R. P. Note #36
January 19, 1983

Fermilab

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and

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Corrected Values for Shielding Calculations

An updated version of the Fermilab Radiation Guide will soon be issued. Table 1 of Chapter 12.1 will reflect changes in the columns for thick soil and thick concrete in accordance with TM-664 and the CASIM booklet, "High Energy Particles Interactions in Large Targets". These changes were proposed by Peter Gollon of Brookhaven, the original author of Chapter 12, in a letter (attached) to Suzanne Gronemeyer of Fermilab dated October 27, 1982.

In the process, we have also noted that the values given for Iron in Table VI.1 of the CASIM book are wrong. The correct values are given in Table 1 of Chapter 12.1 of the Rad Guide and in Table 2 of TM-664.

The iron values should be:

1. Flux: 95,000 $n\text{-}cm^{-2}/star\cdot cm^{-3}$
   (instead of 130)

2. Entrance Absorbed Dose: 77×10^{-6} $rad/star\cdot cm^{-3}$
   (instead of 6.0×10^{-7})

3. Maximum Dose Equivalent: 420×10^{-6} $rem/star\cdot cm^{-3}$
   (instead of 3.5×10^{-6})

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October 27, 1982

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Dear Suzanne:

I discovered an inconsistency in Table 1 of The Radiation Guide, Chapter 12.1. In the last two columns, some of the numbers are taken from TM-266 (ref. 5), others are taken from Van Ginneken's "Bible," ref. 1. Both sources construct neutron spectra at large radii by splicing together a "low energy" spectrum calculated at ORNL with a high energy spectrum calculated at Fermilab. The two low-energy spectra, although calculated by different people for different problems, agree. The two high energy spectra do not. I have taken the large radius curve (300 cm $\leq$ R $\leq$ 750 cm; 0 $\leq$ Z $\leq$ 450 cm) from Andre's Figure VIII.32 and replotted it on Figure 2 of TM-266. The difference is clear: TRANSK used in TM-266 gives a harder spectrum than CASIM. Comparison of Figure 7 from TM-266 with Andre's Figure VI.12 or VI.13 (they are equivalent) shows this. I prefer Van Ginneken's results to the older results of TM-266. I have, therefore, revised Table 1 of Chapter 12.1 accordingly. Lines 9-13 are read directly from Andre's Figure VI.13.

Includes momentum to KE conversion + bin conversion

Lines 6-8 for "thick concrete" come from page 50 of ref. 1 and remain unchanged. For "thick soil" I have scaled these numbers by the ratio of the densities, 2.4/2.0.

Line 5 is derived from lines 8 and 6:

$$\text{Average Dose/Neutron} = \left(\frac{\text{Max DE}}{\text{star cm}^{-3}}\right) \div \left(\frac{\text{N flux}}{\text{star cm}^{-3}}\right) = 9 \times 10^{-6}/350 =$$

2.6×10^{-8} rem/n-cm^2.

Line 4 is similarly derived from lines 7 and 6:

$$1.5 \times 10^{-6} \left(\frac{\text{rad}}{\text{star cm}^{-3}}\right) \div 350 \left(\frac{\text{neutron cm}^{-2}}{\text{star cm}^{-3}}\right) = 4.3 \times 10^{-9} \frac{\text{rad}}{\text{n cm}^{-2}}$$

The QF is the ratio of these and increases to 6.

If my understanding of this error is correct, then the personnel neutron dosimetry and spectrosocopy problems become easier--you (we) only have to go to the 60-odd MeV instead of 400 + MeV to see most of the dose-equivalent. Looking at this paragraph, I'm surprised at how obvious this is and wonder why I didn't question the very high neutron energy range that TM-266 says had to be monitored and thus find the problem long ago.

I'll send you that CERN reprint when it gets copied.

