FN-103
1100.0

SHIELDING REQUIREMENTS FOR THE 200 BEV ACCELERATOR

J. DeWire

October 1, 1967

This note contains recommendations for radiation shielding of the various parts of the accelerator and summarizes the considerations which have been made to produce these recommendations. It is evident that there is sufficient information available at this time to enable us to design shields which will be adequate but not excessive. The design problem could be simplified by making all shields thick enough to attenuate any amount of radiation which could be produced by the accelerator during its life-time to a level comparable to the cosmic ray background. The resulting shields would not only be very expensive, but would also seriously restrict the operation and future development of the accelerator. Furthermore, if the accelerator were ever operated in a manner which required the full capacity of these shields, the radiation levels with in the accelerator housing would be intolerably high with regard to radiation damage and residual radioactivity. The shields must be designed with adequate safety factors to handle the radiation which will be generated by the accelerator under proper operation.

Attenuation by an earth shield

The extensive measurements by a BNL group at the AGS in 1965[1] and by groups from Berkeley, CERN, and Rutherford (BCR) at the CERN PS in 1966[2] provide good data from which we can derive an attenuation curve which applies to the 200 BeV accelerator. The BCR experiment is particularly useful for extrapolation to higher radiation levels and thicker shields, because the analysis of their data includes an excellent fit to their measured points by an empirical formula which takes into account the geometry of the shield, the angular distribution of the intitial cascade, and the linear spread of the initial source. Unfortunately the analysis discussed in refernece 2 refers to the shield above the housing which is only about 14 feet thick (earth equivalent). But according to W. S. Gilbert, the data from the side shield at larger depths shows an attenuation similar to that given in reference 2. The BNL results are in general agreement with BCR, but show a steeper attenuation curve. In using the BCR data we are therefore using the more pessimistic prediction of the two.

The dose curve shown in Fig. 1 is plotted from the maxima of the fitted curves shown in Figs. 9 and 10 of reference 2. The absolute value of the dose in scaled from the BCR data using their Model (a) which assumes that the spread of the source along the beam line scales as the betatron wavelength. Otherwise the dose is assumed to be directly proportional to the power deposited in the radiation source. The plot in Fig. 1 refers to a high radiation area in the main ring, an extraction area or an internal target. The following parameters are assumed:

Energy	-	200 BeV
Intensity	-	1.5×10^{13} protons/sec.
Fraction interacting in target or septum	-	0.10
Density of earth	-	1.8 g/cm^2

A similar curve for the quiet areas of the main ring is shown in Fig. 2. It is based on a loss of one percent of the beam spread uniformly over the circumference. The scaling from the BCR data is done using the expression given on page 12 of reference 2.

The curves given in Figs. 1 and 2 show a 10 fold change in dose for 4.3 feet of earth corresponding to an effective mean absorption length of 103 g/cm^2. This is much less than the interaction length of fast neutrons, but there are two contributing facturs to cause this reduction, both coming from the geometry of the source and shield First the dose is attenuated by the increasing distance from the source-for this geometry the dose falls off as the distance to a negative power between 1 and 2. The second effect, which is more important, is the strong forward concentration of the neutrons, causing them to go through the shield at large angles from the radial direction.

Choice of earth shields

The thickness of the earth shields over the various sections of the accelerator must be chosen on the basis of the source strength, the permissable radiation level at the shield boundary, and the desired factor of safety.

We propose the following values for these parameters:

Table I

	Main ring hot areas	Main ring quiet areas	Booster extraction	Booster quiet areas
Energy (BeV)	200	200	10	10
Intensity (p/sec)	1.5×10^{13}	1.5×10^{13}	2×10^{13}	2×10^{13}
Fraction of beam interating	0.10	0.01	0.05	0.01
Dose at shield boundary (moem/hr	1.0	1.0	1.0	1.0
Shield thickness (ft) (no safety factor)	24	12	20	12
Safety factor	20	50	50	50
Thickness with safety factor (ft)	30	20	28	20

The shield thickness in the plots includes the housing wall, but those given in the above table are the net earth thickness.

The safety factors are more than adequate to allow for higher energy and intensity. They represent minimum values of safety factor, because additional factors of 10 or more can be achieved by the use of shielding within the housing structure. The effective use of beam clippers and shields at the 8 foot straight sections can not only reduce the radiation at the outside boundary of the earth shield but can slso reduce the residual radiation within the housing.

It is interesting to compare the thickness of an earth shield with the radioactivity level which would be present in the housing after the accelerator had been operated at a level requiring the full thickness of the shield. The radiation level at the top of the shield over the AGS averages about 0.5 mrem/hr over the quiet areas during normal operation. Several hours after turn off the level of radioactivity in the housing below is about 10 mrem/hr. Using the approximate attenuation constant of a factor of 10 for 5 feet of earth we get the following values:

Table II

Shield thickness	Radioactivity level
10 ft.	10 mrem/hr.
20	1 rem/hr.
30	100 rem/hr.
40	10^4 rem/hr.

