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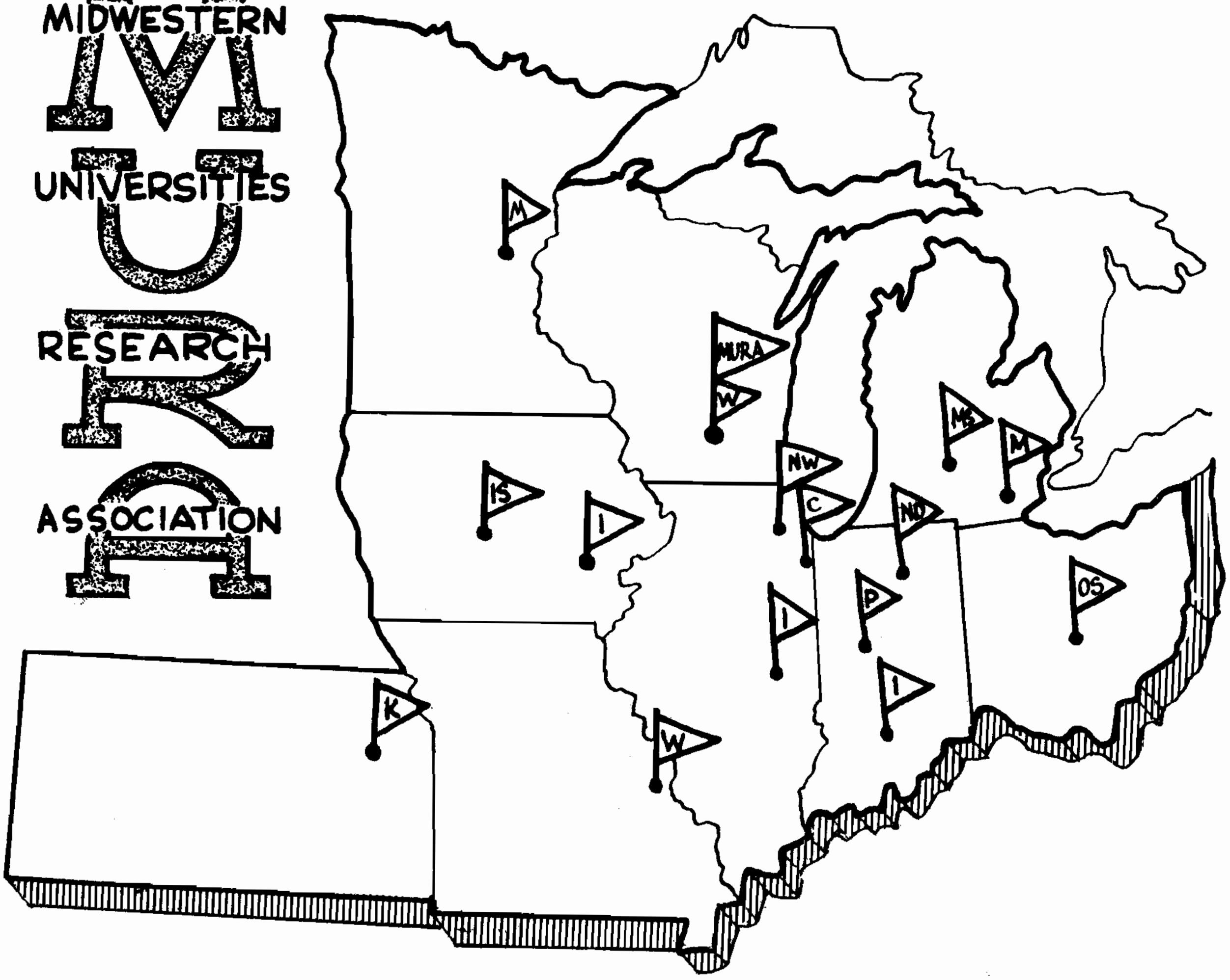

ESTIMATE OF RADIATION LEVELS FOR THE MURA 50 MEV ELECTRON ACCELERATOR

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REPORT NUMBER 507

MURA-507
Internal

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ESTIMATE OF RADIATION LEVELS FOR THE MURA 50 MEV ELECTRON ACCELERATOR

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September 8, 1959

ABSTRACT

On the basis of the MURA-408 report, a rough calculation of the expected levels of radiation for the present shielding is made.

