argon at 8.5 cm and absolute alcohol (100 percent pure) at 1.5 cm, to a total pressure of 10 cm of mercury, the temperature at the time of filling being 33–34°C. The second is a thin walled glass counter[4] of the self-quenching type with external cathode consisting of a thin layer of graphite. (This counter was brought by Dr. P. S. Gill from Paris and was given to Dr. H. R. Sarna of the East Punajb University. The author is grateful to Dr. Sarna for lending this counter for the present investigation.) The counters could be heated or cooled in a suitable enclosure to different temperatures and maintained constant within ±0.2°C by means of a simple thermostat constructed in this laboratory. The total range of variation extended from 8°C to 60°C. A number of plateau curves were obtained at different temperatures for the two tubes (Fig. 1).

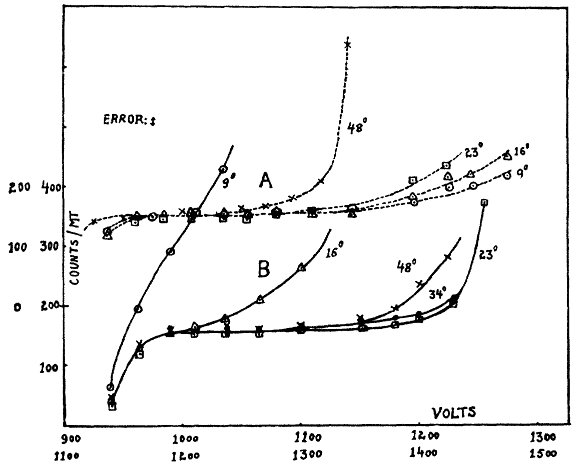

FIG. 1. The temperature dependence of the plateau curves for (A) external cathode and (B) internal cathode G-M counters.

It is clear from the figure that in the case of a counter with external cathode, there has been practically no change in the counting rate within this temperature range, while with the other counter with internal cathode there has been a marked effect near the lower temperatures. In the latter case as well, the counting rate remains independent within about 18° to 60°C; however, below 18°C the plateau has decreased and disappeared at about 9°C. Further it is also clear that the plateau curve becomes flatter at lower temperatures, while there is a definite increase in slope of the plateau at higher temperatures together with a decrease in over-all width of the plateau, possibly due to increase in the number of spurious counts at higher temperatures. (This point is being investigated.) The decrease in plateau width and its disappearance at lower temperatures in the case of a counter with internal cathode might be explained on the supposition that some of the quenching vapor condenses forming semi-conducting paths between the cathode and the central wire, thus giving rise to spurious counts. In the case of the counter with external cathode there is no possibility of such conducting paths and hence no such effect. The extent to which the decrease in the partial pressure of the quenching vapor is responsible for this change will be discussed and a full account of the present investigation published later.

The author is very grateful to Dr. P. L. Kapur, Reader in Physics, Delhi University, Delhi, India, who provided all the facilities for this work. Without his help this work would not have been possible.

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* The work was completed in the Delhi University Physics Laboratories, Delhi, India.

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# On the Latitude Dependence of Nuclear Disintegrations and Neutrons at 30,000 Feet*

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PRELIMINARY measurements of the change in the rate of production of low energy nuclear disintegrations between geomagnetic latitudes 40°N and 55°N have been made at 30,000 feet pressure altitude in a B-29 aircraft using electron collection ionization pulse chambers. Since both fast and thermal neutrons in the atmosphere at this altitude display a latitude dependence much larger (Fig. 1) than for other components observed in the cosmic radiation,[1,2] a measurement of nuclear disintegration rates may indicate the extent to which the observed neutrons are associated with these nuclear disintegrations or "star" events.

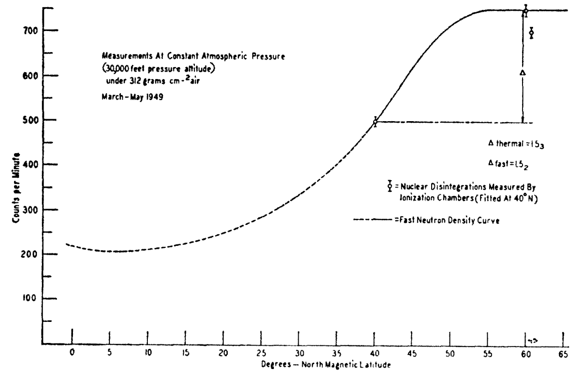

FIG. 1. Comparison of the latitude dependence of nuclear disintegrations and neutrons at 30,000 feet.

