TABLE I. Dielectric constant (K) and loss ($\tan\delta$) of barium titanate at one megacycle.

Temp. °C	K	$\tan\delta$	Temp. °C	K	$\tan\delta$
25	1525	0.009	150	2450	0.002
50	1413	0.011	175	1610	0.001
75	1440	0.010	200	1190	0.001
100	1750	0.014	225	933	0.002
110	2450	0.016	250	761	0.002
115	5070	0.013	275	656	0.007
120	5070	0.009	300	572	0.016
125	4430	0.006	325	506	0.040
130	3820	0.004	350	457	0.087
140	2970	0.003			

where C and T_c are parameters suitably chosen to fit the experimental data and T is the temperature.

However, a new parameter has been introduced in this equation in a more recent article.[5]

$$K=K_0+C/(T-T_c), \tag{2}$$

where K_0 is thought to be the dielectric constant of barium titanate at extremely high or extremely low temperatures. A value of 350 was quoted for K_0, since the dielectric constant reached this value at temperatures near absolute zero. Previously published data, extending only to about 200°C, may be interpreted by either equation since the choice of K_0 is not critical in this range of temperature. The object of the present note is to report measurements of dielectric constant of barium titanate up to much higher temperatures and from these data to determine the value of K_0 directly.

Table I shows results of measurements of dielectric constant and loss of barium titanate ceramic at temperatures up to 350°C. The frequency was one megacycle and the sample was of commercial purity.

In order to find the value of K_0, which most closely fits the experimental data, the reciprocal of $(K-K_0)$ is shown plotted *versus* temperature for different values of K_0 (see Fig. 1). According to Eq. (2), the points corresponding to the correct choice of K_0 should lie on a straight line. This occurs when $K_0=0$ and clearly fails when $K_0=100$ or 300. The line determined by the experimental data, assuming $K_0=0$, is so accurately straight that one can estimate the value of K_0 to be less than 10, if it exists at all, a value quite negligible compared to the dielectric constant measured at ordinary temperatures.

These results at a frequency of one megacycle indicate that Eq. (1) gives a perfectly satisfactory interpretation of the experimental data for temperatures above 150°C. For temperatures nearer the Curie point, there are slight deviations which are not consistent with either equation.

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Fission Fragment Energies in U^{235} and U^{233}

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MANY measurements have been made of the energy distribution of fission fragments.[1-7] Among these, several experiments[3-5] have used a coincident pulse technique. In particular, Deutsch and Ramsey[5] have compared the energy distributions from U^{235} and Pu^{239}. The present experiments were undertaken to extend this comparison to U^{233} and to improve the statistical accuracy of the results.

A double "back-to-back" ionization chamber was used with a thin source mounted on the common cathode. Electron collection was employed with Frisch grids shielding the collecting electrodes.[8] Fragments in a small energy interval were selected from one side of the chamber by an electronic "gate" and the energy distributions of the coincident fragments from the other side were recorded on a thirty-channel pulse analyzer.[9] Energy measurements were made at the collecting electrode (to eliminate the effects of any amplifier non-linearity) by comparison with artificial pulses fed in at this point from a pulse signal generator. The absolute energy calibration of the signal generator was obtained by using the natural α-particles from the sources and assuming that the mean energy spent per ion pair in argon is the same for fission fragments and α-particles.

TABLE I. Slow neutron fission in U^{235}.

	Jentschke and Prankl	Flammersfeld, Jensen, and Gentner	Jentschke	Deutsch and Ramsey	Fowler and Rosen	Present experiment
Most probable energy of light group (Mev)	91	92	92.5	94	92.5	92.7
Most probable energy of heavy group (Mev)	57	59	65	60	61.2	59
Ratio of most probable energies	1.60	1.56	1.47	1.57	1.51	1.57
Most probable mass ratio of coincident pairs (on an equal ratio-interval curve)	—	—	—	1.49	—	1.485
Width at half-maximum of high energy peak (Mev)	17	15	13	12	15	12
Width at half-maximum of low energy peak (Mev)	22	19	20	19	24.5	20
Ratio of peak heights	1.3	1.22	1.49	1.57	1.46	1.37
Foil thickness (mg/cm²)	~0.03	~0.01	0.04	0.012	0.029	0.014

The fission source was a collodion film of ~14 $\mu g/cm^2$ containing 3–5 $\mu g/cm^2$ of U dissolved in it and mounted on a 0.01″ collimator plate with 0.01″ collimator holes. Thus the fragments were collimated in only one chamber but the counting of only coincidence pulses effectively produced an equal collimation in the other chamber. The neutron source was the thermal column of the Chalk River pile.