*AEC Research and Development Report. Research supported by the U. S. Atomic Energy Commission, Contract No. AT(11-1)-384.

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I. Neutron Shielding

The number of neut/sec produced by the machine as a result of (γ, n) reactions is (Ref. 7, p. 4):

$$n = 1.94 \times 10^{12} \ \frac{\text{neut}}{\text{sec}} \ .$$

These neutrons are assumed to have energies between 1 and 3 Mev, interval that corresponds to the highest RBE values. Further, assume an isotropic point source, situated in the plane determined by the top surface of the magnets. The distance between this plane and the ceiling is 10'5", or 317 cm, so the neutron flux at point B, Fig. 1, will be:

$$\phi = \frac{1.94 \times 10^{12}}{4 \times 317^2} = 1.53 \times 10^6 \ \frac{\text{neut}}{\text{cm}^2\text{sec}}$$

For this flux, the corresponding dose rates for different energies are (Ref. 5, p. 23):

E, (Mev)	Dose per neut/cm^2, (m rad)	Dose Rate (m rad/hr)
0.5	2.4×10^{-6}	1.32×10^4
2.5	4.8×10^{-6}	2.64×10^4

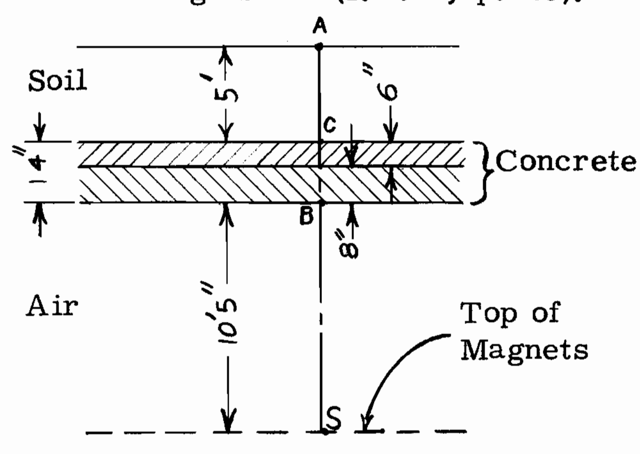

Fig. 1.

The neutrons find first 14" = 35.8 cm of concrete, and then 5' = 152.5 cm of soil. For ordinary concrete we use the curve from Ref. 5 corresponding to the soil R_{10} (page 54). Thus, for 2.5 Mev neutrons, and for $d = 35.8 \times 2.3 = 81.9 \ \frac{\text{gm}}{\text{cm}^2}$ we obtain (Ref. 5, p. 119):

$$\text{dose per } \frac{\text{neut}}{\text{cm}^2 \text{ sec}} \text{ at point C} = 1 \times 10^{-3} \ \frac{\text{m rad}}{\text{hr}}$$

and assuming now that the flux previously calculated is perpendicular to the shielding and uniform, the dose rate at C will be:

$$D_c = 1 \times 10^{-3} \times 1.53 \times 10^{6} = 1.53 \times 10^{3} \ \frac{\text{m rad}}{\text{hr}} .$$

We now consider that the 5' = 152.5 cm of soil on top of the concrete has a density $\rho = 1.5 \frac{\text{gm}}{\text{cm}^3}$.