Sincerely,

Peter

Peter Gollon

PG:sc

Enclosures

Spectrum	Iron Thin r = 20 cm	Iron Thick r = 100 cm	Concrete Thick	Soil Thick
1. Density ρ, g/cm³	7.86	7.86	2.4	2.0
2. Absorption Length; cm	17.3	17.3	44.7	53.6
3. Average Quality Factor, <QF>	7.9	5.4	~~5.3~~ 6.0	~~5.3~~ 6.0
4. Average Dose/Neutron, rad/n-cm^{-2}	2.4×10^{-9}	0.81×10^{-9}	~~9.1×10^{-9}~~	~~9.1×10^{-9}~~ 4.3×10^{-9}
5. Average Dose-Equiv/Neutron, rem/n-cm^2	1.9×10^{-8}	0.44×10^{-8}	~~4.9×10^{-8}~~	~~4.9×10^{-8}~~ 2.6×10^{-8}
6. Neutron Flux/Star-cm^{-3}, n-cm^{-2}/Star-cm^{-3}	540	95,000	350	~~400.~~ 420
7. Entrance Absorbed Dose/ Star-cm^{-3}, rad/star-cm^{-3}	1.3×10^{-6}	$77. \times 10^{-6}$	1.5×10^{-6} (ok)	~~1.7×10^{-6}~~ 1.8×10^{-6}
8. Maximum Dose-Equiv/ Star-cm^{-3}, rem/star-cm^{-3}	$10. \times 10^{-6}$	$420. \times 10^{-6}$	9×10^{-6} (ok)	~~10.5×10^{-6}~~ 10.8
9. E_{10}, MeV	0.1	.0046	~~3.4~~ 0.43	~~3.4~~ 0.43
10. E_{20}, MeV	0.16	.018	~~10.~~ 1.0	~~10.~~ 1.0
11. E_{50}, MeV	0.33	0.1	~~50.~~ 5.4	~~50.~~ 5.4
12. E_{80}, MeV	6.3	0.22	~~230~~ 48.	~~230~~ 48.
13. E_{90}, MeV	46	0.37	~~460~~ 66.	~~460~~ 66.
14. Reference	4	4	~~5~~ 1	~~5~~ 1

Table 1. Shielding and neutron spectral quantities of interest for four side-shield spectra produced by multi-hundred GeV protons. Lines 3, 4, and 5 give average properties of each spectrum. Lines 6, 7, and 8 give conversion factors which compensate for the low energy part of the spectrum ignored by CASIM. The quantities E_i indicate the neutron energies of importance for personnel protection: 10% of the dose-equivalent is due to neutrons of energy less than E_{10}, etc. Thus 80% of the dose-equivalent is carried by neutrons with energies between E_{10} and E_{90}. (Fig VI.13, Ref 1)

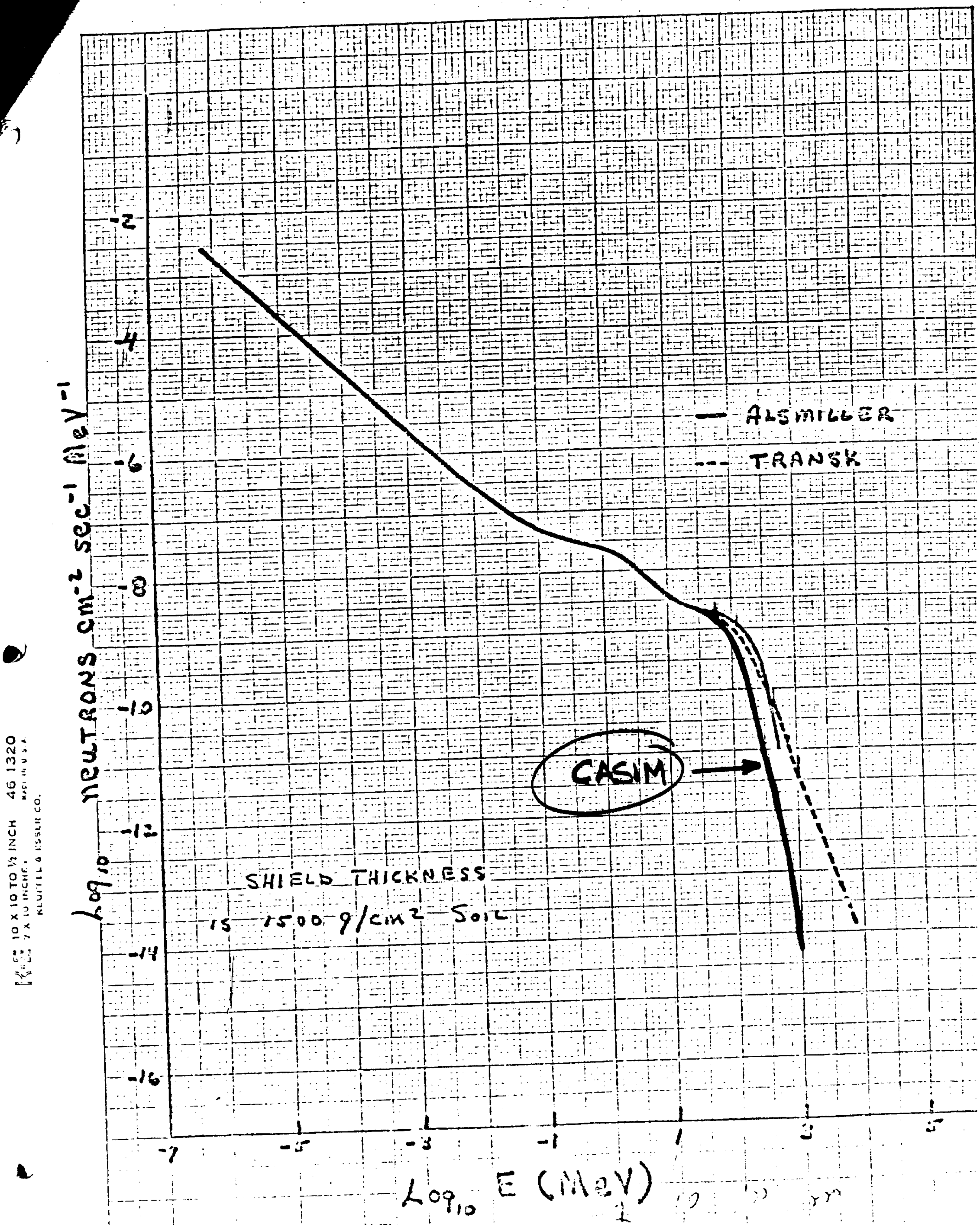
neutrons cm^{-2} sec^{-1} MeV^{-1}
Log$_{10}$
-2
-4
-6
-8
-10
-12
-14
-16
— ALSMILLER
--- TRANSK
CASIM
SHIELD THICKNESS
IS 1500 g/cm^2 SOIL
-7
-5
-3
-1
1
3
5
Log$_{10}$ E (MeV)
46 1320
10 X 10 TO ½ INCH
KEUFFEL & ESSER CO.

