[5]P. J. Coleman, Jr., C. P. Sonett, D. L. Judge, and E. J. Smith, J. Geophys. Research (to be published).

[6]L. Davis, R. Lüst, and A. Schlüter, Z. Naturforsch. A13, 916 (1958).

[7]See, for example, J. R. Pierce, Proc. Symposium on Physical Processes in the Earth-Sun Environment, Defense Research Telecommunication Establishment, Ottawa, Canada, July 20-21, 1959 (unpublished).

[8]E. N. Parker (private communication).

[9]D. R. Bates, Rocket Exploration of the Upper Atmosphere (Pergamon Press, Ltd., London, 1954), p. 355. It is interesting to note that Bates has computed the required energy input into the lower exosphere as ~ 0.3 erg/cm^2 sec to account for an exospheric temperature of 1500°K.

[10]P. J. Coleman, Jr., L. Davis, and C. P. Sonett, preceding Letter [Phys. Rev. Letters 5, 43 (1960)].

MEASUREMENT OF THE NEUTRON FLUX IN SPACE*

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Neutrons are produced in the atmosphere of the earth by cosmic rays, mostly protons, interacting with oxygen and nitrogen nuclei in the air. About 17% of the neutrons are made at high enough altitude so that they leak out the top of the atmosphere. The flux and energy spectrum of leakage neutrons has been calculated by a multigroup diffusion theory treatment.[1] This leakage of neutrons from the atmosphere should be the principal source of neutrons in space close to the earth.

We have flown a $B^{10}F_3$ neutron detector on an Atlas rocket to an altitude of about 1400 km. This was done in order to check these leakage calculations and to see if there are other important sources of neutrons in space. This detector was used because it can easily distinguish neutrons from other particles.

The detector was mounted on a pod on the outside of the Atlas vehicle and was detached during the flight. The trajectory of the pod is shown in Fig. 1. Also shown here are magnetic latitudes inferred from dip angles. The counts from the BF_3 detector were amplified and discriminated and the counts were telemetered to the ground to several receiving stations.

The trajectory and measured count rate data were combined to give the experimental count rate versus altitude curve shown in Fig. 2. Several interesting features are seen here. The peak in the curve at about 20 km is due to the neutrons in the atmosphere of the earth. The low count rate at higher altitudes is due to neutrons in space. The fact that the neutron flux decreases with altitude outside the atmosphere is in keeping with the thesis that the neutrons counted are from the earth. The increase of counting rate starting at ~1000 km is undoubtedly due to penetration of the Van Allen radiation belt. Protons in the radiation belt when they hit the pod will make neutrons, some of which will be counted, thus causing the increase in the count rate.

The solid curve B shown in Fig. 2 is the calculated counting rate based on the previously calculated neutron leakage, $N(E, \lambda, h)$, from the atmosphere of the earth.[1] The calculated curve

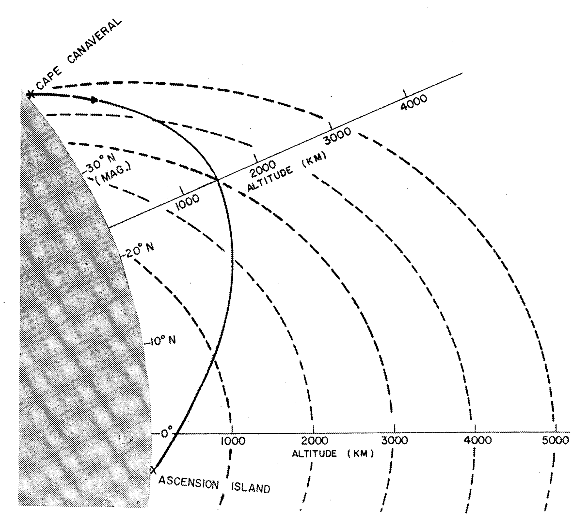

FIG. 1. The approximate trajectory of the Atlas pod flight. Also shown are magnetic latitudes based on dip angles.

