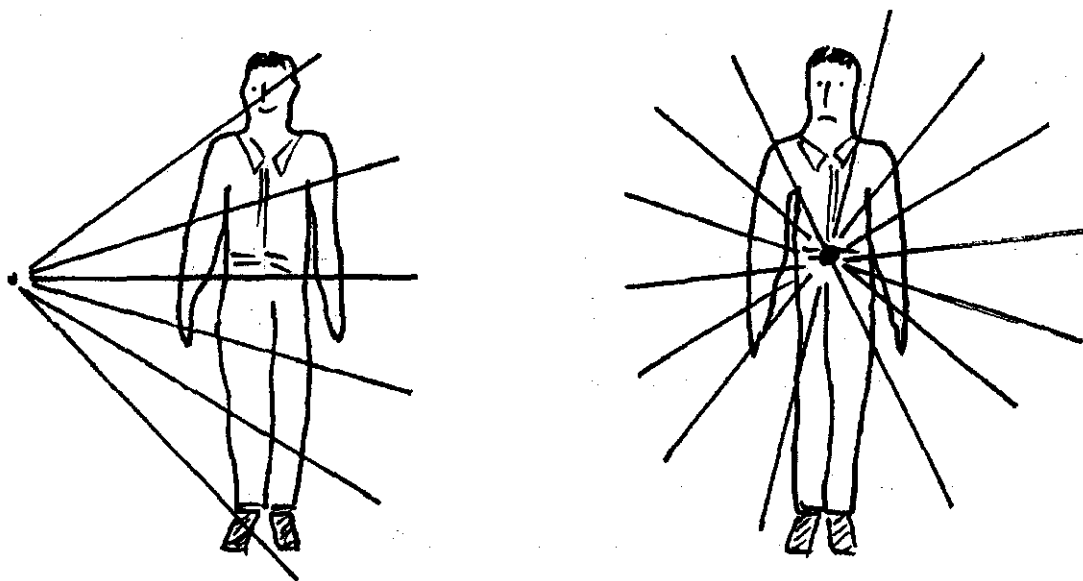


# CHAPTER 6

## PROTECTION FROM EXTERNAL RADIATION



*Fig. 6.1. External and Internal Exposure*

# **TIME, DECAY, DISTANCE & SHIELDING**

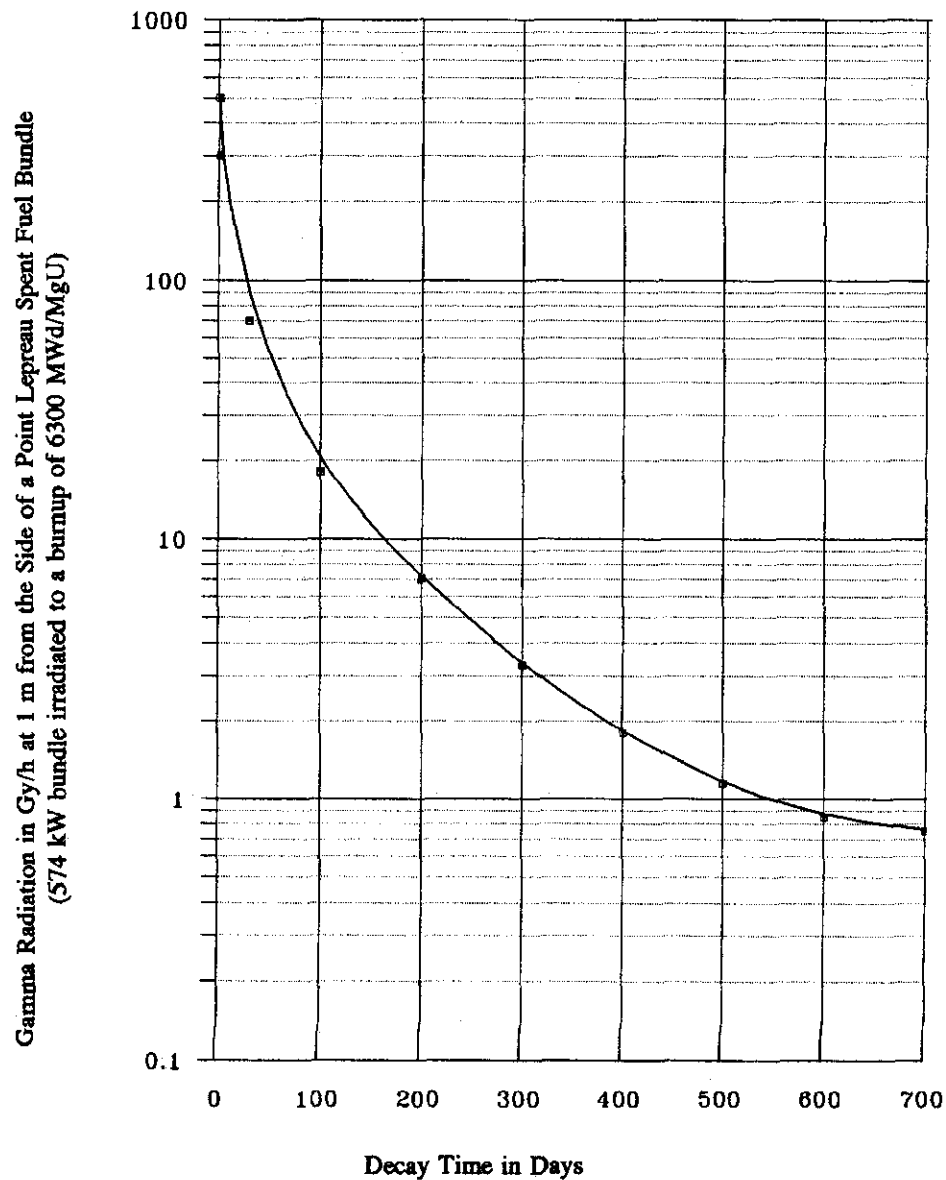
External radiation exposure can be decreased by:

- 1) reducing the **TIME** spent near a source;
- 2) allowing the source to **DECAY** before approaching it;
- 3) increasing the **DISTANCE** between yourself and the source;
- 4) absorbing the radiation in **SHIELDING** material placed between yourself and the source.

