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PET Site Planning and Radiation Safety

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Location of PET Imaging Center Relative to Cameras and Probes.

- Collimation and shielding of these devices will not be adequate for 511 keV photons.
- Make sure PET area is remote from fixed gamma camera and probe locations.
- Establish a path to/from the hot lab around the camera sites to the PET scan area. Locate a second path from PET scan to the outside for patients' use when leaving.

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Limits to Radiation Exposure

- Worker's area has 5 rem per year for whole body radiation dose.
- Extremity and other organ dose is 50 rem per year for workers.
- Worker's Lens is limited to 15 rem per year.
- Public area has limit of 100 mrem per year and 2 mrem in any hour.

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Table of Several PET Sources

Radionuclide	Half Life	Probability of Positrons
F-18	110 minutes	0.97
C-11	20 minutes	1.00
N-13	10 minutes	1.00
O-15	124 seconds	1.00
Cu-64	12.7 hours	0.19

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Mitigating Factors for Radiation Safety in PET Facilities.

- Time Averaging of Source Strengths.
- Patient Intrinsic Attenuation of Approximately a factor of two.
- Mobile one inch Pb Shields which provide 6 HVLs of Pb. This may be available at no cost due to prior use in Cs-137 therapies. Otherwise, $1500 each.

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Time Averaging of F-18 Sources.

We assume a one hour clinical time (τ) and average the F-18 exposure rate:

$$\langle dX/dt \rangle_{\tau} = \frac{\int_0^{\tau} dX/dt\,(t = 0) \exp(-\lambda t)\, dt}{\tau}$$

$$\langle dX/dt \rangle_{\tau} = 0.83 * dX/dt\,(t = 0) \text{ if } \tau = 1.0 \text{ h.}$$

Hence the effective exposure rate is 17% less the initial rate. May be useful in some applications.

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Calculation of Exposure due to Point Sources.

$$dX/dt\ (R/h) = \frac{\Gamma * A\ (mCi) * Attenuation * Occupancy}{R\ (cm)^2}$$

Note presence of distance (R), shielding (attenuation) and time (occupancy) in the formula. Latter two are pure numbers. Γ is the gamma ray constant of the positron emitter.

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Gamma Ray Constants (Γ)

• F-18	• 5.73 R cm^2/mCi/h
• C-11	• 5.91
• N-13	• 5.91
• O-15	• 5.91
• Cu-64	• 1.16
• Tc-99m	• 0.78
• Cs-137	• 3.32

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Exposure Rates with 10 mCi of Unshielded F-18

R	100 cm	200 cm	400 cm
dX/dt	5.73 mR/h	1.4 mR/h	0.36 mR/h
$<dX/dt>_\tau$ only	4.75	1.16	0.30
2.54 cm Pb only	0.090	0.022	0.0057
2.54 cm Pb + $<>_\tau$	0.075	0.018	0.0047

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Relative Importance of Triad Members.

Distance is generally the most important consideration; always try to have a large space available to keep injected patients and sources far from the staff and visitors. New facilities should be designed with emphasis on distance separation.

Shielding is the second most important. Keep something between staff and the patient or other source. Older facilities redesigned for PET may require extensive shielding. Mobile shields (2.5 cm to 5.0 cm of Pb) may be of use here.

Time restrictions may be the least restrictable due to medical care constraints.

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Attenuation (HVL) Factors for Positron (511 keV) Emitters.

- Lead • 4 mm
- Concrete • 9.83 cm
- Earth • 15.4 cm

Note: Attenuation (HVL) for Tc-99m (140 keV) in lead is only 0.17mm. Thus, 511 keV requires approximately 20-fold more attenuating lead for the same effect.

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Sample Calculations for PET Case I: Scanning Area

- Installation into former IVP room of x-ray.
- 1/16 inch of Pb already in walls, window.
- No occupancy below the scanner.
- One outside wall.

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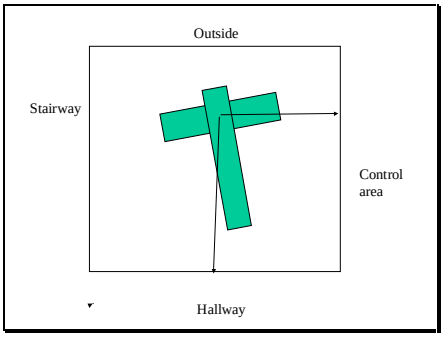

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Control Room Area

Already has 1/16 inch Pb
yearly limit is 5000 mR.; T = 1

R	X (yearly)	X*T	X*T*At.
8 feet	1997 mR	1997 mR	1520 mR

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Hallway Area

Already has 1/16 inch Pb
yearly limit is 100 mR; T = 1/4.

R	X (yearly)	X*T	X*T*At.
13 feet	749 mR	187 mR	142 mR

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Stairwell Area

Already has 1/16 inch Pb
yearly limit is 100 mR; T = 1/16

R	X (yearly)	X*T	X*T*At.
7 feet	2700 mR	169 mR	128 mR

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Ceiling Area

Already has 10 inch Concrete
yearly limit is 100 mR; T = 1/2

R	X (yearly)	X*T	X*T*At.
13 feet	749 mR	375 mR	63 mR

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Conclusions on Example I

- Two areas exceeded their limits: Hallway (128 mR) and Stairwell (142mR).
- We can invoke one mitigating factor which is the patient's own attenuation. This is approximately a factor of two. Hence these two values, in probably only 64 and 71 mR respectively.

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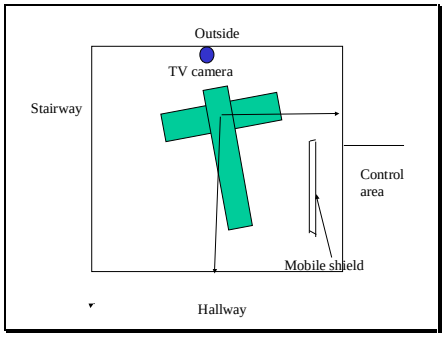

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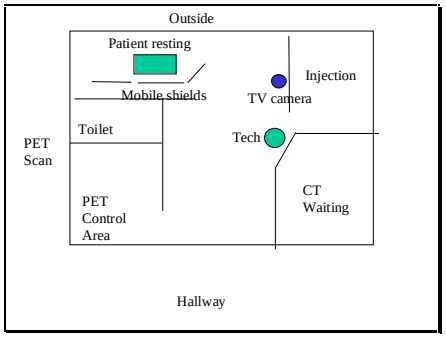

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Television Monitors.

- 1st Monitor for patient in resting area.
- 2nd Monitor for patient being scanned.
- Thus, no need for direct line of sight between patient and nurse or technologist.

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Exposures Should be Measured.

- Technologist area (PET control booth)
- Nurse's desk or cubicle.
- Waiting rooms.
- Hallways.
- Spaces above (and below if occupied) the PET scanning area and resting area.

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Badge Policy for PET

- Use ring badge on dominant hand.
- Use of two ring badges can be justified.
- Document ring badge reading changes with onset of PET scans.
- Document whole body badge reading changes with onset of PET scans.

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Selected References.

- Alan Brodsky, **Handbook of Radiation Measurements and Protection. Section A**. CRC Press, Table 3.5.1 p. 238.
- **NCRP Report No. 39**. Table 4 p.65.
- H.E. Johns and J. Cunningham, **The Physics of Radiology, 3rd Ed.**, Thomas Press, p. 738.
- In preparation, AAPM authors.