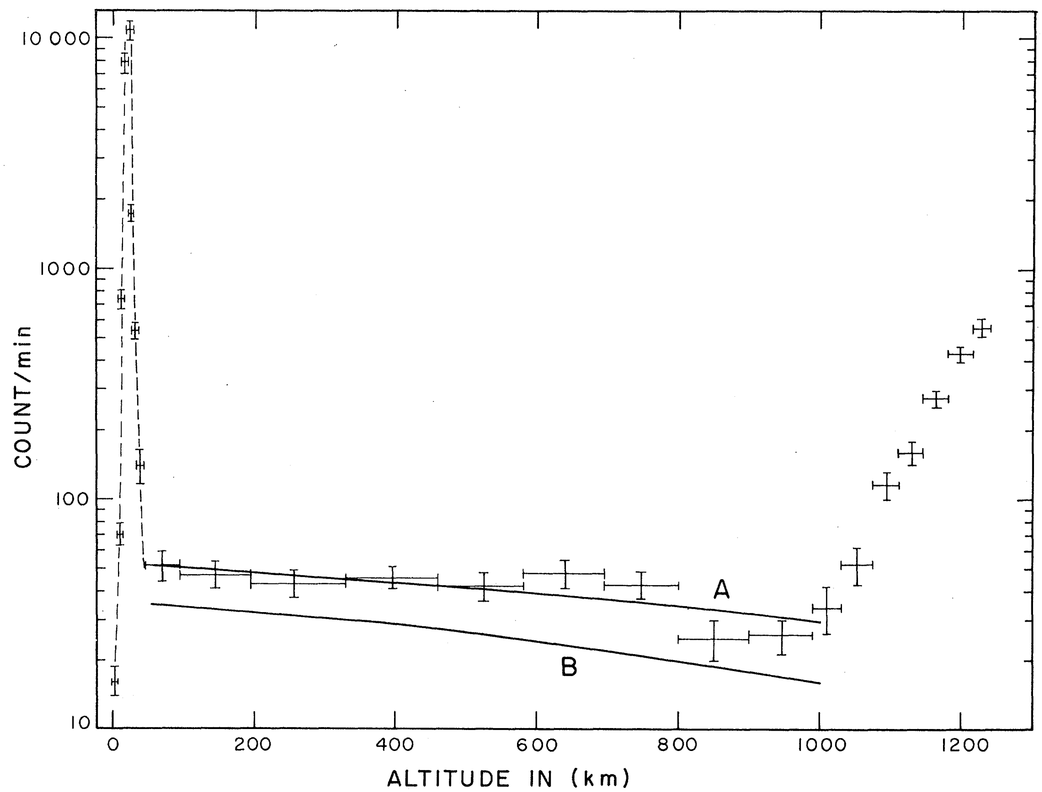

FIG. 2. The neutron detector count rate as a function of altitude. Curve A is a least-squares fit to the experimental data. Curve B is the count rate calculated from earlier work on the neutron leakage flux. No allowance for background counts is made in Curve B.

here includes the change in magnetic latitude of the vehicle (see Fig. 1) as well as the change in altitude. The detector counting rate, C, is calculated by

$$C(h,\lambda)=\int N(E,H,\lambda)\epsilon(E)dE,$$

where h = height from earth surface and λ = geomagnetic latitude. The counter efficiency $\epsilon(E)$ used here is averaged over solid angle. This efficiency was measured by placing Sb-Be, mock fission, and Po-Be neutron sources of known strength at different positions around the counter and measuring the counting rate. The efficiency at 25 kev is 1.15 counts/(neutron/cm^2), at 1 Mev it is 0.65 count/(neutron/cm^2), and at 4 Mev it is 0.35 count/(neutron/cm^2). These measurements are probably accurate to ± 20%. The leakage spectrum is thought to be good to ± 30% so the calculated absolute count rate is probably good to ± 35%. At 1000 km the calculated rate should be down to 66% of its value at 100 km (for constant λ) because the source is further away. The count rate does not fall off as $1/R^2$ close to the earth as one might think. But due to the angular distribution of the neutrons, it falls off as $1/R^{3.2}$ for the first quarter earth radius. This does not imply a violation of the continuity of flow of particles outwards. The change in magnetic latitude from 100 km altitude to 1000 km should cause a decrease in count rate[2] of 30%. The product of these two effects, a decrease of 53%, is shown in the curve B of Fig. 2.

We have estimated what the detector counting rate from other sources should be. The largest background below the radiation belt will be from cosmic-ray protons producing neutrons in the pod, some of which then will be counted. Calculations of the strength of this background and the measured count rate increase in the radiation belt show that this background should be roughly 0.1 count/sec. The calculated leakage flux[1] at 41°N at the top of the atmosphere is 1.1 neutrons/cm^2 sec which would give in this experiment a count rate of 0.58 ± 0.20 count/sec. The experimental count rate at 120 ± 70 km is 0.83 ± 0.08 count/sec. Allowing for 0.1 count/sec background these agree well. The calculated count rate decreases from 0.58 to 0.27 at 1000 km and 31°N. A least-squares fit to the experimental data gives a decrease from 0.85 to 0.50 count/sec which agrees quite well with the calculated count rate plus background. We therefore feel that the experimental data on Fig. 2 from 100 km to 1000 km are due mostly to leakage neutrons from the atmosphere of the earth plus a not very well-known background, and the earlier calculations on the neutron leakage are in good agreement with these measurements. This means also that the other sources of neutrons in space near the earth are substantially smaller than the atmospheric leakage source.