The energy distribution was measured, first with the energy gate wide open so that the whole range of fission energies was recorded. The result was the usual double-humped curve. Then the energy gate, 5 Mev wide, was set on the low energy end of the distribution and the coincident pulses recorded. The position of the gate was increased in 5-Mev steps to cover the whole spectrum and in each case the corresponding distribution recorded.

The results of these gated runs are interesting. When the gate is set on the heavy fragment group, the energy distribution of the corresponding light group is almost independent of the

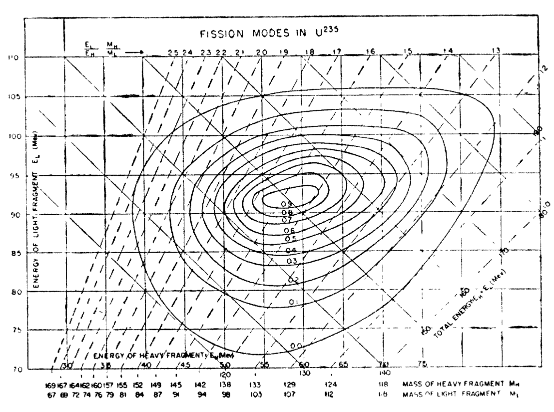

FIG. 1. Contour diagram for the fission modes in U^{235}.

TABLE II Comparison of slow neutron fission in U^{233}, U^{235}, and Pu^{239}.

	Present experiment U^{233}	Present experiment U^{235}	Deutsch and Ramsey Pu^{239}
Most probable energy of the light fragment (Mev)	91.2	92.7	93
Most probable energy of the heavy fragment (Mev)	55.5	59	65
Ratio of most probable energies	1.64	1.57	1.43
Most probable mass ratio (from an equal ratio interval curve)	1.60	1.485	1.32
Width at half-maximum of high energy peak (Mev)	14	12	12
Width at half-maximum of low energy peak (Mev)	22	20	20
Most probable fission mode: total energy	147.5	151.5	156
Most probable fission mode: mass ratio	1.64	1.57	1.43

position of the gate and conversely. For example, a shift of 25 Mev in the gate position produces a total shift in the mean energy of about 4 Mev and a change of width of the distribution of about 1.5 Mev. Moreover, this shift is such that as the gating energy is increased, the energy of the corresponding distribution maximum also increases. Hence, the usual double-peaked fragment energy curve is not, even approximately, a simple inversion of the double-peaked mass curve.

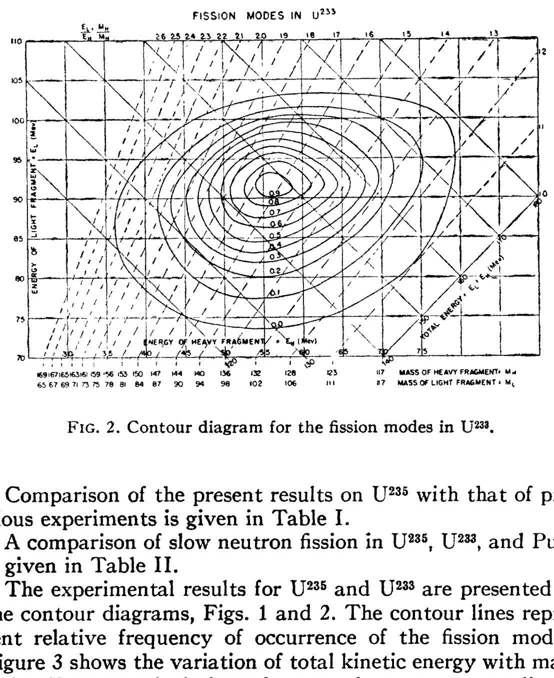

FIG. 2. Contour diagram for the fission modes in U^{233}.