A 40 foot shield would appear to be of doubtful value, because if it were used fully the interior environment would become unfit even for the use of shielded vehicles A 30 foot shield would appear to be an upper limit for use over the high radiation area in agreement with Table I. A 20 foot shield over the quiet areas seems to be more than can be used unless we are willing to take the drastic step of denying unshielded access to the quiet areas for inspection and security checks. But unless significant cost savings can be achieved by reducing this shield below 20 feet, there is probably little reason for doing so.

---

(1) R. Casey, C. H. Distenfeld, G. S. Levine, W. H. Moore, and L. W. Smith, AGSCD - 13 November 9, 1966

(2) R. D. Fortune, W. S. Gilbert, and R. H. Thomas, UCID 10199, April 28, 1967.

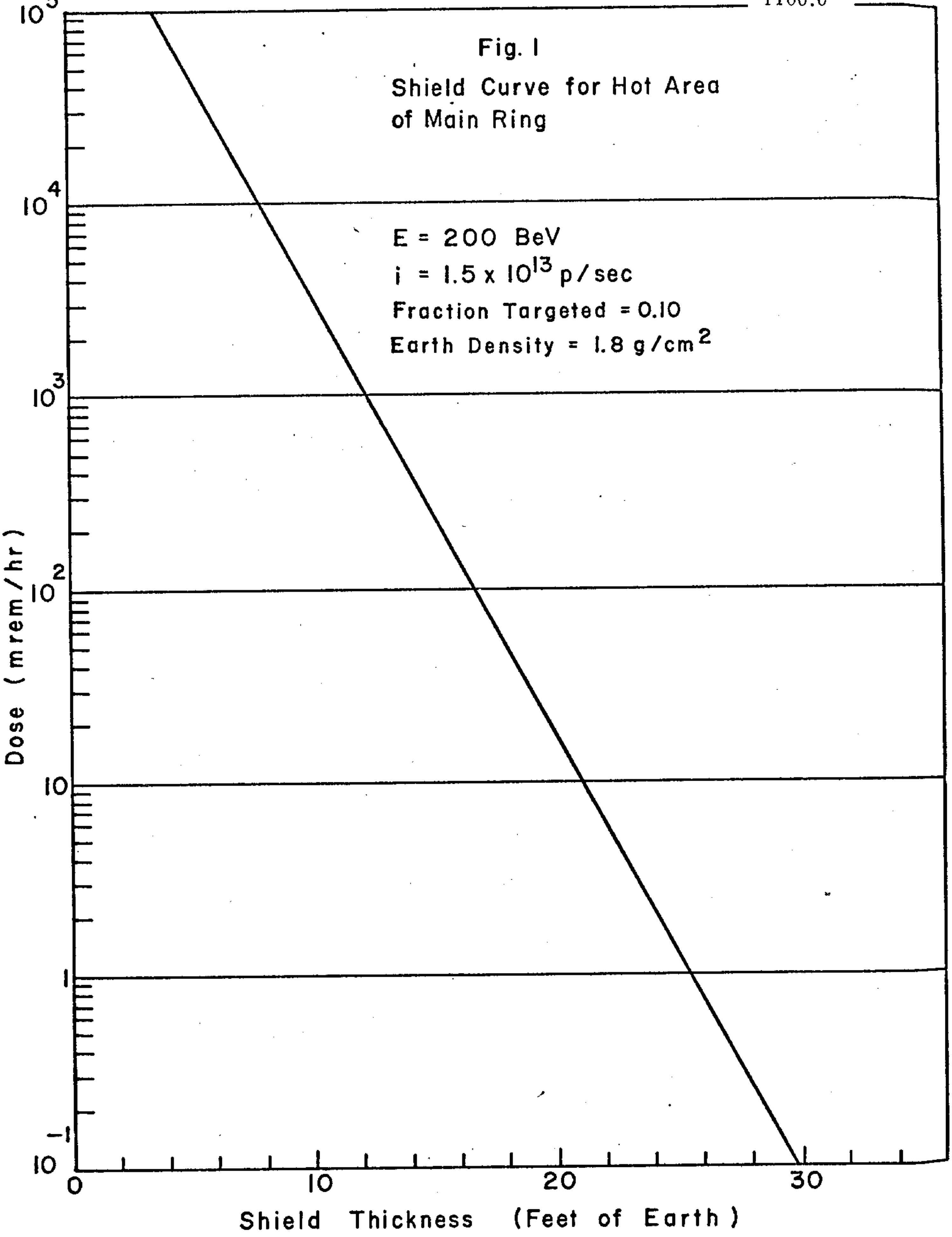
Fig. 1
Shield Curve for Hot Area of Main Ring
E = 200 BeV
i = 1.5 x 10^13 p/sec
Fraction Targeted = 0.10
Earth Density = 1.8 g/cm^2
Dose (mrem/hr)
10^5
10^4
10^3
10^2
10
1
10^-1
0
10
20
30
Shield Thickness (Feet of Earth)