# DECAY

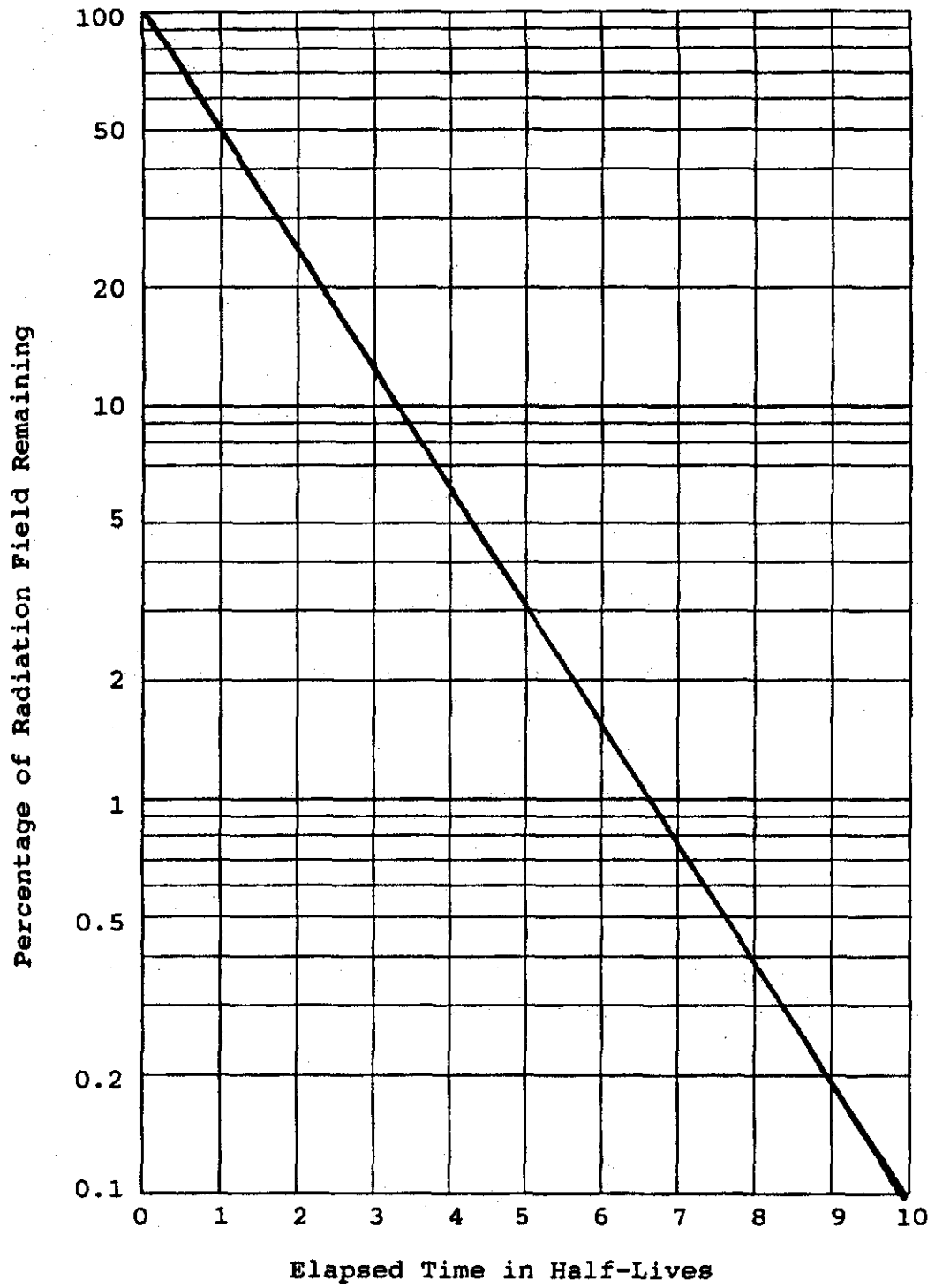
$$n(t) = n(0) \exp(-\lambda t)$$

$$\lambda = \ln 2 / t_{1/2}$$



***Decrease in Fission product Activity with Time.***

**Radiation Fields drop to about 1% after every 7 half-lives**



