#10

DOSE RATE DUE TO IRRADIATED FUEL

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I. T. G. Williamson of the University of Virginia has developed a method for estimating the dose rate at three feet from an irradiated MTR-type fuel element. In order to simplify the calculation, he has made the following assumptions:

a) The element can be represented as a line source

b) The line is assumed to be at the center of the fuel element

c) The radioactivity is uniform along the length of the line source

Figure 1 shows the geometry assumed

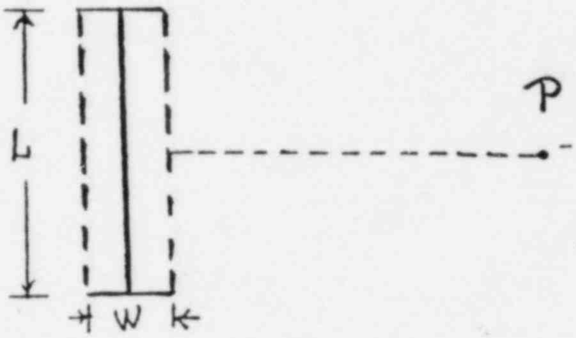

Fig. 1

For the MTR element, L = 61 cm = active length
W = 7.6 cm = width

Including attenuation through the near half of the fuel element, the dose rate at the point P, 3 feet from the surface of the fuel element is given by:

$$D = 1.8 \times 10^{-11} \times \Gamma \text{ rems/hr - watt}$$

where Γ is the fission produce source strength at the time of interest, following a finite irradiation time generating 1 watt of power in the entire fuel element.

Γ is given in Mev/watt - sec, and has been tabulated by several authors for various irradiation times and various decay times.*

II. In the following, some additoinal assumptions are made, and the expected dose rate at 3 feet (in air) from the surface of a compact core of MTR-type fuel is estimated.

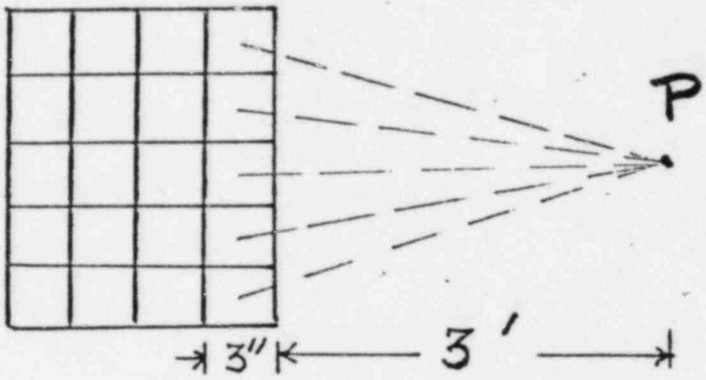

Fig. 2.

Figure 2 illustrates a typical compact MTR-type core. In order to estimate the dose rate from the entire core at the point P, 3 feet (in air) from the surface, the following assumptions are made:

a) The dose rate from each element in the front row is computed as above, for a single element (D)

b) The dose rate from the second row is computed in the same way, but displaced an additional 3" from the first row, hence an inverse square reduction in dose rate.

c) The front row, including the water, attenuates the average photon from the second row by 10%.

d) The power level of each element is just 1/20 of the total core power level

e) Successive rows are treated as described for row 2.

The computed does rate from the core then becomes:

Row 1; $D_1 = 5 \times D \qquad = 5\,D \times 1$

Row 2; $D_2 = 5 \times D \times (\frac{36}{39})^2 \times .9 \qquad = 5\,D \times .77$

Row 3; $D_3 = 5 \times D \times (\frac{36}{42})^2 \times .9^2 \qquad = 5\,D \times .67$

Row 4; $D_4 = 5 \times D \times (\frac{36}{45})^2 \times .9^3 \qquad = 5\,D \times .47$

