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MICA FISSION DETECTORS

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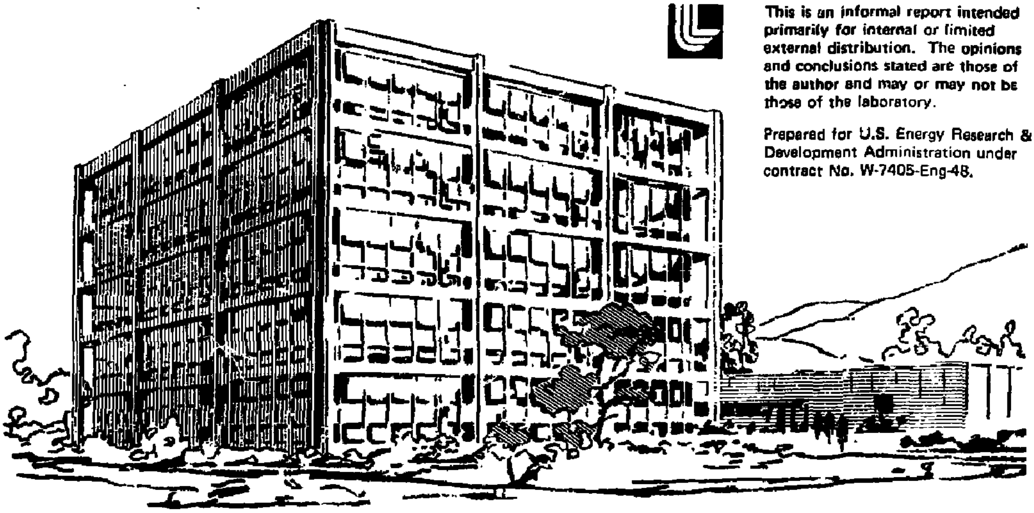

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MICA FISSION DETECTORS

ABSTRACT

This report summarizes the present development status of the mica fission detectors. We conclude that the techniques have been refined and developed to a state such that the mica fission counters are a reliable and reproducible detector for fission events.

Briefly, the mica detectors consist of 1 mil of fissionable material sandwiched between sheets of mica. To reduce fissions induced by thermal neutrons (which represent an unwanted background when experiments are performed with high energy neutrons), the mica is covered with 2 mils of cadmium. The mica sheets are pre-etched for 20 hr in 48% hydrofluoric acid at 80°F in order to develop the background tracks existing in the mica. After exposure to neutrons, the mica sheets are developed for 1 hr in the same manner as for the pre-etching. The fission tracks are then counted in a conventional microscope at 210X magnification.

The detectors are calibrated using 14-MeV neutrons from the d + t reaction on the 2-MeV Van de Graaff generator. The absolute neutron production is monitored by counting the alphas from the d + t reaction with a solid state charge particle detector. Figure 1 shows the fissions occurring in D^{38} at R = 25, 50, and 75 cm from the tritium target. The number of fissions are given by

$$f = \frac{Q}{4\pi R^2} \sigma N + KQN \qquad (1)$$

where Q is the total neutron production, σ is the fission cross section for 14-MeV neutrons, N is the effective number of fissionable nuclei, and K is a proportionality constant. The first term represents fissions from a point source of 14-MeV neutrons. The second term represents fissions induced by room return (degraded neutrons scattered by the walls of the target pit) and hence is proportional to Q and independent of R. Multiplying Eq. (1) by R^2/Q yields

$$\frac{R^2}{Q} f = \frac{1}{4\pi} \sigma N + R^2 KN \qquad (2)$$

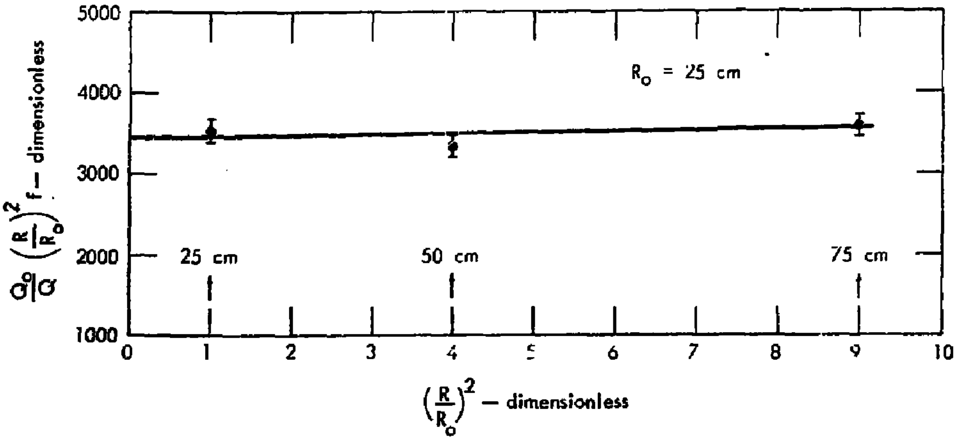

Fig. 1. Fissions occurring in D^{38} at R = 25, 50, and 75 cm from tritium target.