Thus,

$$d = 1.5 \times 152.5 = 229 \ \frac{\text{gm}}{\text{cm}^2}$$

and the total shielding thickness is

$$d_t = 81.9 + 229 = 311 \frac{\text{gm}}{\text{cm}^2} .$$

The dose corresponding to 1 neut/cm^{2}sec at point A, Fig. 1, is then (Ref. 5, p. 119):

$$0.3 \times 10^{-9} \ \text{m rad/ hr} ,$$

and the total dose rate:

$$D_A = 0.3 \times 10^{-9} \times 1.53 \times 10^{6} = 4.58 \times 10^{-4} \ \text{m rad/hr}.$$

Using now a RBE value of 8 (Ref. 3, p. 152) and using the relation:

$$\text{rem} = \text{rad} \times \text{RBE}$$

we obtain

$$D_A = 4.58 \times 10^{-4} \times 8 = 3.67 \times 10^{-3} \ \text{m rem/hr}$$

and for a forty hour week:

$$D = 3.67 \times 10^{-3} \times 40 = .147 \ \text{m rem/ wk.}^{*}$$

This value is way below the maximum of 10 m rem/wk prescribed by the National Committee for Radiation Protection for non-occupational exposure (Ref. 3, p. 148).

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*This calculation is conservative, since actual neutron flux will probably be below the estimated value.

Next, we calculate the shielding produced by a 2 ft-thick concrete wall located at 3 feet from the machine. Again, we calculate the neutron flux at point M

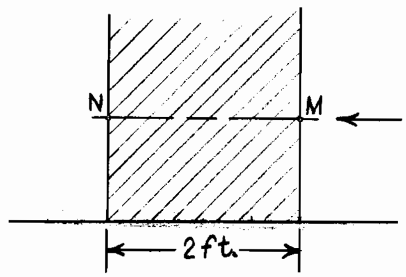

Fig. 2

assuming an isotropic point source, and then we assume that this flux is uniform and perpendicular to the shielding. Thus,

$$\phi = \frac{1.94 \times 10^{12}}{4\pi \times \overline{91.5}^2} = 1.84 \times 10^7 \frac{\text{neut}}{\text{cm}^2 \text{sec}} .$$

Now:

$$d = 2 \times 30.5 \times 2.3 = 140 \text{ gm/cm}^2$$

and the dose rate at N corresponding to 1 neut/cm^{2}sec (Ref. 5, p. 119):

$$0.5 \times 10^{-7} \text{ m rad/hr} \quad \text{for } E = 2.5 \text{ Mev.}$$

The total dose rate is then

$$D_N = 0.5 \times 10^{-7} \times 1.84 \times 10^7 = 0.92 \text{ m rad/hr}$$

and with a RBE of 8, and 40 hr/week:

$$D = 0.92 \times 8 \times 40 = 295 \text{ m rem/wk.}$$

This value is above the 100 m rem/wk for occupational exposure, but is still acceptable since the space beyond the wall won't be accessible while the machine is in operation.

II. Gamma-Ray Shielding

The first step is the determination of the energy and number of gamma-rays produced. As stated in Ref. 7, they are due to the incidence of 50 Mev electrons on iron, and they will be broadly distributed in energy around 7.5 Mev. We assume then that there are (Ref. 7, p. 2):

$$.61 \times 10^{13} \ \gamma\text{-ray/sec} \qquad \text{of } 7.5 \text{ Mev.}$$

The distribution of these γ-rays is not isotropic. In fact most of them will form only a small angle with the equatorial plane, as indicated in Fig. 3, and the