*Fig. 6.2. Decrease of Radiation Fields With Time*

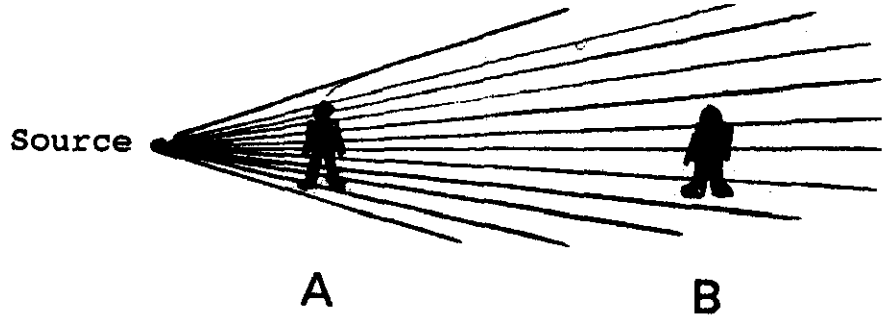
# DISTANCE

"point" sources: inverse square law

gamma only

no shielding

no beams



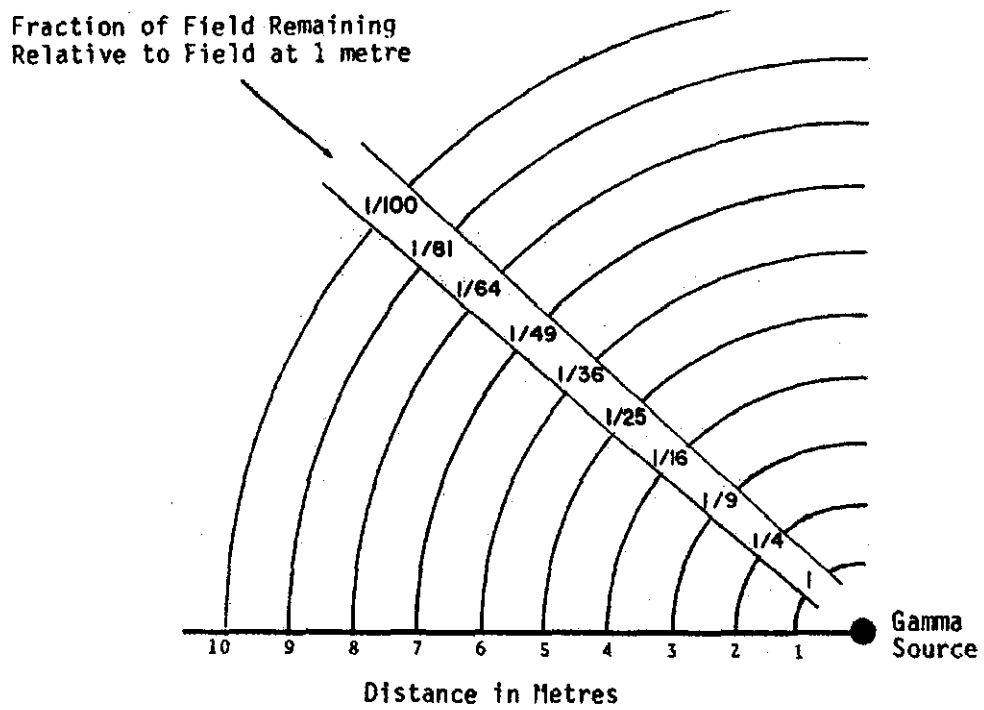