Two identical thin wall ionization chambers filled with 6 atmospheres of highly purified argon (similar to those used at Los Alamos and by Bridge, Rossi, and co-workers[3]) were operated using fast, linear amplifiers with their output pulses mixed in a non-loading circuit before sorting pulse sizes in a multi-channel pulse height analyzer. The ionization chambers were separated so that the probability of a nuclear event being simultaneously detected in both chambers was negligible.[3] Three G-M counter trays were located to cover a shower area of 1.5 $m^2$ including the area occupied by the ionization chambers. They were connected to a three-fold shower recording circuit, and this circuit was, in turn, connected to one of the ion chamber pulse height discriminator channels to form four-fold coincidences.

To determine the absolute energy loss in a chamber due to a nuclear event, the maximum pulse size from a retractable polonium alpha-particle source in the chamber was used as a standard to calibrate the pulse discriminator circuits. A linear oscilloscope deflection system and electronic pulsing circuit provided bias calibrations from 0.8 to 2.0×Po alpha-pulse maximum. The system was recalibrated in intervals of not more than two hours with consequent discriminator bias drifts less than ±5 percent. All data were recorded both manually and by photographic film recording. Test intervals to search for spurious pulses due to vibration or electrical pick-up showed that no spurious pulses were observed on any of the flights.

The results at 40°N geomagnetic latitude in Table I show the reproducibility of results over the period of several weeks in which the flights occurred. The same kind of measurements are given in Table II for latitudes greater than 55° (the aircraft was flown to 65°N). It will be noted that Flight No. 3 gives consistently lower values than Flight No. 4. This might be explained as the kind of variation in time previously found for the fast neutrons.[2]

The latitude factor of increase between 40° and 55° has been calculated separately for Flight No. 3 and Flight No. 4 in Table III.

TABLE I. Nuclear disintegrations at 30,000 feet pressure altitude (312 gms air) at 40° magnetic latitude.

| Mev energy loss in chambers | Flight No. 2 | | Flight No. 6 | | Flight No. 7 | Average events per hour |
|---|---|---|---|---|---|---|
| | Total no. of events | Events per hour | Total no. of events | Events per hour | Events per hour | |
| >4.2 | ··· | ··· | ··· | ··· | 1412±38 | 1412±38 |
| >5.8 | 834 | 535±19 | 1024 | 512±15 | 525±23 | 514±11 |
| >5.8 | 816 | 523±18 | 955 | 477±15 | ··· | |
| two channels | | | | | | |
| >6.9 | 525 | 338±14 | 653 | 326±13 | 334±19 | 332±9 |
| >8.0 | 418 | 268±13 | 479 | 239±11 | ··· | 252±8 |
| >10.6 | 252 | 162±10 | ··· | ··· | 140±12 | 153±8 |

TABLE II. Nuclear disintegrations at 30,000 feet pressure altitude (312 gms air) at magnetic latitudes greater than 55° north.

| Mev energy loss in chambers | Flight No. 3 | | Flight No. 4 | |
|---|---|---|---|---|
| | Total no. of events | Events per hour | Total no. of events | Events per hour |
| >5.8 | 1893 | 644±15 | 1588 | 794±20 |
| >5.8 | 2028 | 689±15 | 1520 | 760±19 |
| >6.9 | 1371 | 467±12 | 1023 | 511±16 |
| >8.0 | 1050 | 357±11 | ··· | ··· |
| >10.6 | 566 in 134 min. | 253±11 | 458 | 229±10 |

TABLE III. Factor of increase $L$ of nuclear disintegration rate between 40° and 55°N magnetic latitude at 30,000 ft. pressure altitude.

| Integral Mev energy loss in chambers | Using flight No. 3 and table C | Using flight No. 4 and table C | Fast or slow neutrons |
|---|---|---|---|
| | $L$ | $L$ | |
| >5.8 | 1.30 | 1.49 | 1.5 |
| >6.9 | 1.41 | 1.54 | |
| >8.0 | 1.42 | ··· | |
| >10.6 | 1.65 | 1.51 | |

In addition to these measurements the production of showers was measured by covering the chambers with lead hemi-cylinders 2.5 cm thick corresponding approximately to the optimum thickness for maximum electronic shower production.[4] The number of events observed with lead over the chamber divided by the number of nuclear events without the lead may be called $R$; $R$ at 55° has an average value of 1.9 and at 40° has a value of 2.4. Using these ratios and the observed latitude factor of increase for nuclear events from Table III, it is found that the number of events produced by the lead shows little or no decrease in going from 55° to 40°. This is in substantial agreement with the observed three-fold shower coincidences and present knowledge of the latitude dependence of electronic showers.[5] It was shown by measurements with additional absorbers around the ion chambers that the contribution of nuclear disintegrations in the lead to the chamber counting rate was negligible.