Comparison of the present results on U^{235} with that of previous experiments is given in Table I.

A comparison of slow neutron fission in U^{235}, U^{233}, and Pu^{239} is given in Table II.

The experimental results for U^{235} and U^{233} are presented in the contour diagrams, Figs. 1 and 2. The contour lines represent relative frequency of occurrence of the fission modes. Figure 3 shows the variation of total kinetic energy with mass ratio. Energy calculations from nuclear masses predict a maximum in the total energy (kinetic+excitation energy) for unity mass ratio. Since the kinetic energy decreases as the mass ratio decreases below 1.25, the fraction of excitation energy must be increasing rapidly in this region. In this regard,

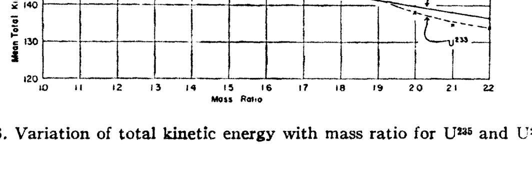

FIG. 3. Variation of total kinetic energy with mass ratio for U^{235} and U^{233}.

Katcoff, Miskel, and Stanley[10] working on the range distributions of plutonium fission fragments have interpreted their results to indicate a decrease in kinetic energy in the vicinity of a ratio of 1.2.

This work will be submitted in greater detail for publication in the Canadian Journal of Research.

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Energies of Heavy Nuclei in Cosmic Rays

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IN Table I we have summarized for fifteen heavy nuclei[1] the velocity on entering plates, nuclear charge, and calculated energy per nucleon at the top of the atmosphere. This latter quantity has been obtained by taking into account the observed angle in the photographic emulsions and the altitude at which the balloon spent the majority of the time. Inasmuch as it usually takes the balloon only about 25 minutes to rise from 70,000 to 90,000 feet and the balloon then remains aloft for three to five hours, we presume that the majority of the measured flux is recorded at the higher altitudes.

Inspection of Table I shows that a fairly large number of the measured nuclei had the rather low energies of 0.5 to 0.7 Bev upon entering the atmosphere. If we take into account the charge-to-mass ratio of the incoming particles, we find (using Vallarta's[2] curves distributed June, 1948) that no nuclei with energies less than 0.5 Bev/nucleon can enter the earth's magnetic field from the vertical at a latitude less than 51°N magnetic latitude. Shadow effects will presumably have completely disappeared for this energy at about 55°N magnetic latitude. The flights were made from Camp Ripley, Minnesota, i.e., at 55°N magnetic latitude.

Our results, therefore, suggest that the sun's magnetic field does not produce an energy cut-off noticeable at latitudes less than 51° and probably is not cutting off any particles even at the flight latitude of 55°.

Some indirect evidence substantiates this conclusion. The measured total flux of heavy nuclei for Z greater than 10 is $2.1\pm3\times10^{-4}/\text{cm}^2\cdot\text{sec.}\cdot\text{ster.}$ assuming 100 percent detection efficiency of the emulsions for these nuclei. If we compare this flux with the flux given by V-2 rocket data[3] at 41° magnetic

TABLE I. Summary of data on electric charge, entrance velocity, and energy per nucleon at top of atmosphere, for 15 heavy cosmic-ray particles.

Z	$\beta=v/c$ on entering plates	Energy/nucleon at top of atmosphere	Angle with vertical
11	0.63	0.5 Bev/nucleon	15°
14	0.86	1.1	23°
20	0.8	1.1	42°
26	0.85	1.3	27°
17	0.61	0.6	38°
12	0.53	0.8	71°
12	0.69	0.6	24°
41	0.8	1.2	30°
15	0.7	0.71	45°
13	0.7	0.61	35°
19	0.7	0.83	48°
12	0.55	0.54	41°
22	0.6	1.2	68°
10	0.6	0.45	10°
20	0.6	1.0	64°