"line" sources: inverse drop off

"plane" sources: little drop off

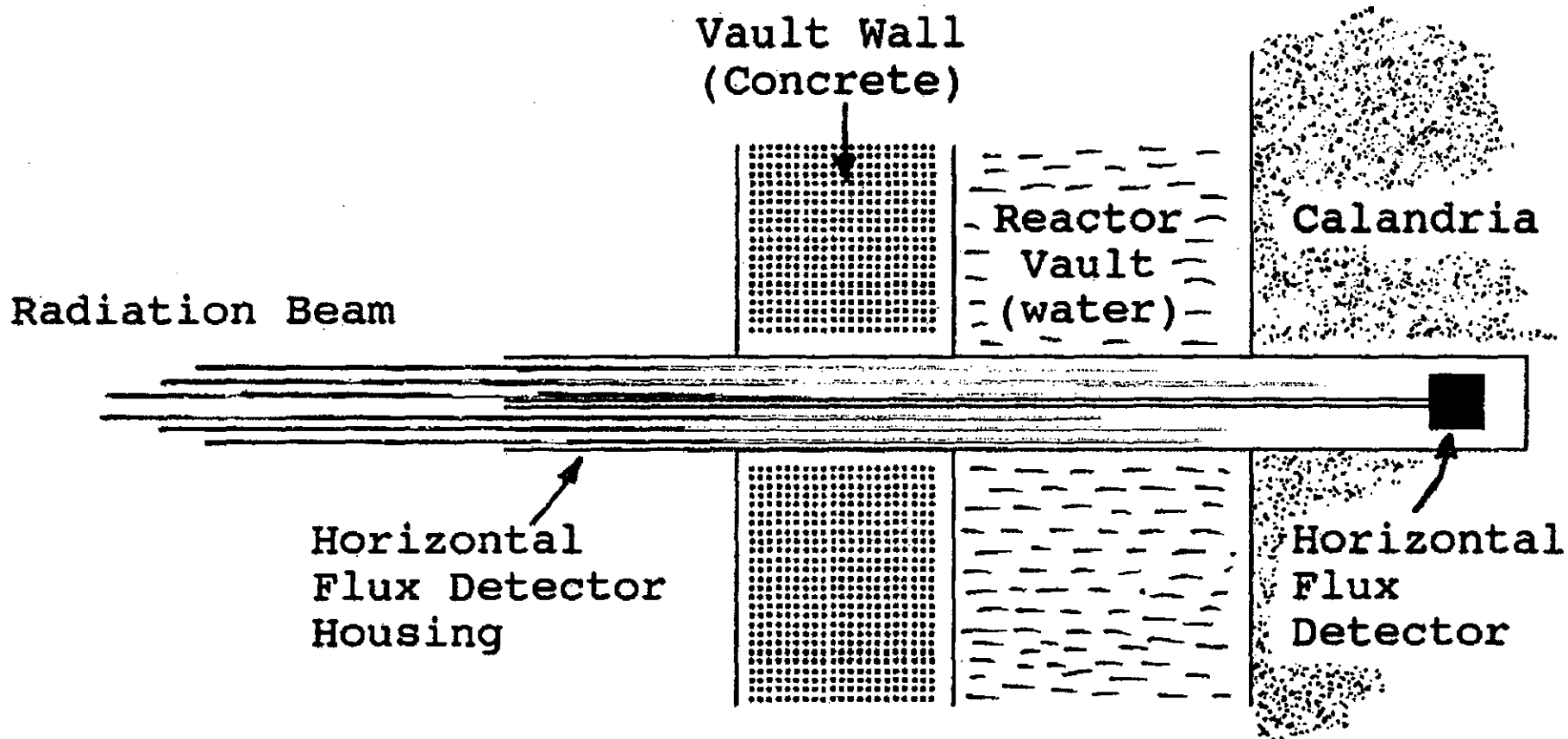
beta sources

alpha sources

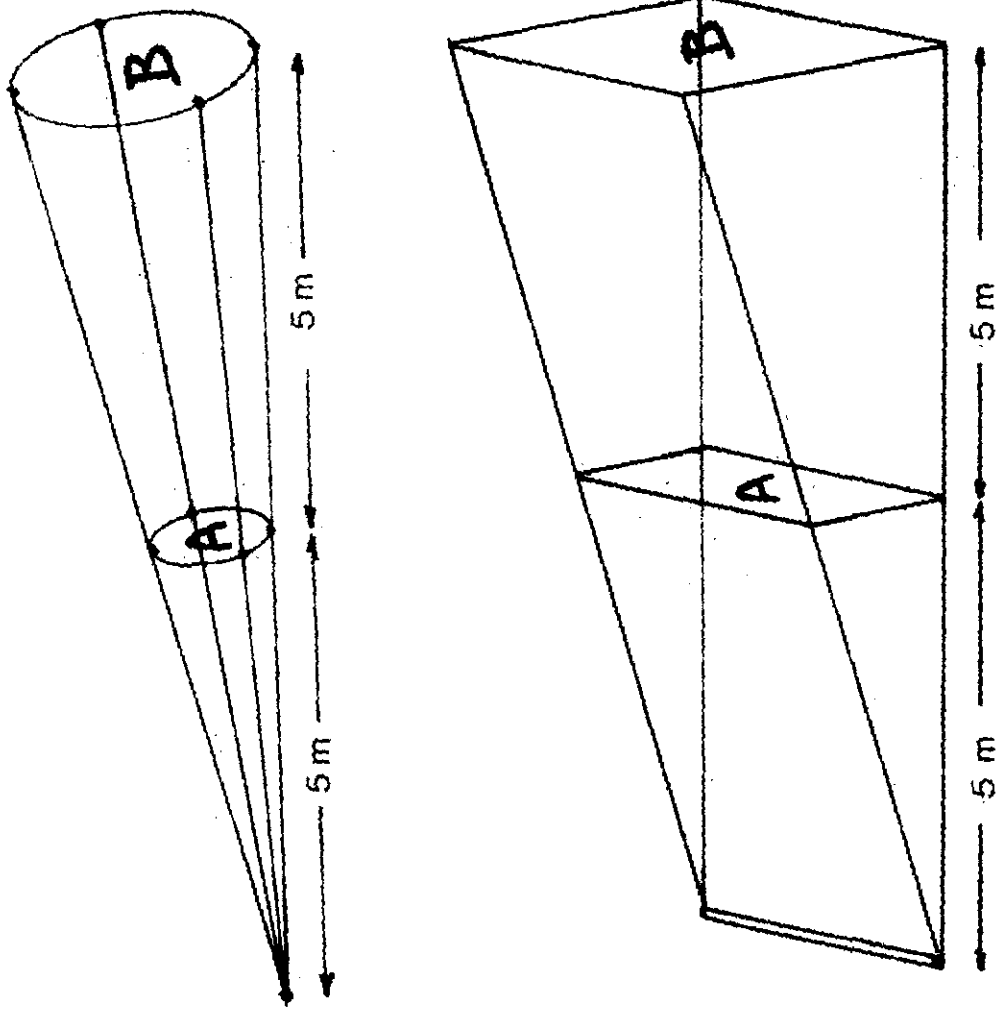
*Fig. 6.4. Fraction of Radiation Field Remaining*