FIG 2, TM-266

8·666·3469
12·16·82
Peter Gollow,
(S.L. [illegible])

What conversion factor did he use to get ~~from~~ TO:

TM 266 — $\frac{\text{neutrons}}{\text{cm}^2 \text{ sec meV}}$
Fig 2

from: VIII . 32 — $\frac{\text{Stars}}{\text{cm}^3 \frac{\text{GeV}}{c} \text{ incp}}$?

~~Andy~~ Peter says yes VIII . 32. RP note 36 with cover page from me + Peter's letter to me + both our names OK with him

Peter converted momentum $\left(\frac{\text{GeV}}{c}\right)$ to KE (MeV) to make the conversion from Andy's plot to TM-266 Fig 2

Peter picked off 300, 500, 1000, 1800 $\frac{\text{MeV}}{c}$ pts from VIII . 32

=> 47, 124, 430, 1087 MeV assuming $m = m_{\text{neutron}}$

~~1150~~ CASIM assumes constant cross sections (in fact, lower cut off is where they are no longer constant 50-150 MeV)

~~Peter assum~~

Also ordinate change:

$\frac{\text{flux}}{p\ \text{MeV}/c} \rightarrow \frac{\text{flux}}{\text{MeV}}$ must transform momentum intervals to Kinetic energy intervals (in addition to abcissa change)

Peter "spliced" CASIM (normalized) to Alsmiller & TRANSK arbitrarily @ ~30MeV
Didn't do CASIM at lower energies
His Fig from Fig 2. TM 266 is irrelevant

Table 1 takes data from 2 different sources.
He proposes to throw out #s from TM266.
His Fig2-TM266 is a consistency check.

→ Put Fig II 13 into Rad Guide??

TM 266 uses TRANSK. Peter believes CASIM is better than TRANSK (15 yr old)
Data was poorer then, so was understanding & models.

Delete reference to TM266 now since will now ref. CASIM book & RP 36.

Peter doesn't want to be an author of something he doesn't believe in.

Peter thinks Fig VI Fe plots (CASIM book) are wrong. Compare TM-664.

Peter says he used same low E tail on Fe + concrete, which is wrong. So Andy's iron plots are wrong. Miguel made the same mistake in TM 266 A100 p. 50 table Miguel + Andy's book.

He is doing up a compilation + how to on Moyer method. He will send me copies. His work is in response to BNL needs + Sam's question about 8 GeV soil activation (from Peter from Carlos, TeV I).