To make the ordinates and abscissae dimensionless in Figs. 1 and 2 we plot instead

$$\frac{Q_o}{Q}\left(\frac{R}{R_o}\right)^2 f \quad \text{vs} \quad \left(\frac{R}{R_o}\right)^2 \tag{2}$$

where R_o = 25 cm and Q_o is the neutron production for the run at 25 cm. Equation (2) shows that if there are no fissions induced by room return, the second term is zero and

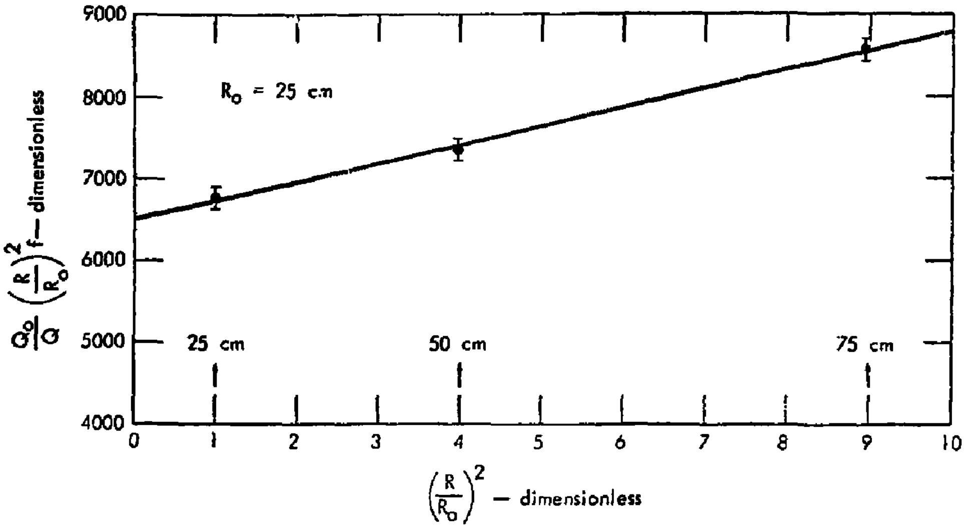

Fig. 2. Fissions occurring in U^{235} at 25, 50, and 75 cm from tritium target.

$(R^2/Q)f$ is constant. This is indeed the case for D^{38} (see Fig. 1), since the threshold for fission is ~1 MeV, and hence D^{38} should be insensitive to scattered (degraded) neutrons. For U^{235}, the opposite is true.* Indeed $(R^2/Q)f$ vs R^2 yields a straight line as predicted (see Fig. 2).

Extrapolated to the origin, the U^{235} fission counts for 14-MeV neutrons are 6500 fission tracks per 2 cm^2. For D^{38} the corresponding number of tracks is 3450. The ratio of the number of tracks should be the ratio of the fission cross sections:

$$\frac{6500}{3450} = 1.89 \; ; \; \frac{\sigma_f(235)}{\sigma_f(238)} = \frac{2.20\text{b}}{1.15\text{b}} = 1.91$$

The excellent agreement (within 1%) shows that we are indeed counting fission tracks and that there are no systematic errors in track counting.

Taking either the D^{38} or U^{235} results (they are equivalent), the effective thickness is calculated to be:

$$f = N\sigma\phi \; ; \; \phi = \frac{\overset{(\alpha\text{-cts})}{3.02 \times 10^5} \times \overset{(\text{neutrons}/\alpha)}{3.08 \times 10^6}}{(4)\,(3.14)\,(25)^2} = 1.18 \times 10^8 \text{ n/cm}^2$$

$$\frac{\frac{1}{2}\,(6500)}{10^{-24} \times 2.2 \times 1.18 \times 10^8} = N = 1.25 \times 10^{19} \text{ nuclei}$$

(We divide by two to account for the two fragments per fission.) The effective thickness is $\frac{1.25 \times 10^{19}}{6.023 \times 10^{23}} \times 235 \times 10^3 \times \frac{1}{2} = 2.44$ mg/cm^2. As expected, the effective thickness is roughly one-quarter the range of fission fragments in uranium (the range is 5-6 μ or ~10.3 mg/cm^2).

The density of fission tracks in the mica is varied by a factor of 100 (from 100 to ~10,000 tracks/cm^2) and in every instance the track density varies linearly with neutron production within counting statistics. This result shows that over a dynamic range of 100 we are not missing any fission tracks. More precisely, the error in track counting does not exceed the counting statistics. Estimating the total number of tracks/cm^2 from a random scan of a portion of the mica also gives agreement within counting statistics. This result again indicates that within counting statistics we are not missing tracks and that the density of tracks is uniform throughout the mica; i.e., there is no domain structure in the mica which would cause a local fluctuation in track density.

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*The 2 mils of cadmium is effective only for thermal neutrons; in the I. C. T. target pit, epithermal neutrons predominate over thermal neutrons.

CONCLUSIONS

A calibration of the mica detectors with D^{38} and U^{235} foils at various distances from the tritium target for 14-MeV neutrons shows that within counting statistics there are no systematic errors associated with these detectors. Over a dynamic range of 100 in track density, the mica counters are a reliable and reproducible detector for fission events.