*Fig. 6.5. Lepreau Maintenance Supervisor*

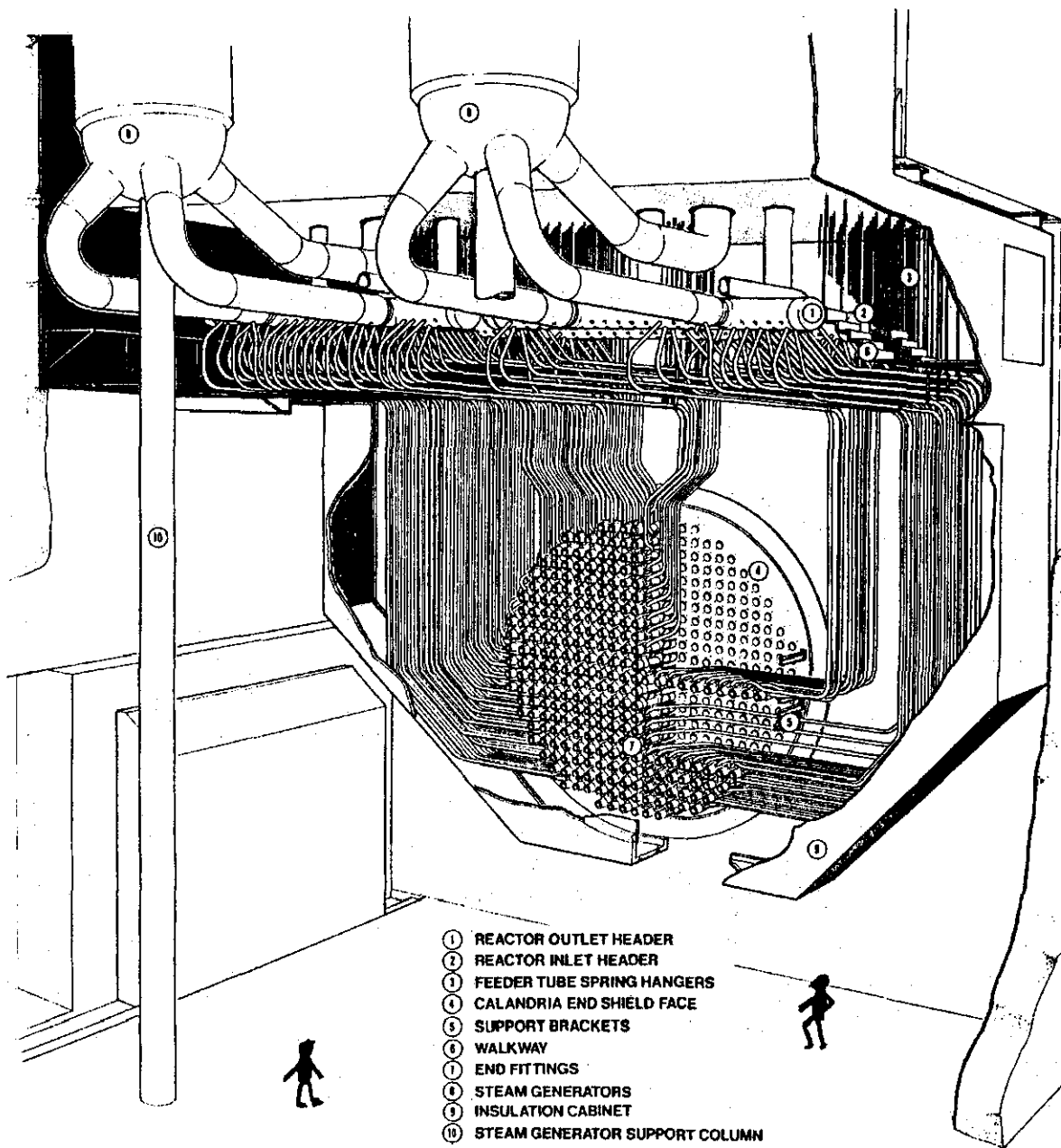


*Fig. 6.6. Radiation Beams*



*Fig. 6.7. The Spread of Gamma Radiation  
From a Point Source and a Line Source*





*Fig. 6.8. An Example of a Plane Source*

## ALPHA SHIELDING

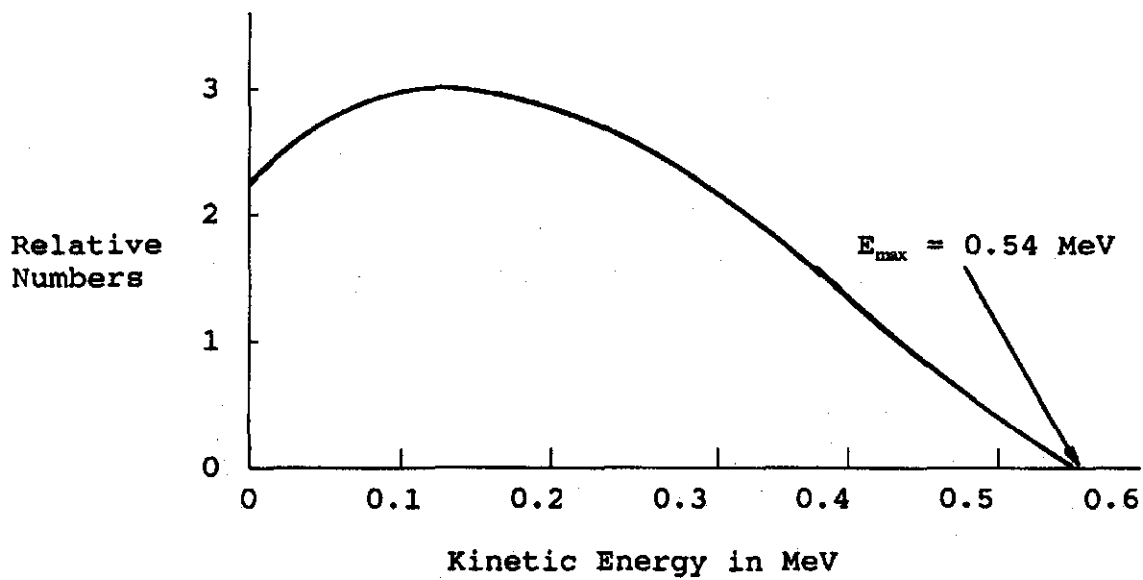
no problem: range = 10 cm in air  
see Fig. 2.9, p.39