R Total $\qquad = 5\,D \times 2.84$

$D = 1.8 \times 10^{-11} \times \Gamma$ rems/watt-hr

Assume

a) Irradiation core power = 100 kW

b) Irradiation time = 2 hrs

c) Decay time = 55.6 hrs = 2×10^5 sec

These numbers are appropriate for the UCLA operations

For these parameters *; for a single fuel element

$$\Gamma = 6.60 \times 10^{13} \times \underline{2} \times \frac{.1}{20} = 6.60 \times 10^{11} \text{ MeV -W}^{-1}\text{-S}^{-1}$$

so $D = 1.8 \times 10^{-11} \times 6.60 \times 10^{11} = 11.9$ rem/hr

and for the 20 element core, the total dose rate, from above, becomes

R total = $5 \times 11.9 \times 2.84 = 169$ rem/hr

*(1) "A Handbood of Radiation Shielding", edited by J. C. Courtney ANS/SD 76/14 (July 1976)

(2) Figure 8.11, Reactor Handbood, Volume III Part B, Shielding, edited by E. P. Blizzard, 2nd Edition; Interscience Publishers (1962)

III. A simplified approach to the same problem would be to assume that the total core radioactivity is concentrated at a point at its center, and to assume simple inverse square fall-off of flux density out to the measuring point, three feet from the core surface.

From figure 2, the distance (d) between the core center and point P is 42". Therefore, the photon (or energy) flux density at P is:

$$\phi = \frac{S}{4\pi d^2} = \frac{S}{4\pi(42\times2.54)^2} = \frac{S}{1.43\times10^5} \quad cm^{-2}$$

For the same operating parameters as used above for UCLA,

$$S = 6.6 \times 10^{13} \times 2 \times .1 = 1.32 \times 10^{13} \text{ MeV -s}^{-1}$$

from which

$$\phi = \frac{1.32\times10^{13}}{1.43\times10^5} = 9,23 \times 10^7 \text{ MeV -cm}^{2} \text{ -s}^{-1}$$

In Williamson's derivation; it was assumed that a flux of 5×10^5 MeV-$s^{-1}cm^{-2}$ is equivalent to one rem-hr^{-1}

$$\text{so R total} = \frac{9.23\times10^7}{5 \times 10^5} = 185 \text{ rem/hr}$$

IV. A "rule of thumb" for estimating exposure rates from a point source is, for ^{137}Cs (.66 MeV)

R total = .33 x Ci = r-hr^{-1} @ 1 meter

For the same parameters as used above for UCLA, but using the total disintegration rate from Courtney, rather than energy emmission rates,

$$\text{R total} = \frac{1.38 \times 10^{14} \times .1 \times 2}{3.7 \times 10^{10}} \times .33 = 7.46 \times 10^2 \times .33$$

$$\text{R total} = 246 \text{ R-hr}^{-1}$$

if we make the small adjustment from <u>1 meter to 42"</u>, to be consistent with all of the foregoing, this becomes

$$\text{R total} = 246 \times (\frac{39.4}{42})^2 = 246 \times .89 = 216 \text{ r/hr}$$

V. On Friday, 10 April, Neil Ostrander gave James R. Miller the following information on the telephone:

Assume that the UCLA reactor is run for 2.0 hours at 100 kW, starting at 1000 on a Friday. At 0800 the next Monday, the exposure rate at 1 meter from the surface of the core, with no intervening shielding, would be 113 R-hr^{-1}. If there were no significant operation of the reactor all that week, on Friday, one week from the initial run, the exposure rate would be 40 R-hr^{-1} @ 1 meter

Still assuming no additional operation on this second Friday, the exposure rate on the second Monday would be 26 R-hr^{-1}.

The following table displays the way in which exposure rate at 1 meter accumulates, assuming that on each Friday, an identical 200 kW-hr operation is performed, with no additional significant operation any other day of the week. Each column gives the total exposure rate on Monday at 0800. Each row gives the residual exposure rate on any Monday from each of the previous Friday operations. The bottom row gives the sum of all previous contributions on any Monday. For simplification, it is carried forward for only 5 weeks, but the extension is clear.

	1st Mon.	2nd Mon.	3rd Mon.	4th Mon.	5th Mon.	etc→→→
200 kW-hr	113	26	14	9	8	
on Friday AM		113	26	14	9	
			113	26	14	
				113	26	
					113	
Total R-hr^{-1}	113	139	153	162	170	

VI. Conclusion

All methods agree that the exposure rate at three feet from the surface of the core with no intervening shielding, can readily be maintained well above 100 rem - hr $^{-1}$.