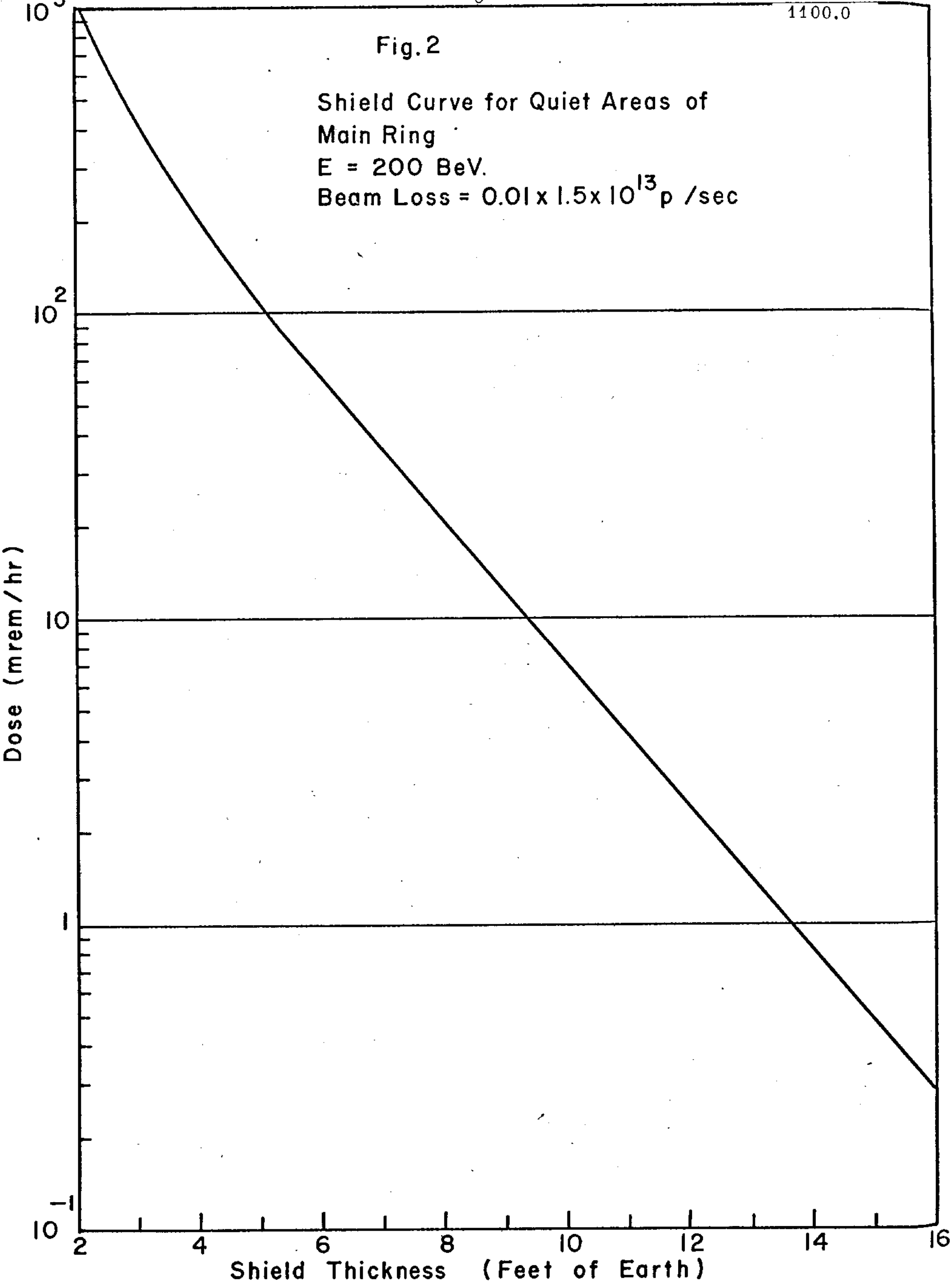
Fig. 2
Shield Curve for Quiet Areas of
Main Ring
E = 200 BeV.
Beam Loss = 0.01 x 1.5 x 10^13 p /sec
10^3
10^2
10
1
10^-1
Dose (mrem/hr)
2
4
6
8
10
12
14
16
Shield Thickness (Feet of Earth)