The dependence of nuclear bursts upon *altitude* at 55° was in agreement with the burst measurements of Bridge[3] and the production of neutrons in air.[1]

Measurements of both thermal neutrons and moderately fast neutrons were made concurrently with the ion chamber measurements. Since these neutrons were slowed down before detection they are incoherent; therefore, a comparison of the latitude factors for neutrons and for nuclear disintegrations is only significant when a wide range of energy losses in the chambers is measured at the different latitudes. Thus, the integral rates have been used in Tables I, II and III.

In Fig. 1 the ion chamber data have been fitted to the fast neutron latitude curve at 40°. This curve is characteristic of a nucleonic component in the cosmic-radiations particularly with respect to the factor of increase of 1.4 to 1.5 between 40° and 55°N at 30,000 feet. Although recently Tongiorgi[6] has found that neutrons are produced in extensive showers, the present experiment indicates that the most predominant process for the formation of most of the neutrons in the atmosphere with energies below 20 Mev appears to be the emission of neutrons and protons from nuclear disintegration or "star" events. These star events, in turn, may be produced predominantly by higher energy nucleons.[1]

Additional flights to the magnetic equator were not entirely successful due to equipment failures at the low latitudes. However, more than a three fold-increase in nuclear disintegration rate between 0° and 55°N magnetic latitude has been obtained and is to be compared with a factor of 3.5 for the neutron densities. Measurements at the low latitudes are being repeated.

The authors wish to thank Mr. Stanley Molner for assisting on the flights. The excellent cooperation of the U. S. Air Force personnel, particularly Major W. Gustafson, was greatly appreciated.

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* Supported in part by the ONR.

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# The Penetration of High Energy Electrons in Aluminum*

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PREVIOUS determinations of the range of monoenergetic electrons in matter have extended up to electron energies of 2.6 Mev. These data as well as measurements of the end points of beta-ray spectra have served as the basis for various empirical range-energy relations.[1-3] In the absence of experimental data at higher energies Fowler, Lauritsen, and Lauritsen[4] have carried through a calculation extending these results to 25 Mev. They integrate the theoretical energy loss in aluminum adjusting the integration constant to yield normalization with Bleuler and Zunti's semi-empirical relation at 3 Mev.[2] Despite the fact that radiation losses introduce straggling at higher energies, the concept of maximum range in the region which they consider remains defined. For moderate energies ($<800/Z$ Mev) an appreciable fraction of electrons will not experience radiative collisions and hence will penetrate to the maximum depth allowed by ionization losses. Though the curve given by Fowler, *et al.* is for maximum range ($R_0$) *versus* electron energy, they also give an expression for the *practical* maximum range ($R_p$). This latter quantity, which is obtained by straight line extrapolation of the linear portion of the absorption curve of a monoenergetic electron beam is the most conveniently measurable range in practice. According to Bleuler and Zunti it is less than the maximum range ($R_0$) of a monoenergetic beam by 0.14 g/cm² Al.

In order to check the calculations of Fowler, *et al.*, we have carried through measurements of the absorption in aluminum of monoenergetic electrons in the range from 3 to 12 Mev. To this end we have used the $B^{12}$ beta-spectrum (produced through the $B^{11}(d,p)B^{12}$ reaction) analyzed by the 90 degree magnet normally used for the Van de Graaff beam (resolution ~4 percent). Using a triple coincidence train of G-M counters, absorption curves in aluminum of the analyzed beam were obtained. Calibration of the magnetic analyzer was checked by running the $B^{12}$ momentum spectrum and matching the distribution with that given by Hornyak, Dougherty, and Lauritsen.[5] A Kurie plot of the data yielded an end point at total energy 27.3 $m_0c^2$ (13.4 Mev). The excellent agreement with the result of Hornyak, *et al.* (27.30 $m_0c^2$) is added assurance that the energy values subsequently used in the range measurements are correct.