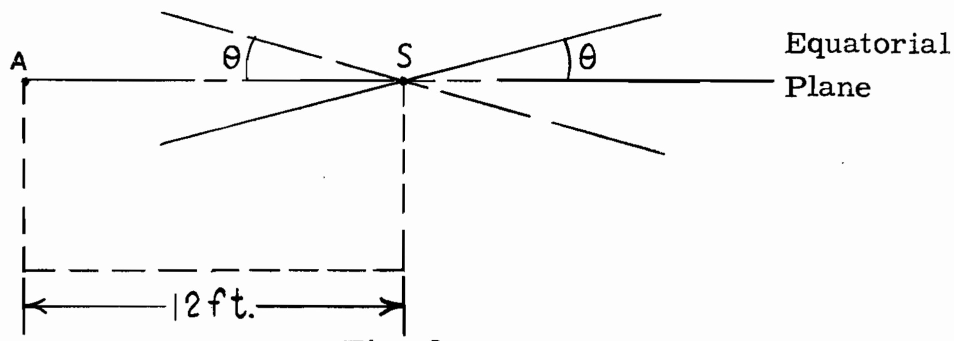

Fig. 3.

intensity corresponding to the angle θ can be related to the intensity corresponding to $\theta = 0$ (Ref. 4, p. 968). To perform the calculation we assume:

a) $\theta = 10^{\underline{o}}$

b) within this solid angle the distribution is uniform. The total solid angle is:

$$\int d\Omega = \iint \sin\theta \, d\theta \, d\varphi = \int_0^{2\pi} d\varphi \int_0^{10} 2 \sin\theta \, d\theta = 0.06\,\pi$$

so we have:

$$\frac{0.61 \times 10^{13}}{0.06\,\pi} \qquad \frac{\gamma\text{-rays}}{\text{sec sterad.}}$$

The gamma source will be then equivalent to an isotropic source at S producing:

$$\frac{0.61 \times 10^{13}}{0.06\pi} \times 4\pi = 4.06 \times 10^{14} \quad \gamma\text{'s/sec}$$

that is, with an activity:

$$S = \frac{4.06 \times 10^{14}}{3.7 \times 10^{10}} = 1.1 \times 10^{4} \text{ curies.}$$

We calculate the dose rate at a distance $d = 12$ ft $= 366$ cm from this source by using the expression

$$D = 10^3 \frac{R_o S}{d^2} \quad \frac{r}{hr}$$

where R_o, the specific radiation flux is obtained by extrapolation from Marinelli's curve:

$$R_o = 18 \text{ r/hr mc} \ @ \ 1 \text{ cm.}$$

Then,

$$D = 10^3 \times 18 \times \frac{1.1 \times 10^4}{366^2} = 1480 \ \frac{r}{hr}$$

or also:

$$D = 1480 \times 40 \simeq 5.92 \times 10^4 \ \frac{r}{40 \text{ hr wk}} \quad .$$

Compare with the value 0.84×10^4 r/40 hr wk given by Ref. 7, p. 5.

To simplify the calculations, we consider no buildup. The γ-rays will pass through 4" of lead plus 20" of concrete. The respective mass absorption coefficients, for $E = 7.5$ Mev, are

$$\text{concrete:} \quad \mu_a = 0.025 \text{ cm}^2/\text{gm}$$

$$\text{lead:} \quad \mu_a = 0.045 \text{ cm}^2/\text{gm}.$$

Hence

$$\Sigma \mu_a d = 0.025 \times 20 \times 2.54 \times 2.3 + 0.045 \times 4 \times 2.54 \times 11.35 = 8.1$$

$$e^{8.1} \cong 3300$$

and using the formulas $D = D_o \ e^{-\Sigma \mu_a d}$

we get:

$$D = \frac{5.92 \times 10^4}{3.3 \times 10^3} = 1.79 \times 10 \quad \frac{r}{40 \text{ hr wk}}$$

Since for gammas RBE = 1, we finally obtain

$$D = 17.9 \frac{\text{rem}}{40 \text{ hr wk}} \quad .$$

This value exceeds by far the 100 m rem/wk limit, especially when we consider that if buildup is taken into account the above value probably will result multiplied by 20.

Conclusion

Attenuation in air for gammas of this energy is very small ($\mu = 0.023 \text{ cm}^2/\text{gm}$). Although some attenuation will result from the inverse square law, the level of radiation in the entrance area will still exceed the permissible levels.

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