target to ceiling = 3.5-1.3-1=1.2 m
(the side adjacent to θ)!

Determination of Solid Angle



Determination of Solid Angle

- Using an architect's scale, the distance from the isocenter to the wall = 5.0 m (the side opposite θ)!

So, $\theta = \tan^{-1}(5/1.2) = 76.5^{o}$

OR……

Determination of Solid Angle

You could just measure θ with a protractor…..

Determination of Solid Angle

So:

$\Omega = 2\pi(1 - \cos 76.5^{o}) = 4.8$ ster

To Calculate H:

From McGinley, page 96:

$\Phi_o = 6.6 \times 10^5$ cm^{-2}s^{-1} based the author's on measurements using an 18 MV beam.

To Calculate H:

From NCRP 51, Appendix F, p 117:

$B_{ns} = 3 \times 10^{-10}$ Sv cm^{-2} for a average neutron energy of 1.1 MeV.

Energy based on "CLINAC 1800, 2100C(/D), 21EX,23EX RADIATION LEAKAGE DATA" VARIAN Oncology Systems (4/98)

To Calculate H:

So:

$H = (8.4\times10^{4})(3\times10^{-10})(6.6\times10^{5})(4.8)/(3.4)^{2}$

$= 6.9$ nSv/s

How well does it work?

McGinley, page 98:

Photons: predicts measured exposures within a factor of 1.5 at d_s = 10.6 meters. Off by a factor of 5 at greater than thirty meters. **Generally underestimates actual exposures at distances significantly beyond the vault wall!**

How well does it work?

McGinley, page 98:

Neutrons: Predicts a constant exposure out to d_s = 20 meters. Measured data varies by a factor of three over this range.

What has changed?

- Skyshine: NCRP report 151, pp 84-87:

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NOTHING NEW!!!