## BETA SHIELDING

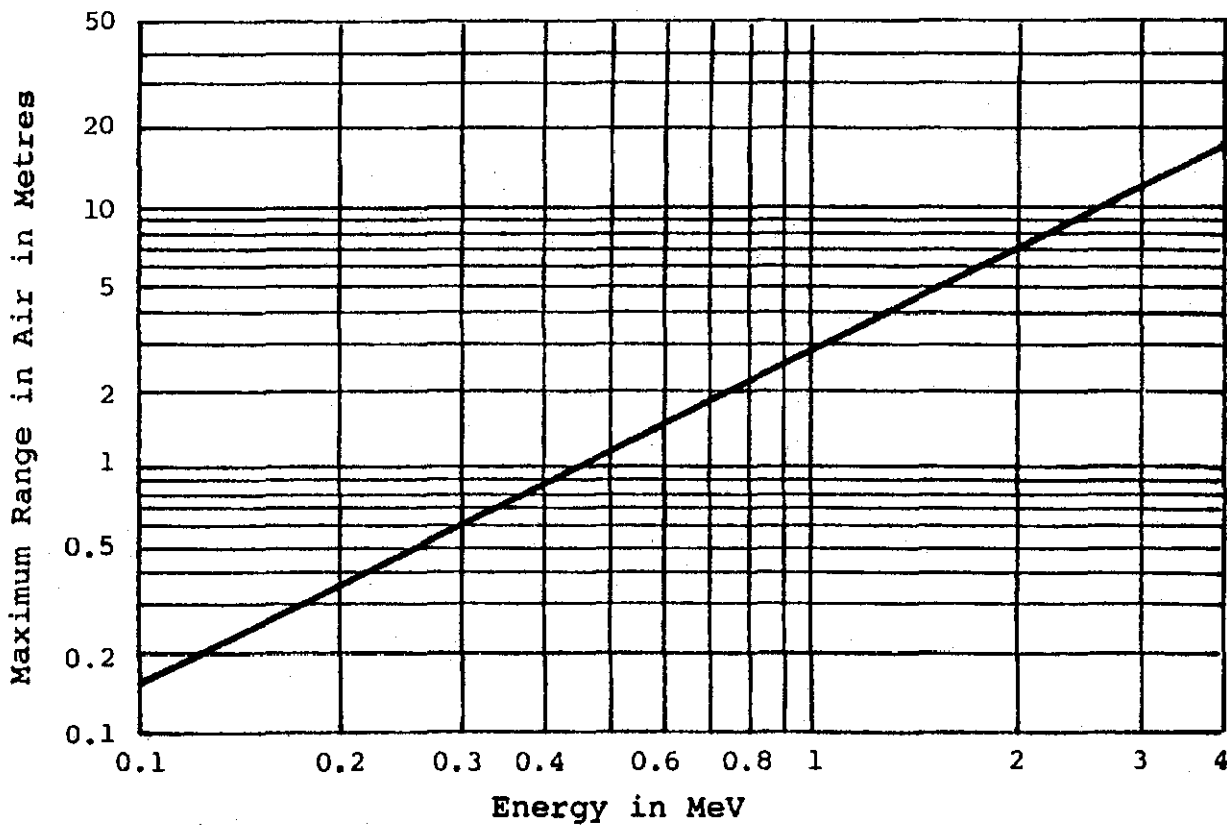
beta radiation exposes skin and eye lens  
range = few metres in air  
see Fig. 2.10, 2.11, 2.12 (p.40-42)

### ABSORPTION OF BETA RADIATION Sr-90 (2.2 MeV) and Tl-204 (0.763 MeV)

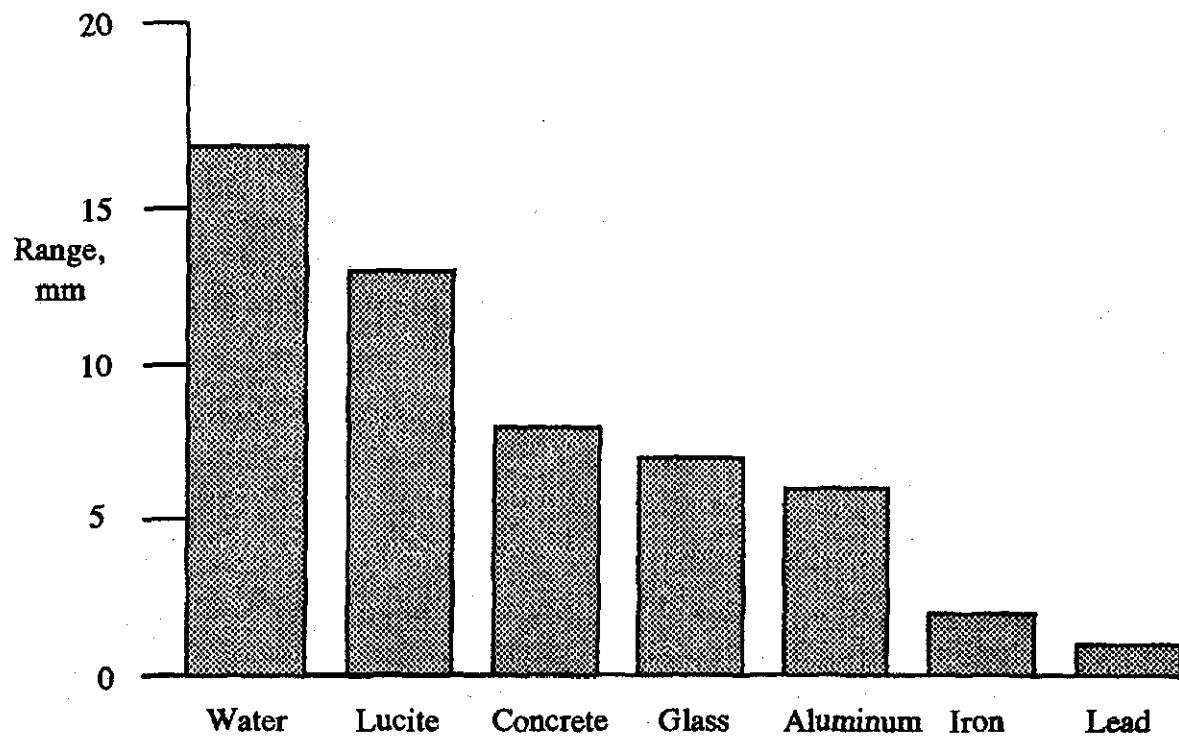
Type of Material	Percent Absorption	
	Sr-90	Tl-204
Safety Glasses (Lens)	95	100
Full-Face Respirator (Lens)	80	100
Plastic Suit	10	60
Rubber Gloves (for suit)	10	60
Cotton Gloves (new)	0	80
Disposable Hood (for suit)	0	25
Brown Coveralls (new)	0	15



