

## Appendix 1 Example Shielding Calculations

### 1. Determine the shielding requirement for a shielding category not defined by the “Cossairt Criteria.”

Given from the Cossairt Criteria:

| Category | Dose Range | Posting/Barrier    | Magnet in enclosure (feet) | Pipe in enclosure (feet) | Buried pipe (feet) |
|----------|------------|--------------------|----------------------------|--------------------------|--------------------|
| 1        | D<1        | No occupancy limit | 22                         | 20                       | 24                 |
| 2        | 1<D<10     | Minimal Occupancy  | 19                         | 17                       | 21                 |

Problem: A shield category is needed for 1<D<5.

Solution: Observe difference in shielding required for Category 1 and 2 is 3 feet and that the maximum dose rate is a factor of 10 greater for Category 2 compared to Category 1.

To calculate the magnet in enclosure shielding requirement for 1<D<5 by scaling up from Category 2,

$$S_{(5)} = S_{(10)} + 3 \cdot \log_{10}(D_{\text{initial}}/D_{\text{final}})$$

$$S_{(5)} = 19 + 3 \cdot \log_{10}(10/5)$$

$$S_{(5)} = 19.9 \text{ feet}$$

Alternately, the same result may be arrived at by scaling down from Category 1:

$$S_{(5)} = S_{(1)} + 3 \cdot \log_{10}(D_{\text{initial}}/D_{\text{final}})$$

$$S_{(5)} = 22 + 3 \cdot \log_{10}(1/5)$$

$$S_{(5)} = 19.9 \text{ feet}$$

The shielding requirement determinations for pipe in enclosure and buried pipe are done similarly.

NOTE: The laboratory normally uses the standard shielding thicknesses effectiveness factors of 2.8 feet and 2.6 feet for soil and concrete, respectively as equivalent for factor of 10 reduction in dose rates. In this assessment, we use the difference between categories as the scaling factor so that the same result is obtained whether scaling from the higher or lower Category.

### 2. Determine the shielding requirement when beam intensity, beam energy, and magnet to ceiling distance is different than given by the standard Cossairt Criteria.

Problem: 1.8 E16 protons per hour at 120 GeV will be run through an enclosure with a minimum of 20 feet of shielding, a magnet to ceiling distance of 1.6 feet. The shielding berm is fenced and is posted with Radiation Area signs. Determine if shielding is adequate under these conditions.

Given from the Cossairt Criteria:

| Category | Dose Range | Posting/Barrier | Magnet in enclosure (feet) | Pipe in enclosure (feet) | Buried pipe (feet) |
|----------|------------|-----------------|----------------------------|--------------------------|--------------------|
| 3        | 5<D<100    | Signs and ropes | 16.5                       | 15.5                     | 18                 |

Beam energy – 1 TeV; Beam intensity 1.2E15 protons per hour; Magnet to Ceiling distance 3 feet.

Determine scaling factor for magnet to ceiling distance. (See attachment to this Appendix regarding the justification for use of distance scaling factors.) Since the ceiling to magnet distance is less than 3 feet, we use:

$$F = (3 / 1.6)^2$$

$$F = 3.5$$

The energy scaling factor is 0.8.

The required shielding is given by:

$$S = 16.5 + 2.5[0.8 \log_{10}(120/1000) + \log_{10}(1.8E16/1.2E15) + \log_{10}(3.5)]$$

$$S = 16.5 + 2.5$$

$$S = 19 \text{ feet}$$

Since the shielding required is less than the shielding actually present, no additional precautions are necessary.