Victor Kiernan, Norman Jenson, Donald Peters, and Leonard Gibson of LRL did the electrical engineering of the detection instruments. Nicholas Yanni and Robert Henderson of LRL did the detector mechanical engineering and environmental testing. Captain Alex Kuros and Mr. Olin Long of AFSWC built and tested the telemetering equipment. Also, Major Lew Allen of AFSWC gave his valuable help in carrying out the experiment.

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[1]Hess, Canfield, and Lingenfelter, J. Geophys. Research (to be published).

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DISLOCATION LOOPS DUE TO QUENCHED-IN POINT DEFECTS IN GRAPHITE

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Small prismatic dislocation loops, presumably due to the precipitation of vacancies, were first observed in NaCl by means of decoration techniques.[1,2] Unambiguous evidence that, on quenching, dislocation loops are formed in metals (Al, Cu) was presented by Hirsch[3] using transmission electron microscopy. Large dislocation loops due to point defects formed during cold work were found in zinc.[4]

Evidence is presented here that on quenching followed by annealing, dislocation loops are formed in natural graphite, and that the point defects involved are vacancies rather then interstitials.

The graphite crystals were treated in the following way. They were first heated in a vacuum of 10^{-5} mm by means of electron bombardment to around 2700-3000°C for 2 minutes. The electron beam was then switched off suddenly and the crystal flakes were allowed to cool. In about 4 seconds the temperature was below 600°C as judged by pyrometry. After this treatment no change in aspect was found as observed in the electron microscope. After annealing the specimens in a vacuum at 1200°C, it was, however, found that they contained large dislocation loops in the c plane of the kind shown in Fig. 1, which is a transmission electron micrograph of a thin cleavage flake. The loops contain a stacking fault, as can be concluded from the contrast shown in Fig. 1. When using the $(11\bar{2}0)$ reflection to make a dark-field image, it is found that the loop exhibits an inverted line contrast as shown in Fig. 2(b). This observation proves that the Burgers vector is not perpendicular to the c plane. The structure of the dislocation loop is therefore most probably as shown schematically in Fig. 3(a), assuming the point defects to be vacancies. The Burgers vector has a component

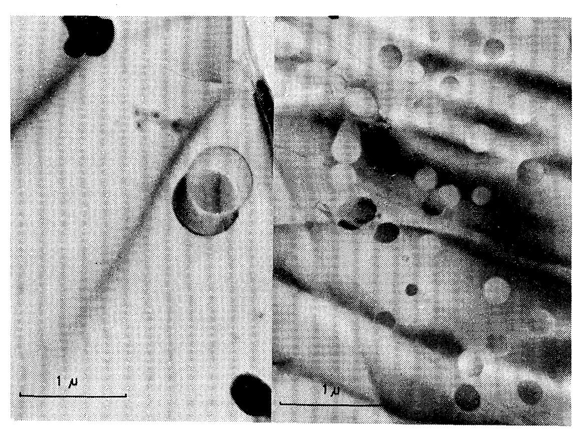

FIG. 1. Quenched-in dislocation loops in graphite. The loops exhibit stacking fault contrast.

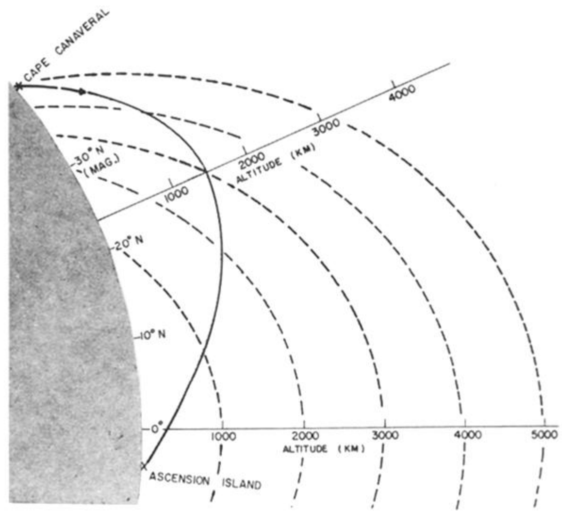

FIG. 1. The approximate trajectory of the Atlas pod flight. Also shown are magnetic latitudes based on dip angles.