***The Beta Energy Spectrum of Sr-90.***



***Penetrating Ability of Beta Radiation in Air***



***Maximum Range of 3 MeV Beta Particles in Various Materials***

# **GAMMA SHIELDING**

## **Half-Value Layer, HVL**

Photoelectric effect ( $Z^5$ )

Compton scattering ( $Z$ )

Pair Production ( $Z^2$ )

Figs. 2.13 (p.43), 2.14 (p.44), 6.9, p.255

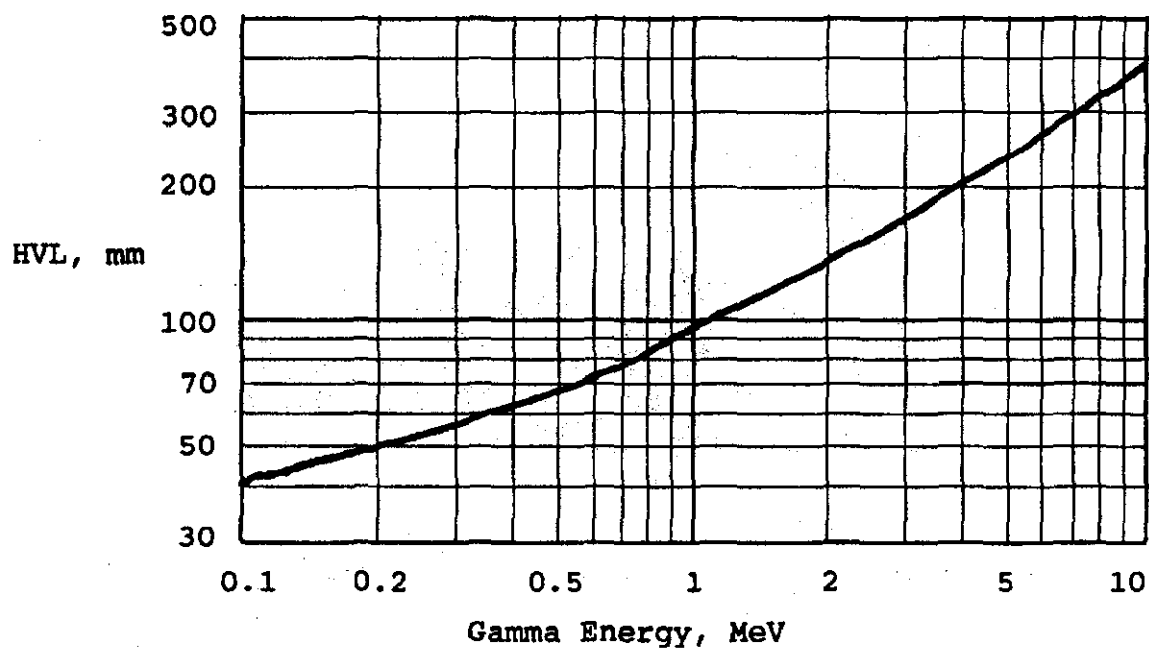
Gamma Build-Up

# **NEUTRON SHIELDING**

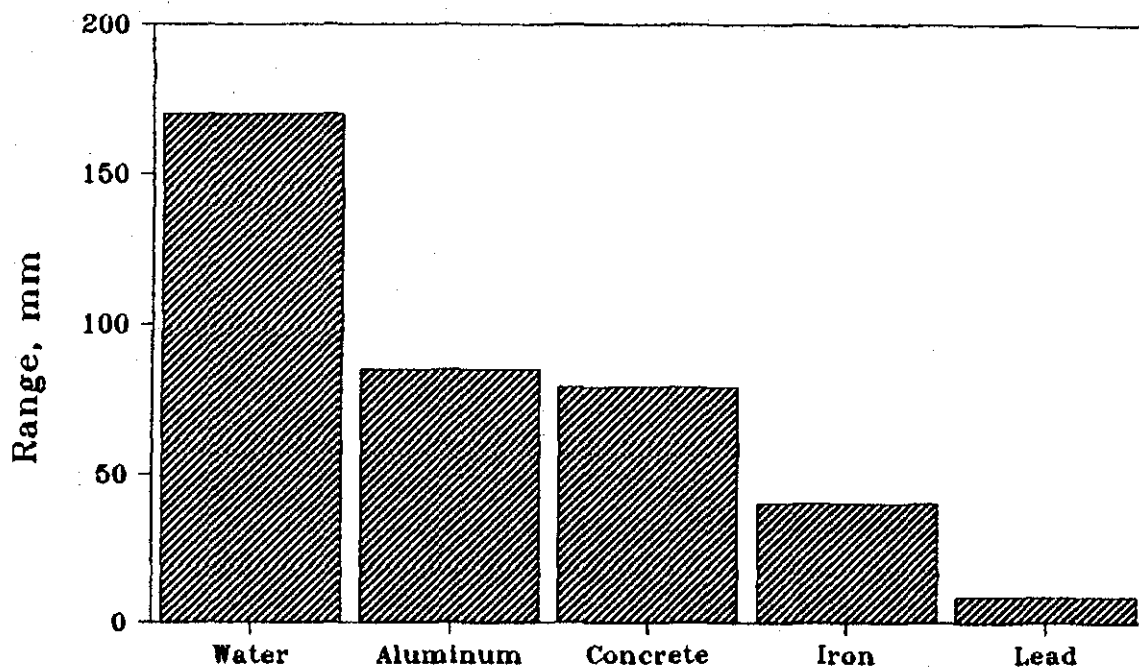
Inelastic scatter: high  $Z$ , below 1 MeV

Elastic scatter, low  $Z$ , low energy

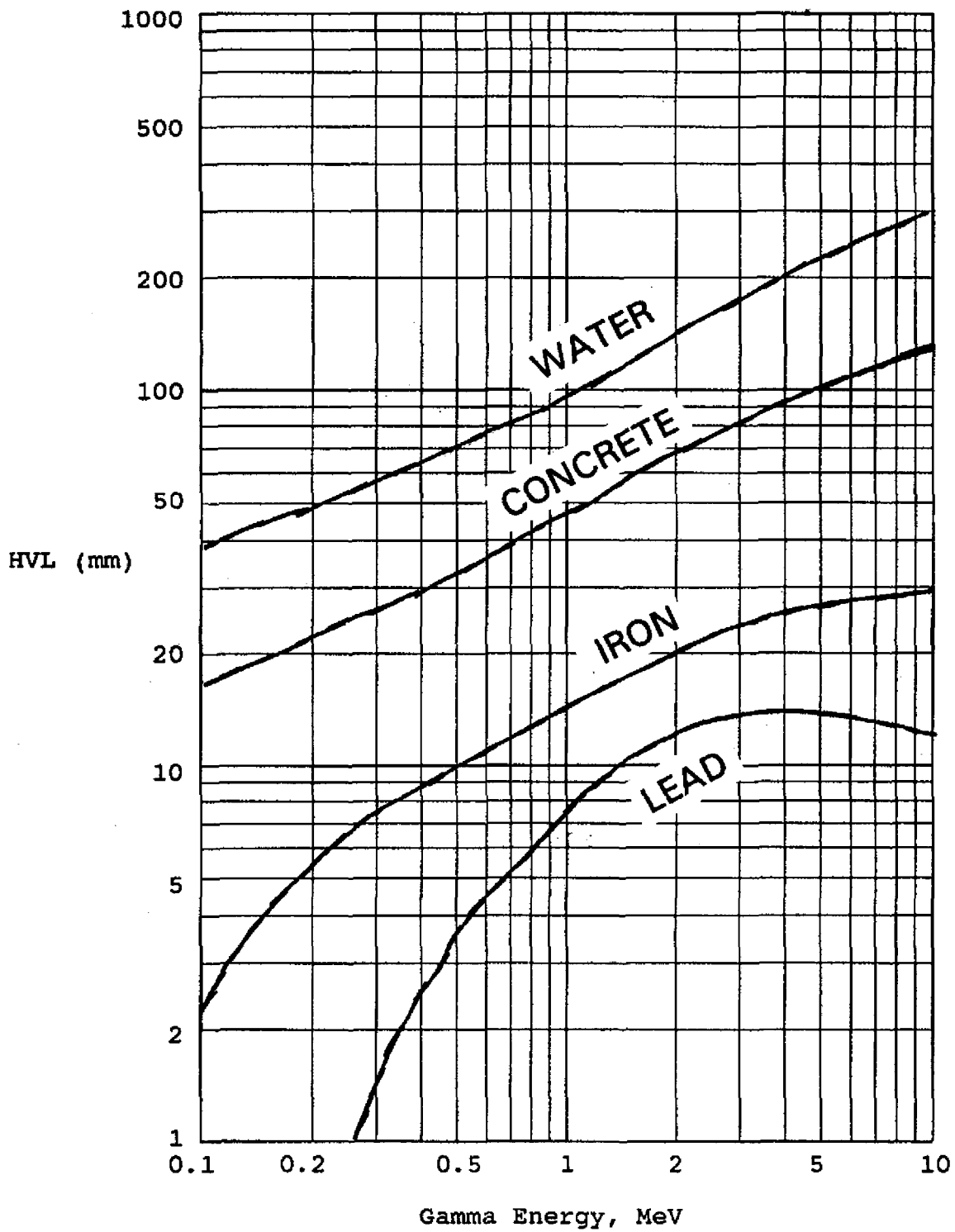
therefore: composite shields



***Half-Value Layer of Water for Various Gamma Energies***



***Half-Value Layer for 3 MeV Gamma Radiation***



***Fig. 6.9. HVLs of Various Materials***

# **TYPES OF SHIELDING**

Permanent Shielding

Biological Shield

Thermal Shield

Operational Shield

Shutdown Shield

Shielding Penetrations



# **SAFETY PRECEDENCE SEQUENCE**

1. Eliminate the hazard
2. Minimize the Hazard
3. Install physical barriers
4. Install warning devices
5. Minimize chance for human error
6. Establish procedures
7. Train, motivate, supervise workers
8. Accept hazard as is

## **ACCESS CONTROL**

interfaced to Alarming Area Gamma  
Monitoring System

Subsystems A, B, C:

*Subsystems A*

conditioned by Reactor Power

*Subsystem B*

conditioned by Fuelling Machines

*Subsystem C*

controlled by Shift Supervisor

**Question 5.1 (Biological Effects)**

**MARKS      QUESTION**

Rank the following in order of increasing significance and give the reasons for your ranking order.

- 10 (18 min) (a) (i) 500 mGy from an acute intake of tritium
- (ii) 500 mGy thyroid dose from an acute intake of I-131
- (iii) 50 mGy to the whole body from an acute exposure to gamma radiation
- (iv) 50 mGy to the whole body from an acute exposure to slow neutrons.
- 10 (18 min) (b) (i) 5 mGy to the whole body from an acute exposure to fast neutrons
- (ii) 50 mGy to the whole body from an acute exposure to gamma radiation
- (iii) 50 mGy from an acute intake of tritium
- (iv) 200 mGy thyroid dose from an acute intake of I-131
- (v) 300 mGy from an acute exposure to beta radiation (external).
- 6 (11 min) (c) (i) 500 mSv from an acute intake of tritium,
- (ii) 500 mSv to the thyroid from an acute intake of I-131,
- (iii) 500 mSv acute whole-body exposure to gamma radiation.

**Note:** Information from Module 6 on Dose Limits is required to answer this question.